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FINAL REPORT

Water quality, Aquatic Life and Fish in Song Bung River

A Part Study of the Environmental Impact Assessment for the Song Bung 4 Hydro-power Development Project in Central Vietnam

Norwegian Institute for Water Research
– an institute in the Environmental Research Alliance of Norway

REPORT

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Abstract

The study comprise three main tasks: 1) Assess the present situation in the river with respect to water quality, aquatic life, fish and fishery; 2) Assess the impact of the hydropower regulation scheme on these items, and 3) Propose and outline mitigation measures to reduce the negative impacts. The study also deals with impact from mining and how this will conflict with the regulation plans. It also elucidates the potential for releases of greenhouse gases from the reservoir. Finally the study proposes a monitoring programme, as well as Terms of Reference for a study of the aquatic resources in the whole Vu Gia River system.

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Water Quality, Aquatic Life and Fish

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FINAL REPORT

Oslo, November 15, 2006

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Preface

This study is part of the EIA for the Song Bung 4 Hydropower Development Project (ADB TA 4625-VIE) in Central Vietnam.

The field work of the biology part of the study was conducted in February 2006 by Ho Thanh Hai and Nguyen Kiem Son, Institute of Ecology and Bio-Resources, Hanoi. The field work of the water quality part was done in March 2006 by Dag Berge (Norwegian Institute for Water Research, NIVA), Nguyen Kiem Son, Institute of Ecology and Bio-Resources, and Pham Thai Nam, Inst. Geological Sci., Hanoi The chemical analyses were done at NIVA.

Dag Berge has been the project leader, and performed most of the reporting after getting input from the domestic experts. The co-operation has been pleasant and fruitful throughout the project.

The report is amended after comments from the client, the Vietnamese experts, and the Quality Assurance System at NIVA.

Oslo, November 15, 2006

Dag Berge

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1 Executive Summary

1.1 BASELINE CONDITIONS PRIOR TO THE REGULATION

1.1.1 Water Quality

1.1.1.1 Water Quality Sampling Programme

As part of the EIA a study was conducted in the period March 19-26 2006 aimed at assessing the impact from mining on water quality, sediment quality and fish flesh quality in Song Bung 4 impact area. In total our water quality study comprised 11 sampling stations. In addition to elucidate the impact from mining, the study also aimed at describing general water quality, impacts from other human activities like settlement and agriculture, as well as to serve as quality assurance for earlier WQ studies performed (by PECC3). The results from the PECC3 water Quality Study is also included in the assessments.

1.1.1.2 General water quality

Temperature varied from 26 to 28 degrees Centigrade. The water was well saturated with oxygen at all stations, also in the tributaries. pH was slightly alkaline from 7.8 to 8.1. The water was relatively soft with conductivity values of 9-10 mS/m, and an alkalinity of 0.9 mmol/l. The turbidity was moderate at all stations during the days of sampling and showed values from 8-35 FNU, also in the tributaries. As the relationship between turbidity measured as FNU (or FTU) and suspended particulate matter measured as mg/l is close to 1:1, this indicates that the concentration of particulate matter was in the range of 10-30 mg/l. These are normal values for the dry season of the year, with low erosion activity. According to the PECC3 study and the Hydrodynamic Modelling Study of this EIA, the concentration can increase to 200 mg/l during rainy weather (Basberg 2006). During the period we were sampling, the gold mining barges were operating for full speed (11 barges only in the Song Bung between Pa Dhi and Ta Vinh), but this did not cause large increase in the turbidity of the river water, and the values were much lower than what is known to cause problems for aquatic life. As the PECC3 water quality study has revealed that most of the year the concentration of suspended particles are below 100 mg/l, erosion does not seem to cause any problems for the river biota today.

The concentration of both phosphorus (varies from 10-15 µg P/l) and nitrogen (90 -150 µg N/l) is low and describe an oligotrophic water quality that will not create eutrophication problems in the planned future reservoirs. The P-concentrations show the same variations between stations as the turbidity, which indicate that it is P adsorbed to erosion particulate matter that constitutes the concentration of total phosphorus and not discharges from human activity. The concentrations of total nitrogen and other N fractions are very low, and indicate almost pristine natural values, and no use of chemical fertilizer in the catchment. The concentrations of the main ions seem natural. There are relatively high concentrations of iron and manganese, which is, however, regarded as normal in the runoff from the type of soils that are dominating in the catchment area (Ferralite soils and Ferralic acrisols, cf NHP 2005).

1.1.1.3 Heavy metals and impact from mining

For arsenic the highest concentrations in Song Bung varied from 0.8-1.2 µg As/l. In the tributaries the highest concentration was found in Ta Vinh (2.3 µg/l). The values are well below the limit that WHO sets for drinking water (10 µg/l). The Vietnamese standards set a limit of 50 µg/l. Several places in Northern Vietnam high content of arsenic in ground water represent a problem for drinking water. If people, after the river regulation, should be supplied with drinking water from deep ground water wells, it is necessary also in the Song Bung catchment to analyse the water for arsenic content.

For mercury, which is used to extract gold from the river sediments, the concentrations in the water were found to be low at all stations. The highest concentration in Bung River was 12 ng/l and was found at the downstream end of the gold mining reach. There was a gradually increase from 2 ng/l upstream of Pa Dhi, which is upstream of the gold dredging area, to the Ta Vinh area. At the 2 lowermost stations (Khe Vinh and Song Bung Bridge), the concentrations were lower. The Ta Vinh tributary had the highest observed Hg concentration of 21 ng/l. In this river there are several ongoing gold panning activities in the upstream river, and metallic mercury is used in the extraction. The other tributaries had values approximately as in Bung River upstream Pa Dhi, which can be regarded as natural background levels.

In the Bung River from Pa Dhi to Ta Vinh tributary as well as in Ta Vinh it self, the water had enhanced mercury concentrations clearly above natural background levels. The levels were, however, low compared to national and international water quality risk standards. The Vietnamese water quality criteria recommend that the concentration should be below 1000 ng Hg/l, the US EPA criteria says that no damage to biological life is observed at concentrations of Hg below 700 ng Hg/l. The Canadian Water Quality Guidelines also has a limit for water use of 1000 ng Hg/l.

1.1.1.4 Sediment and Fish contamination

In the stretch of Song Bung where the mining took place (from Pa Dhi to Ta Vinh), the river sediments had significantly elevated mercury levels. The tributary Ta Vinh had particularly enhanced values. However, all values were below levels regarded as hazardous to the environment and human use. Fish up to 6.5 kg in size were tested for mercury content, but all fish had low and unproblematic levels in the flesh. There is no danger of eating fish from the Song Bung River.

1.1.2 Aquatic Ecology

Prior to this study there have been none biological studies in Song Bung except for a few samplings within the framework of the National Hydropower Plan. The knowledge of the aquatic life in the river was very poor prior to this study, and almost no scientific information existed on fish.

1.1.2.1 The sampling stations in the aquatic life survey

During February 2005, a survey of aquatic ecology in Vu Gia – Song Bung was conducted, including sampling of all main biological groups, phytoplankton, periphyton, zooplankton, bottom dwelling animals (insect larvae, crustaceans, snails, bivalvia, oligochaeta, etc) and fish. For the lower groups the survey undertook practical sampling, whereas for fish the study was mainly based on interviews with fishermen and local residents that fish for daily life. A photo-album with fish species likely to be present was prepared. This was used to identify correct species during the interviews. Some practical test fishing was also performed in tributary junctions to cover smaller fish species that the fishermen were not so concerned about. In total the aquatic life study comprised 17 sampling stations.

1.1.2.2 Aquatic Biodiversity

The aquatic survey of this study identified 78 phytoplankton species belonging to 26 families; 45 algal species and 4 moss species in the periphyton community; 40 species of zooplankton belonging to 15 families; 48 zoo-benthic taxa. Among them, some species of shrimps are not yet identified and may be new species to science. The survey identified 107 fish species belonging to 31 families and 9 orders occurring in the Vu Gia – Song Bung River system. The real number of aquatic species of Vu Gia-Thu Bon river system is obviously larger that what has been revealed through this rapid study. Several species are listed in the Vietnamese Red List Book, but not so many are on the IUCN red list.

1.1.2.3 Fish migrations

The Vu Gia – Thu Bon river system is a continuous water body without fish migration barriers. In such a system the fish community will always be comprised of many migratory populations. The migrations are performed both with the aim of spawning and with the aim of feeding. There are two main fish migration periods in the Song Bung, the small rainy season in May-June and the main rainy season in Sept-Nov. In addition to the time of the year, it is the hydrological rhythm of the river that triggers the migrations.

The highly priced *Anguilla marmorata* lives all along the river, even in the Song Bung 2 upstream area. This species migrates down the river and spawn in the deep sea. The *Clupanodon Thrissa* lives in the sea and river mouth area, but migrates up the river for spawning. Other species are migrating into flooded forest, and wetlands and rice fields for spawning, or swim far upstream and spawn floating eggs that are developing while drifting downstream.

The migratory pattern of the Song Bung fish is not studied and is only partly known. There are about 15-20 species of the important fish species; frequently used for food by humans, that are migratory. The migratory species are particularly vulnerable to hydropower development, both with regards to the barriers that the dams create, but also by the fact that the changed hydrology often results in wrong timing of the migrations.

1.1.2.4 Fishing

The people living along the river are fishing in the river more or less every day. Most fish are used for own food, but some fishes are also sold. Particularly the highly priced *Anguilla marmorata*, that are sold alive. Up to 250 000 VND per kg are paid for this fish. Song Bung has many deep pools which makes it possible to have large fish specimens in the river also in the low flow season. Song Bung is known for its large fishes, and fishermen from far downstream of Vu Gia go up Song Bung for fishing, often up to the junction with A Vuong River. The fishery yield has declined over the years, and high fishing pressure is the most likely explanation. The widespread use of highly efficient mono filamentous gillnets and the use of electric fishing gear is mentioned as causes. There has also been complains about the workers from A Vuong Hydropower Development Project were fishing with explosives.

Local people are also catching crabs, shrimps, mussels, snails, frogs and turtles from the river, mostly for their own consumption, but some of these products are also brought to the markets in Than My and Ai Gia for sale.

1.2 POTENTIAL IMPACTS IN THE CONSTRUCTION PHASE

In the construction phase the water flow will be approximately as it was before. As there has been no damming yet, and the river is still passable for fish, there will be almost no upstream impacts in this period. During the construction phase, the following activities can affect the water quality and aquatic life negatively:

- 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
- Erosion due to accidental water releases
- Sedimentation in the slow flowing river stretches, with shallowing of deep pools
- Reduced primary production due to siltation of periphyton producing substrates, as well as due to reduced light penetration of the water column from increased turbidity.
- 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
- Temperature effects are not expected
- Dry-ups during initial filling of the reservoir

1.3 POTENTIAL IMPACTS DOWNSTREAM THE DAM IN THE OPERATIONAL PHASE

1.3.1 Impact on erosion and water quality

In the first years after the damming there will be substantial erosion taking place in the reservoir. The silt and clay fraction of this erosion material will also impact the river downstream. From experience, this impact will disappear after 3-5 years.

The diurnal flow- and water level variations will be large downstream the power plant, and even larger downstream the A Vuong Power Plant if both plants are run in peaking mode (which is most likely that they will, although it has not yet been decided). The diurnal variation in water level can be as high as 3 m downstream of A Vuong Power Plant. These variations will create large erosions in the river sides and river banks.

The erosion from the land will also increase in general due to increased human activity in the area, more erosion prone road sides, deforestation, agricultural land, excavating, and quarries.

It may happen that the reservoir, in short periods, has to discharge large amounts of water through the spill way. Such events often give large-scale erosion in the downstream river.

To prevent the build up of sediments in the reservoir bottom, it is sometimes practiced so called sediment flushing. This practice brings large concentrations of suspended sediments to the downstream river, which causes considerable stress and damage to the downstream biota. However, sediment flushing of the Song Bung 4 reservoir is not planned.

In the downstream 5 km stretch between the dam and the outlet from the power plant, the flow will be very low and the water susceptible to pollution discharges on the stretch. The reservoir will retain coliform bacteria from the upstream, and will also retain sediment particles after the first initial erosion period is over. The water flowing out of the dam will thus be clearer than the water entering the reservoir. In the first 2-3 years after the damming the water flowing out of the reservoir will have low oxygen content due to decomposition of organic material from the inundated terrestrial catchment. This water will also contain high levels of bio-available nutrients for a period of 2-3 years, which may cause some eutrophication impacts downstream.

The temperature downstream the power plant will be 2-3 degrees lower than it was prior to the regulation, but on the way downstream it will reach the average air temperature relatively quickly, so this is not regarded as a problem of concern.

1.3.2 Impact on aquatic life

The regulation will have a great impact on the aquatic life downstream the dam. The long distance migratory species, like e.g. the highly priced fish *Angulla marmorata*, will disappear due to the barrier effect of the dam. The large diurnal flow and water level variations in the river between the dam and the confluence with Song Cai (up to 3 m water level fluctuations when both Song Bung 4 and A Vuong are operated in a peaking mode) will strongly reduce the biological productivity of the river. Periphyton, bottom animals and fish will decline, both in production and in biodiversity. In the stretch downstream the confluence with Song Cai the impacts will be smaller. As a conservative estimate, the fishery yield downstream will decline as given in the estimates in Table 1.

Table 1. Anticipated reductions in fish yield in different downstream stretches of Song Bung - Vu Gia River after the Song Bung 4 hydropower regulation (based on experience and professional judgement).

Downstream River Reach	% reduction of fish yield	
	With minimum release from the dam	Without minimum release
Between the dam and the outlet from the power plant	90	100%
Between the outlet of the power plant and the junction with Song Cai	70	80
Downstream the junction with Song Cai	30	30

When all the 8 planned hydropower development projects are finished in the Vu Gia – Thu Bon River system, the impact on the downstream stretches will be much more sever, even estuarine and coastal fisheries will be impacted.

1.4 POTENTIAL IMPACTS UPSTREAM THE DAM IN THE OPERATIONAL PHASE

1.4.1 Impact on aquatic habitats

The inundation will result in a loss of river habitat of 30 km, which will be replaced by a lake with large water level fluctuation (planned 27.5 m between Full Supply Level (FSL) and Minimum Operation Level (MOL)). All life in the littoral zone will die due to the periodical dry ups. The regulation zone will be heavily eroded rendering back a denuded, inorganic, desert like zone of sand, gravel and stones where hardly anything can grow. Inorganic erosion material will settle in the reservoir bottom and reduce the nutritional value of bottom sediments for the bottom dwelling animals.

In the first years after the regulation the fish productivity will be relatively good because of food and nutrients from the inundated terrestrial land. However, over time fish productivity will be markedly reduced, and the potential for fish harvest will be low.

1.4.2 Impact on biodiversity

Only a few fish species will succeed in adapting to the lake life. In the reservoir the biodiversity of fish will be reduced by an estimated 30-50%. However, most of these species that disappear from the reservoir will survive in small populations in the upstream part of the river and in the tributaries. The creation of the dam will eradicate the long distance migrants from the upstream areas of the watershed.

1.4.3 Impact on fish productivity and fishery yield

Based on empirical fishery yields from a number of Vietnamese reservoirs of similar regulation height as Song Bung 4, it has been estimated that the Song Bung 4 reservoir will have a fish productivity of 20 kg/ha per year. The surface area equals 1600 ha, and by multiplication the total fish production of the reservoir will be 32 000 kg per year.

An adult person subsiding on fish needs as a minimum 100 g fish per day, which is 36.5 kg/year. This means that the reservoir will supply a population of 1000 persons with annual protein need if fish is the only protein source. Similarly, if they eat fish every second day, the reservoir fisheries can supply proteins for 2000 persons.

On average for Vietnamese reservoirs, the utilisation of natural fisheries gave 4 times as much yield as aquaculture. If this is also anticipated to apply for the Song Bung 4 reservoir, the reservoir can provide approximately 40 000 kg fish flesh per year with developing both fisheries and an average density of aquaculture. This means that it can supply a population of 1250 persons with protein if fish is the only source. Similarly, if they eat fish every second day the reservoir can supply proteins to a population of 2500 persons.

If the reservoir water level fluctuation was kept to 4 m between FSL and MOL, about 50% of the littoral zone could be living. This could increase the natural fish productivity by a factor of 3. The aquaculture would not be much impacted by this as it is based on feeding the fish.

1.4.4 Impact on eutrophication

Eutrophication will not be a problem in the Song Bung 4 reservoir. The low soil fertility in the catchment, the low population density and the low agricultural activities, will result in an oligotrophic reservoir. The reservoir will during the first 3-5 years be somewhat more productive due to release of nutrients from the inundated terrestrial catchment.

1.4.5 Impact on greenhouse gas emission

The sediment surface in the deepest waters will be anaerobic, at least in the first years after the damming, and the greenhouse gas methane as well as carbon dioxide (also some other gases of minor importance) will be produced. Methane has 21-23 times stronger climate impact than CO_2. The gases escapes through the turbines, and the spillway (if deep water gate- type), and they can bubble off through the surface (tiny bubbles) when the water level of the reservoir is lowered (bubbles released by pressure fall). Tropical reservoirs can create large amounts of greenhouse gases. Many Brazilian hydropower plants have been shown to produce many times more greenhouse gases than if the same amount of electricity was produced by fossil fuels. There are, however, large variations in the emissions from tropical reservoirs. Some reservoirs produce much less greenhouse gases than thermal power plants. By using the average emissions from a set of 12-15 tropical hydropower reservoirs, it can be roughly estimated that the Song Bung 4 Reservoir will emit between 108 000 and 1620 000 tons of CO_2-equivalents. This is between 25% and 276% of the greenhouse gas emissions from an oil fired thermal power plant producing the same amount of electricity. However, as this reservoir will be oligotrophic in the long run, the emission of methane will be small after some years, and it is likely that the Song Bung 4 reservoir will be lying in the lower end of the range of the estimate for greenhouse gas emissions. Only monitoring can give a more precise estimate of this impact.

1.4.6 Impact on bioaccumulation of mercury from the gold mining

The formation of the reservoir will create low oxygen content in the sediments in the deep waters. This will create conditions for methylation of the metallic mercury that are deposited in the sediments from the gold mining activities. The methyl mercury is much more bio-accumulative than the metallic mercury present to day. However, our studies showed that the contamination of the sediments was low, and it is therefore not anticipated that the mercury contamination will be any significant problem in the future reservoir.

1.5 MITIGATION MEASURES DURING THE CONSTRUCTION PHASE

1.5.1 Measures against erosion

During the construction phase there are substantial risks for heavy erosion that will create considerably stress for the river biota, as well as creating problems for human use of the water. Therefore, erosion abatement measures should be taken at all construction sites. Roadsides and other areas with denuded soils should be sowed by grass, road drainage should be strengthened with appropriate concrete/stone settings, machine parking areas and roads should be paved to the extent possible, etc.

1.5.2 Measures against oil and chemical spills

The large machine park that will be involved in the construction work will include the use of comprehensive amounts of fuels, oils, hydraulic fluid, battery acids, glycol cooling fluid, etc. In addition there will be needs for workshops and maintenance areas. The machine parking area, the workshop area, and the fuel and oil filling area should be concentrated to one area that should be paved, and equipped with a controllable drainage so that all diffuse spills and accidental spills could be collected any time.

1.5.3 Measures against sanitary effluents from workers camp

Toilet water should not be allowed to be discharged into the river, which could cause health hazards for those living downstream. The black water (toilet water) should be collected and infiltrated at a site with necessary infiltration capacity. The grey water (washing and kitchen water) could be infiltrated at the site before discharging into the river.

1.5.4 Measures against blasting chemicals

Tunnel blasting uses large amount of ammonium-nitrate, and if concrete (particularly spray concrete) is used for tunnel tightening, the runoff becomes strongly alkaline, and reacts with ammonium to create free ammonia, which is very toxic to fish and other aquatic animals. Runoff from tunnels and spoil rock deposits can thus cause fish kills in periods with low flow. The runoff from the tunnel should be monitored and channelled through a sedimentation basin where neutralisation could be performed if extremely high pH values are observed.

If the tunnel is made by full profile drilling, the runoff does not contain toxic chemical.

1.6 MITIGATION MEASURES DOWNSTREAM IN THE OPERATION PHASE

1.6.1 Compensation flow

A compensation flow should be released from the Song Bung 4 dam. This shall secure the ecological river continuum, spawning areas for fish, and secure some more water for the fish in their migration periods. A small turbine in the dam-foot could be installed that can utilise the compensation flow also for electricity production, which will again reduce the el-production loss. The proposed compensation flow discharged from the reservoir is given in Table 2.

Table 2. Proposal for a compoensation flow released from the dam in different months of the year (values in m3/s)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5	5	5	5	8	8	5	5	9	11	9	7

The switch on-switch off of the power plant should be done as smoothly as possible to give the slow moving bottom animals the chance to follow the retreat of the water, and prevent them from being killed by the daily dry ups of large bottom areas.

When Song Bung 5 is built, the reservoir should be used as a re-regulation basin for the water level- and water flow fluctuations from Song Bung 4 and A Vuong power plants.

1.7 MITIGATION MEASURES UPSTREAM IN THE OPERATIONAL PHASE

1.7.1 Measures to keep a good fish productivity in the reservoir

The water level fluctuation of the reservoir should be kept within 4 m (FSL-MOL). This will secure that the reservoir will function as a lake ecosystem, and the fish productivity will be so good that it can sustain the livelihood of local people.

The reservoir should be self-populated by indigenous fish species that can adapt to lake life. If, after some years, it turns out that the natural recruitment of the lake is too low, it should be considered to launch a fish stocking programme for the reservoir.

If people choose to settle along the lake, one could consider establishing floating cage aquaculture in the lake. This should be based, preferably, on indigenous species, or species already present in the river system.

1.7.2 Measures against greenhouse gas releases

As much of the release of the greenhouse gases derives from anaerobic decomposition of organic matter from the inundated areas, clearance of the reservoir area for forest, trees and bushes, prior to filling the dam represents an important measure.

Another efficient measure is to withdraw the water to the powerplant, minimum release and spillway from the surface layers (epilimnion) instead of from the hypolimnion. This can be accomplished by building an adjustable intake in the dam.

Keeping the water level fluctuation in the reservoir low, will also reduce the release of greenhouse gases via diffusion through the reservoir surface.

1.8 MONITORING

A monitoring programme should be launched both in the construction phase, and in the operational phase. The monitoring programme in the construction phase should be aimed at controlling that the work is complying with the regulations set, which is not part of aquatic life study. This chapter deals with the monitoring of water quality and aquatic life in the operational phase. That is after the reservoir is filled and the power plant has started its operation. The monitoring should cover the following items:

1. Water quality
2. Fish flesh mercury content
3. Fish yield and fish species composition
4. Algal biomass and species composition in the reservoirs
5. Release of greenhouse gases

The monitoring should be carried out 4 times a year, in the upstream, in the reservoir, in the river section between the reservoir and the confluence with Song Cai, and Vu Ghia upstream of the connecting canal to Thu Bon River.

2 Introduction

In their national plan for hydropower development (NHP 2005) Vietnam has planned 8 potential hydropower plants in the Vu Gia – Thu Bon River System in Nam Giang Province in Central Vietnam. Song Bung 4 is the second hydropower development in the Vu Ghia river system. The first to be developed is the A Vuong HPP, which is on a tributary to Song Bung. The Asian Development Bank is financing the project and has developed the Terms of Reference of the Environmental Impact Assessment Study (EIA).

This part of the EIA study is dealing with Water Quality, Aquatic Life and Fish. It aims at assessing the present situation (baseline conditions), assessing the potential impacts from the regulation scheme on the aquatic environment, and proposing relevant mitigation measures that can be taken to reduce the negative impacts. A special part of the study (Berge 2006) is looking into the pollution from the gold mining in the catchment and how this can conflict with the hydropower development. At a proposal to Terms of Reference for a new study of the aquatic resources in the whole Vu Gia River Basin is presented.

To able to answer these questions the previous studies have been reviewed, which i.a. include The National Hydropower Plan reports (NHP 2005), the Feasibility Study performed by PECC3, the water quality study performed by PECC3, the Phase I Study for the Song Bung 4 HPP (Bird at al 2005), and The Hydrodynamic Modelling Study (Basberg 2006), as well as the aquatic life studies performed in connection with the A Vuong HPP. Very little scientific information existed on aquatic life from Song Bung and practically nothing on fish prior to this study. To provide the necessary information to comply with the aims of this study, practical studies with field work in the period February – May 2006 were conducted. The study has covered general water quality, nutrients, heavy metals with particular emphasis on mercury which is used in the gold extraction process, the aquatic life like phytoplankton, zooplankton, periphyton, insect larvae, crustaceans, gastropoda and bivalvia, and fish stocks, fish migration, spawning and nursery, as well as fish biodiversity, and fisheries and aquaculture, on emissions of greenhouse gases, on potential impacts and mitigations, and at the end a proposal for a monitoring programme. The impacts and mitigations are assessed both for the construction phase and the operational phases. The estimates of the potential for fish production and aquaculture in the reservoir are based on empirical data from a large number of reservoirs in Vietnam. The estimates of the potential for releases of greenhouse gases are mainly based on empirical data from 12-15 reservoirs in South America, first of all from Brazil, as this phenomenon is poorly studied in Asian reservoirs. With respect to assessment of Environmental flow we have made a state of the art review, and used what could be used from the recommended methodologies for this particular regulation.

The geographical area of the study is the Song Bung from upstream the reservoir and all the way down to the coast, as well as several tributaries, and part of the Song Cai. The lowermost reach, from the connection canal between Vu Gia and Thu Bon and down to the coast, is mainly studied with respect to impact on anadromous and catadromous migratory fish, and impact on the fisheries.

No cost estimates for the mitigation measures (other than monitoring), are made as the most important measures are related to environmental flow downstream, and recommendations for restrictions on the water level fluctuations in the reservoir. The costs confined with these measures are mainly reduced electricity production. In the construction phase the measures are mainly aiming at avoiding too much erosion and pollution discharges, i.e. normal construction work precaution regulations that should be built into the entrepreneur contracts. With respect to aquaculture measures we feel that this belongs to the livelihood programme of the Sosio-group. With respect to the measures against releases of greenhouse gases, as well as the construction of fish bypass system for the high dam, we feel that it is doubtful whether these should be included in this project due to lack of properly tried-out technology; we have anyway chosen not to include them. We have the theoretical knowledge on how such measures can be implemented, but there is too little practical experience with their functioning.

3 Methodology for the practical surveys

3.1 Water Quality and Sediment Sampling Stations

According to the Terms of Reference we should samples 6 stations in the main stream Song Bung and 6 tributaries. However, two of the tributaries proved to be dry, so we sampled additional stations in the main stream river instead, as well as from 4 tributaries suspected of being impacted by gold mining. Two of the tributaries were impacted by gold dredging, and some by hardrock mining in the upstream areas. The sampling stations are shown in Figure 1.

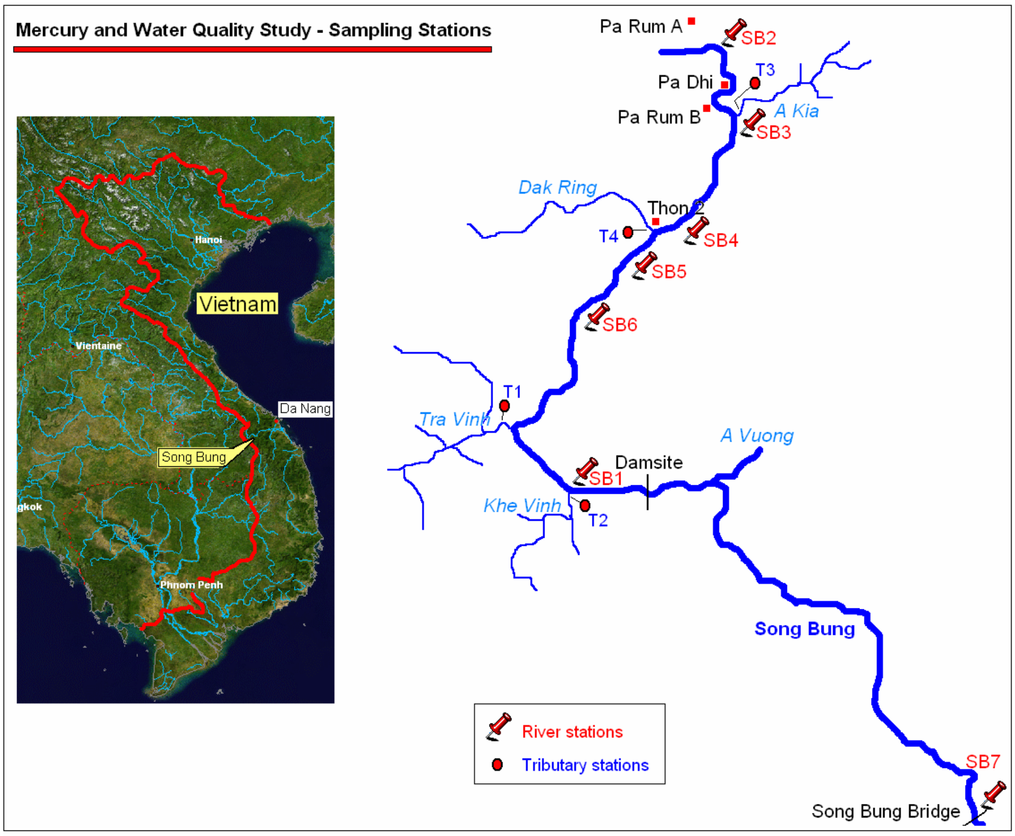


Figure 1. The Samplings sites for the mercury and water quality study March 19-26 in the Song Bung 4 Hydropower Project Area.

3.2 Study media

Mercury and heavy metals are often not very soluble in water. They bind to particles which are settling to the bottom where they contaminate the sediments. Many of the bottom dwelling animals are living like the earthworm, feeding on the bottom sludge and thus getting the heavy metals into their body. The fish are feeding on bottom animals and in this ways the fish get contaminated. Some of the metals are not excreted as easily from the body as they are taken in, and thereby tend to accumulate in the body. Therefore older and larger fish contain more metals than a young fish (called bio-accumulation). Mercury, which is almost not excreted from the body at all, increases also throughout the nutrient chain (called bio-magnification). Based on this, the most important in our study was to look for contamination in large carnivorous fish, bearing in mind that the carnivorous fish is often also the most popular fish in the diet of people, because they are large, and good tasting.

Therefore we have taken samples of the 3 media:

- Water samples
- Sediment samples
- Samples of flesh (filets) from large fish (also some small when we were unable to catch large fish)

3.2.1 Water sampling

Oxygen and Temperature were measured in the field using an YSI instrument. Prior to the sampling the electrodes were equipped with a new membrane, filled with new KCL-solution and calibrated to air-bobbled distilled water.

Water sample were take from the river by wading out in the river filling the bottle upstream of the sampler. Water for mercury and heavy metals was sampled on specially rinsed bottles, which contained a stabilising solution that was poured out just before the bottles were filled by river water. Water for general water chemistry was sampled on bottles washed with Deconex lab flask cleaning soap and thereafter rinsed in distilled water.

3.2.2 Sediment sampling

Sediment samples were taken from quiet pools where particulate matter was allowed to build up soft sediments on the river bottom. The sediment was taken by a sediment corer, a plastic tube that was pressed down into the sediment. This was done by wading out into the pool. A stopper was put on the top end of the corer, and the sediment core pulled out from the sediment. Before taking the core out of the water, a stopper was also put in the lower end of the tube. The core, which then contained 15 cm of sediments in the bottom and 15 cm of water on the top, was brought to the shore. There the bottom stopper was replaced by a piston while the top stopper was removed. The piston was pressed up allowing the surface of the sediment to come to the top of the tube. The uppermost two cms of the sediment were placed in a plastic box and brought to the laboratory for analysis.

3.2.3 Fish filet sampling for mercury testing

Firstly, we tried first to fish ourselves to be sure that the fish was really caught in Song Bung. However, it turned out that we were only able to catch small fish during day time. Therefore, on our way upstream, we arranged with fishermen to try to catch big fish for us, fish that we could buy from them on our way back. In this way we managed to get samples from large specimens of fish for the mercury sampling, fish that people normally use for food along Song Bung River, see Figure 2. The fish samples were taken from the filets and conserved in 70 % ethanol prior to the analysis.

Large representatives for the same species as above, Tor Strachey (4 kg) to the left and Spinibarbichtys denticulatus (7 kg) to the right

Bagarius yarelli (3 kg)

Samples for mercury and heavy metal analysis were taken from the fish filets…

and conserved in 70 % ethanol prior to analysis

Figure 2. When we let local fishermen do the fishing, it was no problem of getting large fishes. Samples were taken from the filets and conserved in alcohol.

3.2.4 Water samples analysis parameters

The water samples were analysed for the following parameters:
Temperature, pH, conductivity, turbidity, oxygen concentration, oxygen saturation, alkalinity, total phosphorus, total nitrogen, ammonium, nitrate, chloride, sulphate, cyanide (tributaries), fluoride, calcium, magnesium, sodium, potassium, iron, manganese, cadmium, cobalt, chromium, arsenic, copper, mercury, nickel, lead, and zinc.

3.2.5 Sediment samples analysis parameters

The sediment samples were analysed for the following parameters: Arsenic, cadmium, cobalt, chromium, copper, iron, manganese, mercury, nickel, lead, and zinc.

3.2.6 Fish filet samples analysis parameters

The fish filet samples were analysed for the following parameters: Arsenic, Cadmium, cobalt, chromium, copper, iron, manganese, mercury, nickel, lead, and zinc.

3.3 Chemical analysis methods

The analyses were carried out in line with accredited methods (EN 4500) at the Norwegian Institute for Water Research. In most cases these are the same as Norwegian Standards (NS) and European Standards (SEN).

3.4 Methodology applied in the study of aquatic life

3.4.1 Dividing the river into “impact-relevant” sections

The study area of the Bung River was divided into 5 river sections ranged from upstream to downstream to the river mouth area: 1) Bung river upstream, 2) Reservoir area, 3) Bung river downstream, 4) Vu Gia upstream, and 5) Vu Gia downstream (Figure 3). This division of the study area is conducted for the purpose of clearing longitudinal succession of aquatic ecological factor of river system from upstream to downstream, as well as because the impacts and mitigation will be different in the different sections. As the rivers are connected without migratory barriers, information from the lower Than River and from Cai River is also collected.

These five river sections have different characteristics of natural conditions such as hydrological regime (current velocity), substrates, depth, width, and water quality. Generally, in the Vu gia-Thu Bon basin, as in every river, there are specific aquatic habitats such as rapids (often found in the sections 1-3) and floodplains (in Vu Gia downstream) that are important for fish as spawning and nursery grounds, and deep pools which are important as fish refuge in the dry season. Those features of natural conditions can create many types of different aquatic biotopes which are of the hard bottom type, including solid bedrock, boulders, shingles, gravels and sand which are occurring in the upstream area. The biotopes with soft bottom as fine silt, mud-sand or sand-mud which are mainly found in downstream area. Bed material type and hydrological regime have a major influence on the community of organisms found in a river.

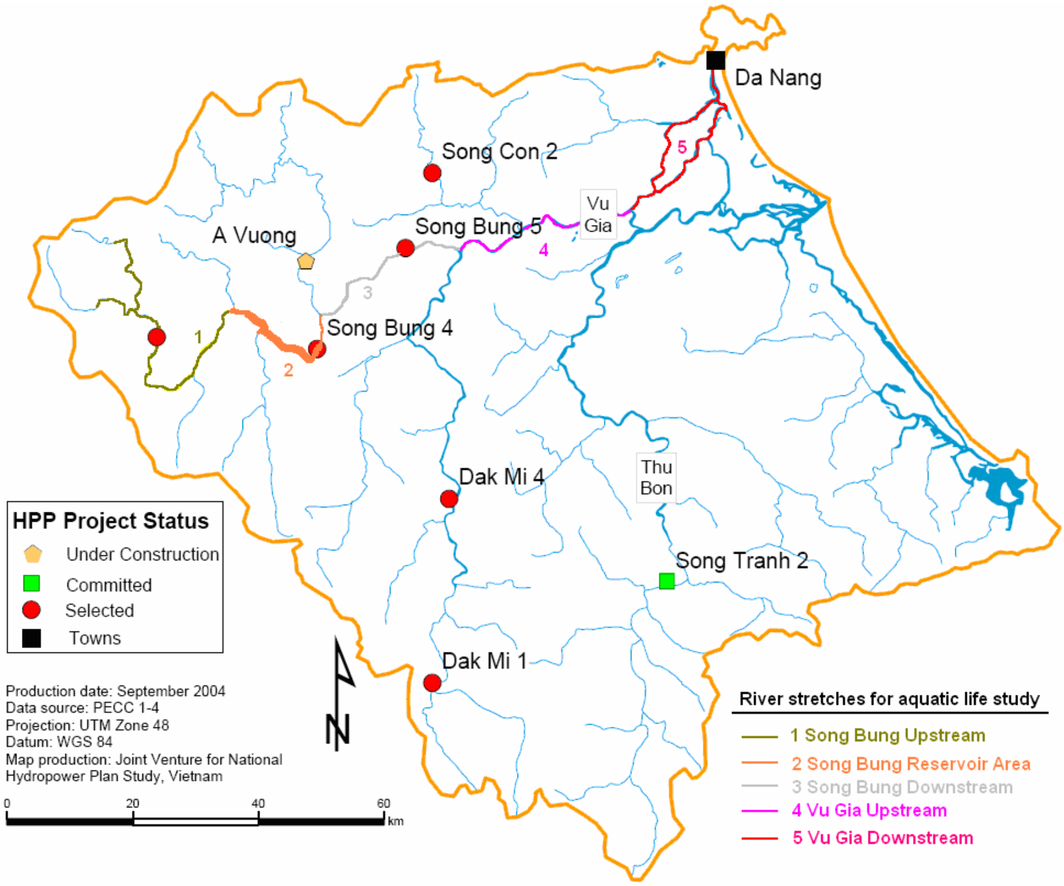


Figure 3. For the aquatic life study the river was divided into 5 sections

Some fundamental characteristics of the five river sections given in Figure 3 are summarised in the following:

Section 1

Most of section 1 of Bung River is of the upland type of rivers. The stream bed is narrow, the width of about 20 m, low depth (less than 1m), high flow velocity, many rapids; substrates mainly include bedrock with boulders, shingles and gravels. There are only a few locations with soft-bottom with woody debris. These are often habitat for stream insects and crustaceans. The vegetation is growing well on the banks of streams.

Section 2

This river section will be inundated by the future reservoir. The composition of the stream bed is similar to the section 1, but the river is larger after having received several tributaries. The width is more than 30 m, some places up to hundred metres, and the river is deeper. As in section 1, the river is also here mainly fast flowing, with many rapids, with substrate mainly of bedrock with boulders, pebbles and gravels. Some locations along of the Bung River are banks with sand or sand-silt.

The big trees (forest) are cut many years ago, so the vegetation along Bung River consists of smaller to medium high trees and bushes that form dense stands along the banks of the river.

The river has a wide variety of habitats on this stretch, with rocks, big boulders, smaller boulders, and stones of all sizes, deep pools, as well as sandy banks and soft bottoms. This forms the basis for a rich aquatic life of all categories, with many hiding places and dry season refuges for big fish. The rocks and boulders tend to be smoothened from the action of water flowing over it. Snails can often be seen crawling over the surface of bedrock areas grazing the attached periphyton. Aquatic mosses can grow well on the bedrock and if these are extensive they can provide some areas of good habitat for insects.

In this river section, dredging for gold is going on in Bung River from Pa Dhi Village and down to approximately the entrance of Ta Vinh tributary. There are also several barges operating in A Kia tributary. In total 11 barges is operating in Song Bung mainstream (**Figure** 4). A separate report is describing the different mining activities in the catchment area (Nam 2006).

In addition to potential pollution, the gold dredging makes large physical and ecological impacts on the river bed, as well as making the river water turbid

Here it is not easy to go boating, or for the fish to find back to its old living places.

Figure 4. Machine extracting gold from river banks and river bed

Within the catchment of Song Bung River, it is only in the upper part of Ta Vinh that they are performing hard rock mining after gold. They exploit the gold ore in rocks by blasting tunnels, and take out the gold containing rock layers (ore). They crush this material to fine sand and silt, and do separation by using a combination of gravity washing and dissolution with cyanide. The chemical step includes a pond where the gold containing slurry is mixed with sodium cyanide. The cyanide dissolves the gold into the water – cyanide solution. The gold is then precipitated onto metal shavings, most commonly used is zinc shavings or zinc powder. The metals in the precipitate are separated by heating as they have different melting points.

The cyanide containing remaining water and sludge are very toxic to fish and aquatic life above certain concentrations. At low concentration cyanide does little harm. It is broken down to carbon dioxide (CO_2 and nitrogen (NH_4) and disappears. More about the method of hard rock gold mining in the catchment is shown in a separate report (Berge et al 2006).

Section 3

This is the section from the dam and down to the confluence with Song Cai. The stream bed of this river section is similar with the section 2 described above. The A Vuong tributary enters the river on this stretch. This tributary is now being built out for hydropower, so the original river will soon be dry, and the water will enter the Song Bung 7-8 km downstream of Song Bung 4 dam.

Section 4

Downstream of the confluence of Song Bung and Song Cai, the river is called Vu Gia all the way to the sea. This river section then comprises the reach from upstream to midstream of Vu Gia River where the river is connected with Thu Bon River via a canal. The river bed is large, the width can reach more than 200 m, the river is deep and the current velocity is moderate. A range of materials make up the river bed, from small gravels, sand through to sand-mud, and mud-sand. The land bordering the river consists to a large part of lowland alluvial deposits on which there are farmland (corn-fields and rice-fields). In the junction between Vu Gia and Thu Bon there are flood plains which are important spawning and nursery areas for many fish species of Song Bung River.

Section 5

River section 5 is Vu Gia downstream and goes down to the sea area. The river bed is moderately large, current velocity is lower, transparency is higher, and water colour is green or dark green. Bottom substrates are made up by soft materials such as fine silt, mud-sand and sand-mud.

3.4.2 Biology Sampling Stations

In each river sections there were several locations (sampling stations) where there were taken biological samples, and where fishermen were interviewed:

- Section 1: In Song Bung upstream including 3 representative stations (2 stations are on tributaries) for collection of hydro-biological samples (aquatic primary and secondary producers)
- Section 2: Song Bung 4 reservoir area comprises 3 stations (2 stations on the Bung River itself and 1 station in a tributary).
- Section 3: Song Bung downstream has 2 stations.
- Section 4: Vu Gia upstream includes 3 stations.
- Section 5: Vu Gia downstream includes 4 stations.

The locations of the sampling stations are shown in **Figure 5**.

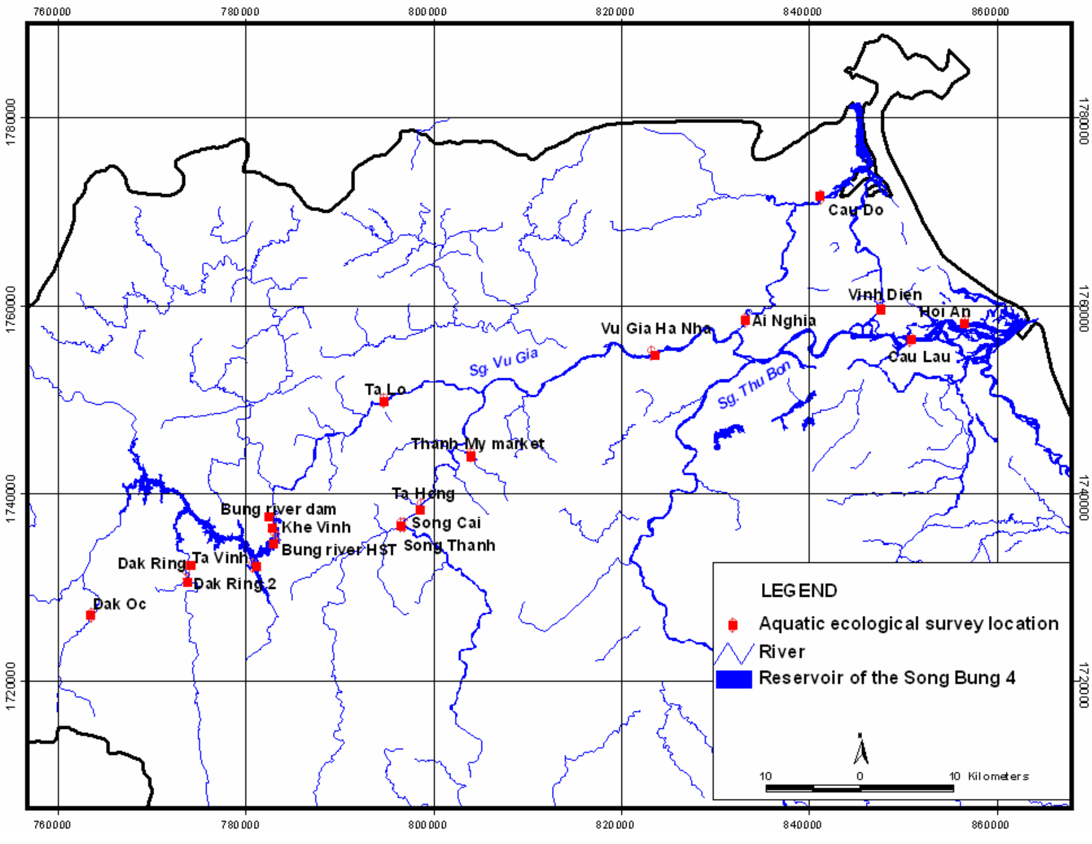


Figure 5. Sampling stations in the aquatic life survey in February 2006

Phytoplankton

Phytoplankton is collected by a net screen with mesh size of 25µm. The samples were then conserved with formalin solution of 5 %, and the species were analysed in a traditional microscope for species composition. Filtering of a certain amount of water through the net, gave the possibility to analyze the quantitative biomass of species greater than 25 µm.

Periphyton

The sampling of periphyton was done in rapids in the sections 1 and 2. The coverage (% of covered bottom) of the periphyton elements was evaluated in the field. The collection of the tiny diatom cover was done by brushing the stones. The periphyton-samples were conserved with 5 % formalin and the species composition was analyzed in microscope with appropriate magnification.

Zooplankton

Zooplankton was collected by a Juday net screen with mesh size of 45µm. The samples were conserved with formalin solution of 5 %, and the species analyzed in a traditional microscope.

Zoobenthos

The zoobenthos (bottom animals) were collected by hand net consisting of a metal frame holding a conical net with a mesh size of 400 µm. In addition, in some locations, samples of fast moving species like shrimps, etc., were also collected by hand. The samples were conserved with formalin solution of 7-10 % concentration, and the species analyzed in a traditional microscope.

Fish

The fish study was mainly based on interviews with fishermen (including local residents catching fish for own consumption). The fishermen were mostly of Kotu people and they had their own local names of the fishes, often different names for small fish and big fish of the same species. A collection of photos of the fish species that were likely to occur in the river was prepared. The photos were used in the interviews to help in identifying the correct scientific names of the different fish, see Figure 6.

Pictures and colour photos of the actual fish were taken from Rainboth (1996) and Kottelat (2001), and black & white photos from Mai Dinh Yen et al. (1978, 1992), Nguyen Van Hao (2001, 2005), Chen Yiyu et al.(1998), Chu Xinluo et al. (1999), Yue Peipi et al. (2000). The pictures were shown to the local fishermen, so they could agree upon which species they knew were present.

Figure 6. Identifying fish species in Bung River by converting the local species names into scientific Latin names using the prepared photo album of species likely to be present

In addition to interviews with people along the river, market surveys were also performed in the towns of Than My and in Ai Nghia. These also gave information about the fish present in the river system. It was carefully checked where the fish in the markets were coming from. However, as the Vu Gia river system is a continuous water habitat without migratory barriers, it is likely that most of the lower and middle parts of these rivers contains the same species.

Some samples of fish were collected by the team in the Ta Vinh tributary.

In addition to fish, several samples of shrimps, and mussels (originating from Vu Gia River system) were brought back to the laboratory for identification.

All samples of fish are identified into species, and other organisms to species if possible, at least they were identified down to genus-level.

4 Assessment of the present situation

4.1 Rainfall and Flow

The average monthly rainfall from different meteorological stations in the area is shown in Figure 7. There are 2 rainy seasons, one small in May-June, and one large with heavy rain and high flood in September to October, see Figure 8. The local Kotu people call these for the small and the large rainy season, and they are important fisheries taking place in both of them due to fish migration.

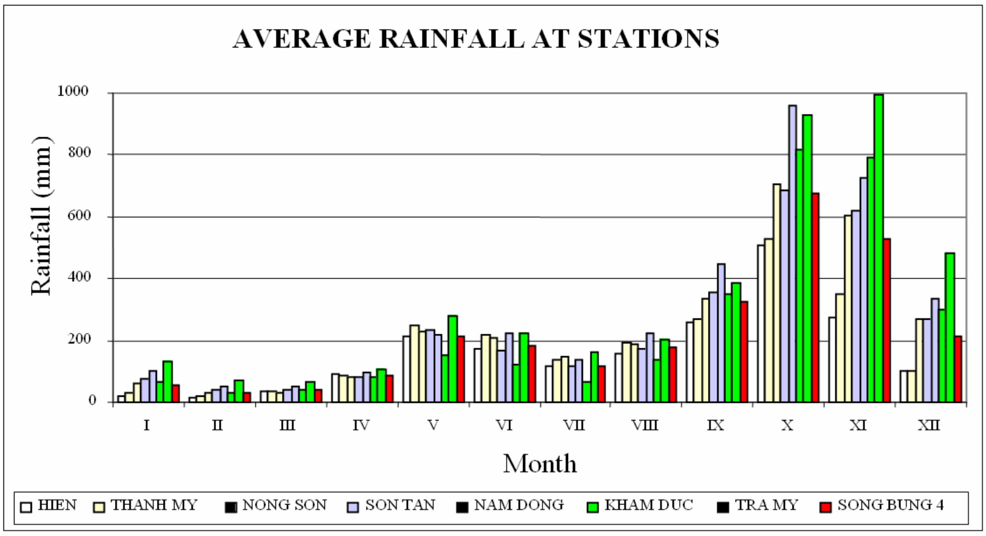


Figure 7. Average monthly rain fall at different meteorological stations (Figure taken from the PECC3 Feasibility Study)

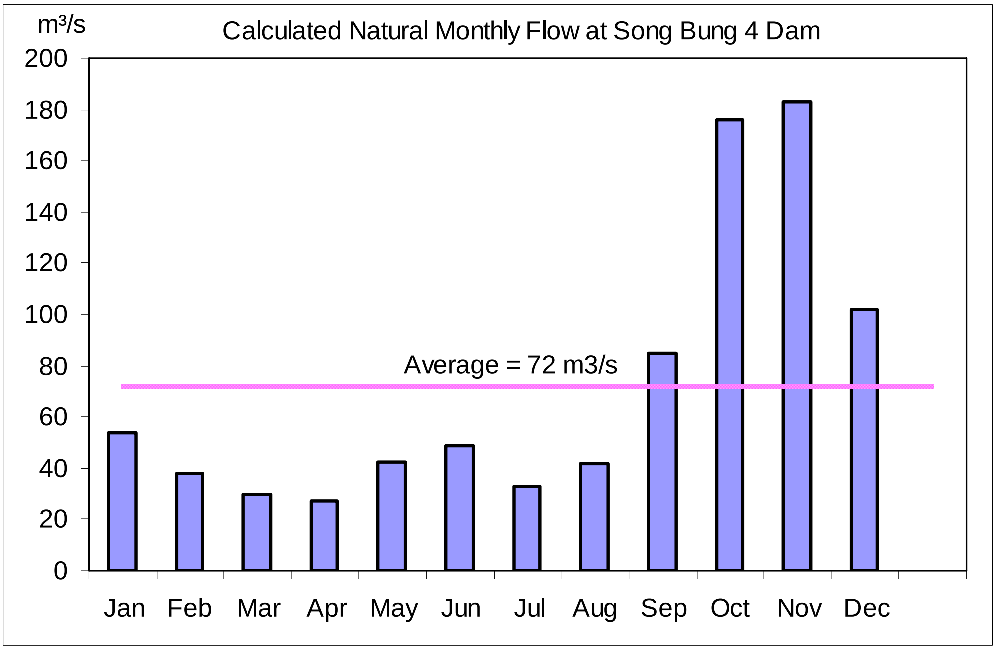


Figure 8. Model estimated un-regulated (natural) monthly flow at the Song Bung 4 damsite.

4.2 Water Quality

4.2.1 General water quality

Some general water quality parameters from Song Bung mainstream are given in Figure 10 while those from the tributaries are given in Figure 11. The temperature varied from 26 to 28 degrees Centigrade. The water was saturated with oxygen at all stations, also in the tributaries. The PECC3 found that the water had only around 60 % oxygen saturation, which most likely was wrong due to the fact that they brought the water samples to the lab without conserving the oxygen in the field. The oxygen will then be consumed by micro organisms on the way to the lab. pH was slightly alkaline from 7.8 to 8.1. The water was relatively soft with conductivity values of 9-10 mS/m, and alkalinity of 0.9 mmol/l. The turbidity was moderate at all stations during the days of sampling and showed values from 8-35 FTU including the tributaries. As the relationship between turbidity measured as FNU and suspended particulate matter measured as mg/l is not far from 1:1 (Berge et al 1995), this indicates that the concentration of particulate matter was in the range of 10-30 mg/l. These represent normal values for the dry season of the year, with low erosion activity. According to the PECC3 study and the hydrodynamic modelling study the concentration can come up to 200 mg/l during rainy weather (Basberg 2006). During the period we were sampling, the gold mining barges were operating for full speed (11 only in the Song Bung between Pa Dhi and Ta Vinh), but this did not cause large increase in the turbidity of the river water, and the turbidity was much lower than what is known to cause problems for aquatic life. According to water quality criteria set up by the European Inland Fishery Commission (EIFAC) (Alabaster & Lloyd 1980), no damage is proven to occur to aquatic life below 35 mg/l of particulate matter. On the other hand, they state that it is impossible to have good fish productivity in a river if the concentration of suspended sediments is above 100 mg/l.

Figure 9 shows the water quality parameters analysed in the PECC3 study. The samples were taken 4 times a year 2004-2005 at 4 stations from the Song Bung 2 area and down to the coast. The values have been evaluated by the Hydrodynamic Modelling Study (Basberg 2006). This study was not able to show any systematic variation in the data depending on the location, so all data are given in Figure 9.

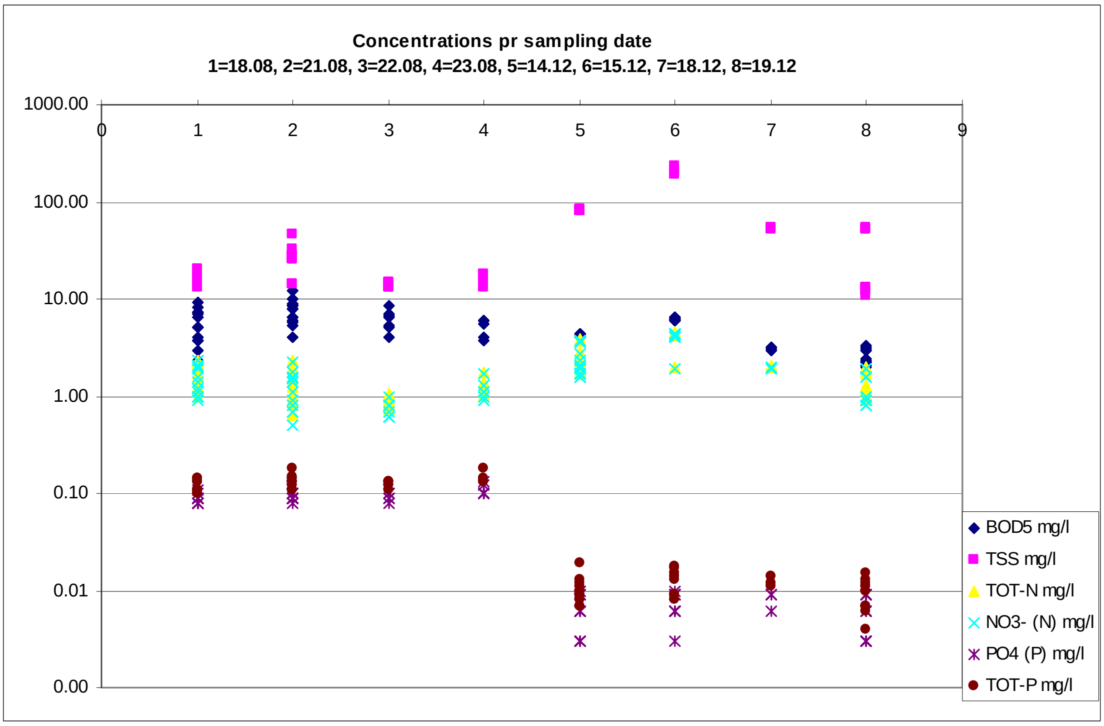
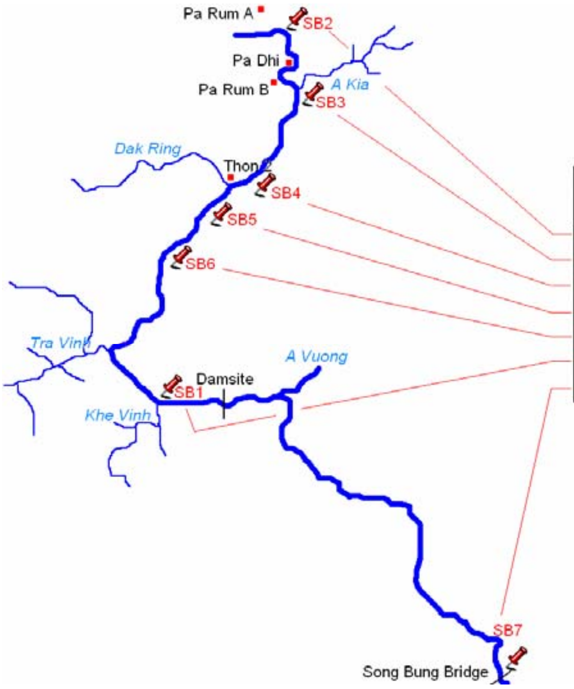


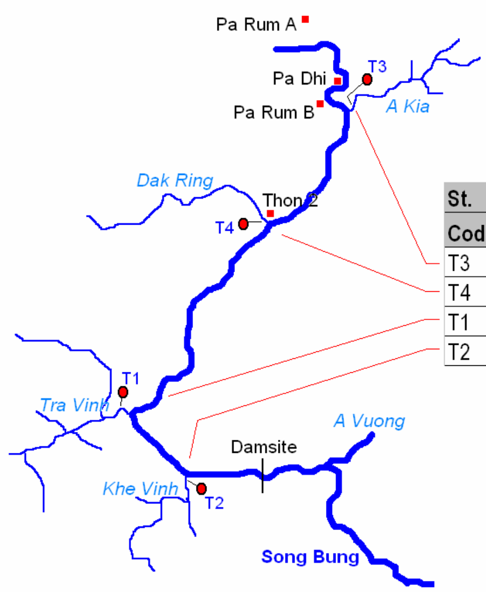
Figure 9. Water quality parameters analysed in the PECC3 Study (from Basberg 2006).

The concentration of suspended sediments varies mostly between 10 and 100 mg /l. Only in the peaking rainy season a few data above 200 mg/l were recorded. Total phosphorus concentration varies between 10-100 µgP/l. BOD5 varies between 3 and 10 mg/l. The values of total nitrogen in Figure 9 are much higher (about 10 times higher) than what can be expected from this area and are most likely wrong.



St. Code	Temp °C	O2 mg/l	O2 Sat %	pH	KOND mS/m	ALK mmol/l	TURB FNU
SB2	26.0	8.3	100	8.04	10.09	0.97	8.04
SB3	27.1	8.3	104	8.11	9.98	988	16.3
SB4	25.2	8.2	97	7.94	9.95	0.974	27.7
SB5	26.7	7.7	99	7.93	9.3	0.917	15.6
SB6	26.9	8.6	104	7.97	9.35	0.919	21.4
SB1	27.7	8.2	100	7.92	9.59	0.93	20.7
SB7	28.1	8.1	103	8.03	8.53	0.799	14.6

Figure 10. Some parameters of general water quality at different sites in the Song Bung Bung River, March 19-26 2006.

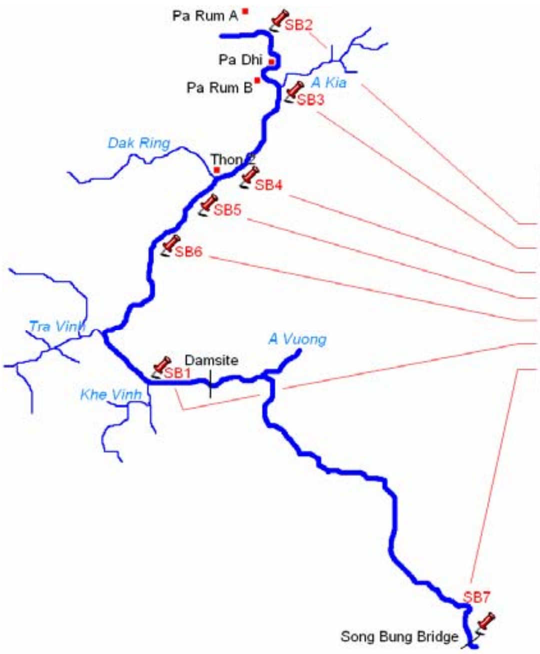


St. Code	Temp °C	O2 mg/l	O2 Sat %	pH	KOND mS/m	ALK mmol/l	TURB FNU
T3	28.7	8.7	110	8.31	9.94	0.982	9.08
T4	25.2	8.2	98.8	7.83	8.32	0.806	5.95
T1	27.1	8.7	104.7	8.13	10.99	1.09	34.9
T2	27.8	7.9	99.1	8.06	13.11	1.35	3.08

Figure 11. Some parameters of general water quality in different tributaries of Bung River, March 19-26 2006.

4.2.2 Nutrients and main ions

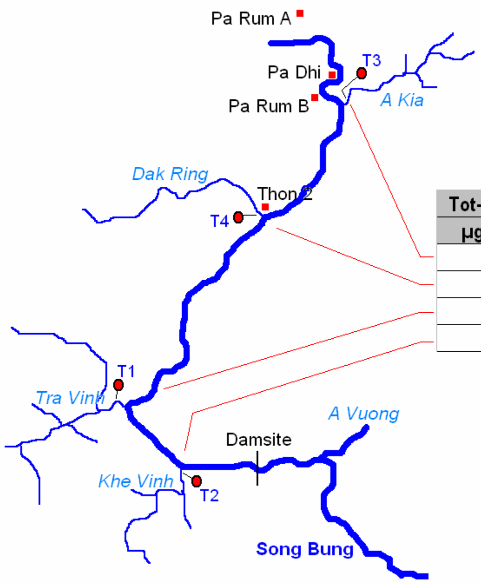
Results from analyses of nutrients (Nitrogen and Phosphorus components) and major ions, are given for Song Bung mainstream in **Figure** 12, and for the tributaries in **Figure** 13.



St. Code	Tot-P/L µg/l P	Tot-N/L µg/l N	NH4-N µg/l N	NO3-N µg/l N	Cl mg/l	SO4 mg/l	Ca mg/l	Fe/MS µg/l	K mg/l	Mg mg/l	Mn/MS µg/l	Na mg/l
SB2	11	140	<2	24	1	1.6	10.3	226	0.9	4.61	33.6	4.55
SB3	18	105	<2	20	0.99	1.67	10	245	0.95	4.4	33.9	4.42
SB4	26	110	<2	27	0.99	1.62	9.7	378	0.91	4.61	55	4.42
SB5	14	107	<2	28	1.21	1.43	9.28	247	1.1	3.96	83	4.58
SB6	15	98	<2	32	1.18	1.43	8.9	252	1.08	4.16	42.2	4.61
SB1	15	117	<2	29	1.27	1.51	9.73	251	1.08	4.1	41.7	4.6
SB7	12	98	<2	17	1.19	1.36	8.33	242	1.18	3.39	28.6	4.2

Figure 12. Nutrients and main ion composition at different sites in Sung Bung River March 19-26 2006.

The concentrations of both phosphorus and nitrogen are low. The P shows the same variation between stations as the turbidity, which indicate that it is P adsorbed to particulate matter that constitutes the total-P concentration and not discharges from human activity. The concentration of total nitrogen and other N fractions are very low, and indicate almost pristine natural values, and no use of chemical fertiliser in the catchment. The concentrations of the main ions seem normal. There are relatively high concentrations of iron and manganese, which however, are also normal in the type of soils which are dominating in the catchment (Ferralite soils and Ferralic acrisols, cf NHP 2005).



Tot-P/L µg/l P	Tot-N/L µg/l N	NH4-N µg/l N	NO3-N µg/l N	Cl mg/l	SO4 mg/l	Ca mg/l	Fe/MS µg/l	K mg/l	Mg mg/l	Mn/MS µg/l	Na mg/l
61	195	10	58	1.02	2.07	8.93	111	1.17	5.78	33.2	3.12
10	155	7	49	1.51	1.11	7.84	133	1.37	3.16	15.1	4.76
13	92	<2	30	1.88	2.55	10.3	279	0.72	5.81	37.4	4.99
22	80	<2	<1	1.95	0.67	15.5	207	0.54	3.74	16.5	7.97

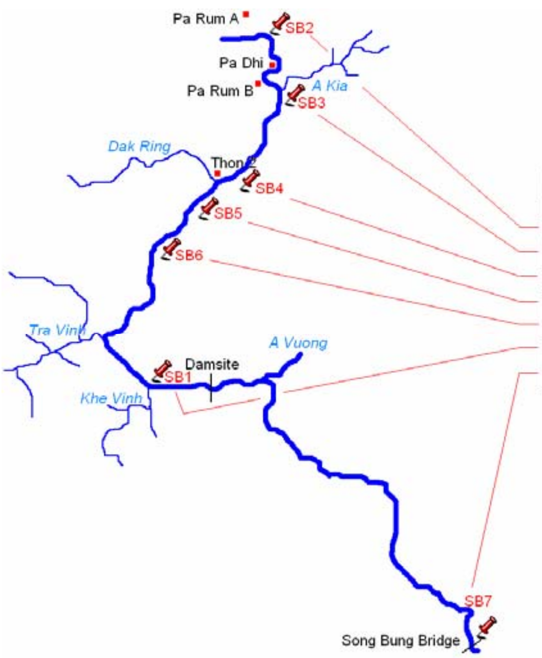
Figure 13. Nutrients and main ion composition in different tributaries of Sung Bung River March 19-26 2006.

4.2.3 Mercury and other heavy metals

The results from the water analyses of mainstream Song Bung River are given in Figure 14 while the values for tributaries are given in Figure 15. For arsenic the highest concentration in Song Bung was from 0.8-1.2 µg As/l. In the tributaries the highest concentration was found in Ta Vinh (2.3 µg/l). The values are well below the limit that WHO (Drinking Water Quality Standards) set for dinking water (10 µg/l). The Vietnamese standards set a limit of 50 µg/l. At several places in Northern Vietnam high content of arsenic in ground water is a problem for dinking water. For example in the raw drinking water wells for Hanoi the arsenic content ranges from 240-320 µg/l, and after treatment it is varying from 25-91 µg As/l (Berg et al 2001).

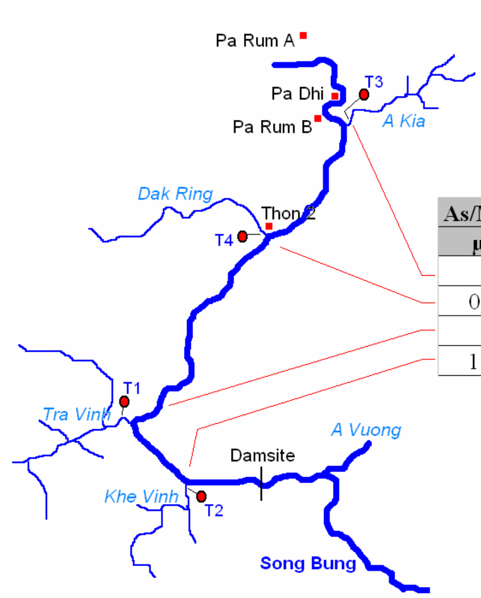
For mercury, which is used to extract gold from the river sediments, the concentration in the water was also found to be low at all stations. The highest concentration in Bung River was 12 ng/l and was found at the downstream end of the gold mining impacted reach. There was a gradually increase from 2 ng/l upstream of Pa Dhi, which is upstream of the gold dredging area, and to the Ta Vinh area. At the 2 lowermost stations (Khe Vinh and Song Bung Bridge) the concentrations were lower. The Ta Vinh tributary had the highest observed Hg concentration of 21 ng/l. In this river several gold panning activities take place in the upstream river, and metallic mercury is used in the extraction. The other tributaries had values approximately as in Bung River upstream Pa Dhi, which can be regarded as natural background levels.

In the Bung River from Pa Dhi to Ta Vinh tributary as well as in Ta Vinh it self, the water had enhanced mercury concentrations clearly above natural background levels. The levels were, however, low compared to national and international water quality standards. The Vietnamese water quality criteria recommends that the concentration should be below 1000 ng Hg/l, the US EPA (Water Quality Criteria) says that no damage to biological life is observed at concentrations of Hg below 700 ng Hg/l. The Canadian WQG also has a limit of water use of 1000 ng Hg/l.



	As/MS	Cd/MS	Co/MS	Cr/MS	Cu/MS	Hg/L	Ni/MS	Pb/MS	Zn/MS
Merket	µg/l	µg/l	µg/l	µg/l	µg/l	ng/l	µg/l	µg/l	µg/l
SB2	0.81	0.066	0.29	0.4	0.618	2	0.33	0.261	0.72
SB3	1.02	0.009	0.28	0.5	0.95	<1,0	0.37	0.323	0.88
SB4	1.26	0.057	0.45	0.6	1.23	2	0.53	0.447	1.23
SB5	1.04	<0,005	0.22	0.4	0.833	6	0.35	0.231	0.83
SB6	0.92	0.074	0.33	0.5	0.971	12	0.42	0.309	0.85
SB1	1.03	0.009	0.37	0.5	0.963	5.5	0.43	0.372	0.94
SB7	0.89	<0,005	0.24	0.4	0.835	5.5	0.35	0.323	0.99

Figure 14. Concentration of Mercury and other heavy metals in the water at different sites of Song Bung mainstream, March 19-26 2006



As/MS	Cd/MS	Co/MS	Cr/MS	Cu/MS	Hg/L	Ni/MS	Pb/MS	Zn/MS	CN
µg/l	µg/l	µg/l	µg/l	µg/l	ng/l	µg/l	µg/l	µg/l	µg/l
2	0.026	0.18	0.5	0.549	<1,0	0.8	0.148	0.69	<2
0.32	0.082	0.15	0.4	0.682	2	0.23	0.128	0.59	<2
2.3	0.303	0.54	0.5	0.649	21	0.49	0.544	1.15	<2
1.38	<0,005	0.09	0.2	0.236	2.5	0.08	0.073	0.42	<2

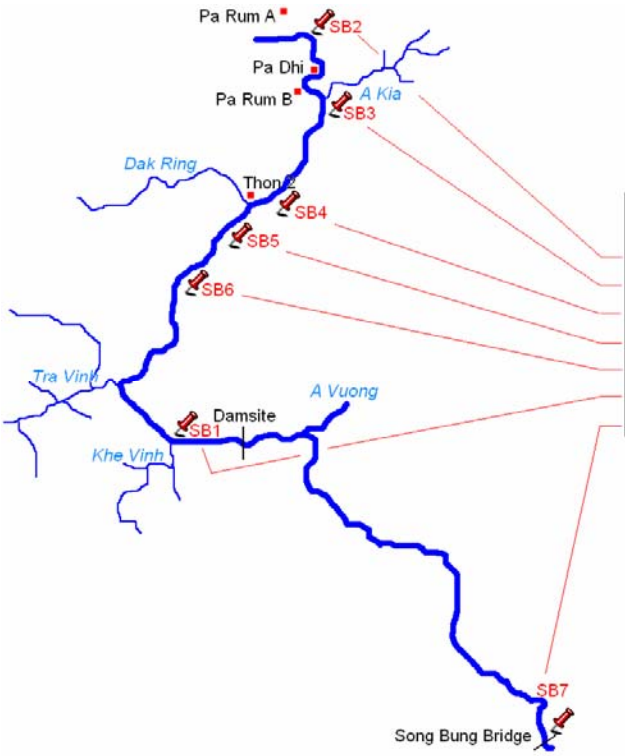
Figure 15. Concentration of Mercury and other heavy metals, and cyanide in the water of different tributaries of Song Bung, March 19-26 2006

The other heavy metals did all show values well below the limits of concern of both the Vietnamese water quality guidelines as well as the cited international guidelines.

4.3 River Sediments

4.3.1 Mercury and other heavy metals

The analytical results from the sediment samples from the Bung River itself are given in Figure 16, whereas the results from tributary sediments are given in Figure 17.



As	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
5	<0,2	13.5	26.8	14.7	18900	0.008	531	11	8.8	33.7
9.2	0.2	22.2	65.2	36.5	41200	0.025	871	31.1	16	80.6
7.9	<0,2	20.7	65.2	44.2	37400	0.067	741	30.1	15	72.7
No soft sediments on this station										
7.5	<0,2	16.8	52	31.1	29100	0.02	671	26.2	11	56.7
4	<0,2	8.06	22.4	14	15300	0.009	349	12.5	6.2	32.2
6	<0,2	13.4	30.6	18.7	21600	0.016	439	17	13	44.7

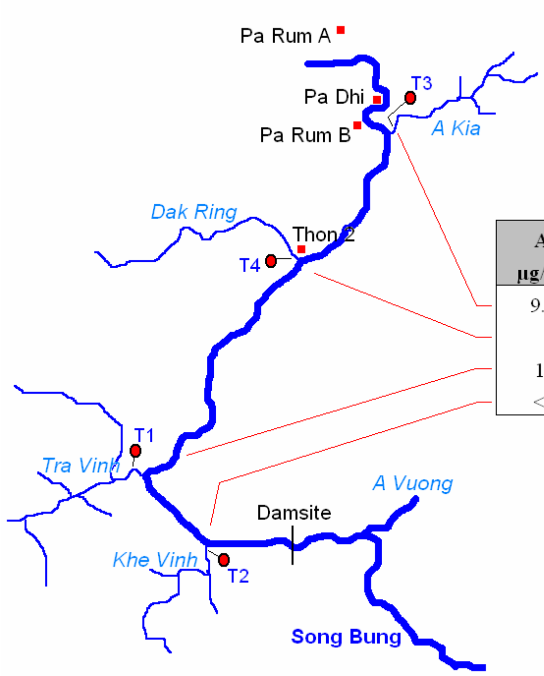
Figure 16. Concentration of Mercury and other heavy metals in the bottom sediments at different sites of Song Bung mainstream, March 19-26 2006

Only a few nations have adopted quality guidelines for sediments. Vietnam has not. Canada has adopted a set of sediment quality guidelines where they operate with 2 limiting levels. They give one level above which possible environmental impacts can occur, and based on that, they give a recommended level well below this as a guideline for water managers to try to keep the water recipients below. The Canadian Environmental Guidelines are among the strictest in the world. With respect to mercury, which is the most dangerous heavy metal, the Canadian Environmental Quality Guidelines recommended value is of 0.170 µg/g, and a value of possible environmental effects of 0.486 µg/g sediment. In Bung River the highest sediment concentration of 0.067 µg/g was recorded in the middle of the gold dredging area at Thon 2. This is well below the values in the Canadian guidelines.

Among the tributaries, the highest concentration of mercury was found in the sediments from Ta Vinh (0.110 µg/g). This is approaching the Canadian guideline, but still well below the limits of observed environmental impacts given in the Canadian Environmental Guideline system.

The highest sediment Hg-concentrations were found in the same places as the highest water phase Hg-concentrations were found, and correspond to the places where sediment extraction of gold has the highest activity. This shows that the gold dredging and the use of mercury can be detected in water and sediment contamination, but the contamination is low, and well below the limit that is regarded as impacting the environment and the people.

Iron showed high values in the sediments. However, iron is an essential and not toxic element. The type of soils in the catchment area (Ferralite soils and Ferralic acrisols, cf NHP 2005), is known for having high iron content. There are no limit values for iron in most sediment quality guidelines because iron is not known to cause environmental problems.



As µg/g	Cd µg/g	Co µg/g	Cr µg/g	Cu µg/g	Fe µg/g	Hg µg/g	Mn µg/g	Ni µg/g	Pb µg/g	Zn µg/g
9.5	<0,2	19.3	52.8	22.5	31700	0.041	694	28.4	13	60.7
2	<0,2	8.4	31.3	44.9	16000	0.008	306	12	4.9	28
14	<0,2	10.1	29.8	14.1	13900	0.11	468	22.7	8.9	25
<2	<0,2	3.9	5.4	4	11700	0.027	222	3.6	3	24

Figure 17. Concentration of Mercury and other heavy metals in the bottom sediments in different tributaries of Song Bung in March 19-26 2006

Arsenic, which often follows iron (Berg et al 2001, Tran Hong Con et al 2003) showed maximum values in the Song Bung sediments of 9.2 µg/g and 14 µg/g in Ta Vinh sediments. The Canadian guideline value is 5.9 µg /g, and the level for possible environmental impacts is set to 17 µg/g. The soils in Vietnam are rich in both iron and arsenic (Berg et 2001, Tran Hong Con et al 2003, Christen 2001), which creates a considerable problem of utilising groundwater as drinking water without treatment. For example in the deep soil of the Red River flood plane (Berg et al 2001) found from 600 to 3300 μg/g arsenic. This gives high concentrations of arsenic in the ground water. In that region, a large number of people are subjected to health wise dangerously high concentration of As in their drinking water from private deep wells. These wells do not have any water treatment. The values from Song Bung sediments must be regarded as low in comparison with many areas in SE-Asia, and they are all below the level of environmental impact given in the Canadian Environmental Guidelines, which again are among the strictest guidelines in the world.

For copper, the maximum concentration of 44 μg/g was found in Song Bung at Thon 2 village. The Canadian Guidelines recommends a limit of 36 μg/g, whereas the limit of possible environmental impact is estimated to 200 μg/g. The sediment content of copper is not anticipated to give any environmental problems in Song Bung.

All the other heavy metals showed values that are well below the international sediment quality guidelines and far below the values where environmental impacts are likely to occur.

4.4 Fish Flesh Quality

4.4.1 Mercury and other heavy metals

Heavy metals tend to be associated with particulate matter, which settles out in quite water in the rivers and ends up in the sediments. A large part of bottom dwelling animals are feeding on sediments, like the earth worm, digesting the organic material that is in the sediments. The fish eat the bottom animals. In this way heavy metals tend to accumulate in fish. Mercury is particularly dangerous in this respect, which has led to many incidents of seriously poisoning of people. The most well known accident was the Minimata case in Japan (c.f Canuel et al 2006) where a factory had discharged methyl mercury into the water for years, and where people where fishing for daily consumption. Big carnivorous fish are those who get the highest concentrations of heavy metals in their body flesh. Therefore we tried to catch big fish from the impacted river stretch for the study.

The results from analyses of fish are given in Table 3. Except for the small *Hainania serrata* of 10 g, where the whole fish was analysed as a mixed sample, the other samples are from bone free fish filets. The result from the *Hainania serrata* analysis is strongly impacted by the “sediment-containing” gut contents, and is not comparable with the results from the other fish.

The *Bagarius yarelli* is a purely carnivorous fish, while the large *Spinibarbichthys denticulatus* is mainly a plant eater, but also eats insect larvae and small bottom worms in periods. The highest concentration of mercury was found in large carnivorous *Bagarius yarelli* from the Thon 2 area, which is in the central part of the gold dredging area. The maximum value of 0.18 μg/g (= 0.18 ppm) must, however, be regarded as rather low. WHO has 0.5 ppm as a general limit for consumption of fish by humans. In the 6.5 kg *Spinibarbichtys denticulatus*, the concentration was only 0.005 ppm. In Sweden they use 1 ppm as a general limit for human consumption. In some lakes in Norway and Sweden, which have been polluted with mercury from pulp and paper industry, the mercury content of big carnivorous fish can be found as high as 10 ppm and more (cf. Berge 1983).

All the other elements in the fish filet analyses showed low values that are not of concern with respect to utilising the fish in Song Bung River as food.

Table 3. Concentrations of mercury and other heavy metals in the meat of fishes in the reach of Song Bung River impacted by gold mining.

Site	Fish species	Weight	As	Cd	Co	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
		gr.	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
Thon 2	*Spinibarbichthys denticulatus*	6500	<0,05	0.019	0.016	0.13	0.412	18.9	0.005	0.471	0.03	<0,02	7.82
Khe Vinh	*Hainania serrata*	10	0.335	0.055	0.187	0.83	1.24	348	0.084	16	0.35	0.215	62.3
Thon 2	*Tor Strachey*	3400	<0,05	0.03	0.017	0.2	0.561	25.8	0.11	0.513	0.043	0.02	10.4
Pa Di	*Bagarius Yarelli*	2500	<0,05	0.011	0.018	0.33	0.585	14.2	0.11	0.346	0.053	<0,02	9.38
Thon 2	*Bagarius Yarelli*	3000	<0,05	0.019	0.011	0.17	0.267	6.6	0.18	0.339	<0,02	<0,02	5.81
Tra Vinh	*Spinibarbichthys denticulatus*	80	0.058	0.03	0.012	0.14	0.303	12.6	0.06	0.512	0.027	0.024	6.81

The fact that no accumulation of was found in the fish, confirms the findings of low, and environmentally insignificant, values of heavy metals both in the water phase and the sediment phase from the Song Bung River and tributaries.

It is believed that the mercury contamination of fish in many rivers, like for example in the Amazon, is due to this gold mining using mercury as extraction technique (c.f. Castilhos et al 2006). However, it is metallic mercury that is used and this is not very bio-accumulative. Recent research indicates that it is the mobilization of methyl mercury from deforestation in the Amason catchment that is the reason for much of this environmental contamination that the gold mining has been blamed for. It is the burning of coal and heavy oil that is the main source for the diffuse mercury contamination of the world wilderness areas. The mercury in the smoke is widely spread through atmospheric fallout and it binds to the organic material, both living biomass and organic material in the soil. Deforestation accelerates the mineralization of forest litter, wheel tracks cause drainage, which causes mineralization of top soils. All these factors result in leakage of organic mercury, which is very bio-accumulative in fish (c.f. Willis 2006).

5 Aquatic life

5.1 Phytoplankton

5.1.1 Species composition

In the analyses, 78 phytoplankton species belonging to 26 families were recorded, which included phyla of Bacillariophyta, Chlorophyta, Cyanobacteria, Pyrophyta, Xanthophyta and Euglenophyta. Among them, Bacillariophyta comprised 33 species, which dominated the species composition (42.3%) of the phytoplankton community, see Table 4.

Table 4. Phytoplankton taxa observed during the field work in February 2006.

Taxon	Family		Species	
	Number of families	Percentage	Number of species	Percentage
Bacillariophyta	6	23.1	33	42.3
Chlorophyta	11	42.3	31	39.7
Cyanobacteria	6	23.1	10	12.8
Euglenophyta	1	3.8	2	2.6
Xanthophyta	1	3.8	1	1.3
Pyrophyta	1	3.8	1	1.3

5.1.2 Quantitative distribution

The results of the quantitative analyses of the phytoplankton in February 2006 are presented in Table 5. The density of phytoplankton in the Bung River and Vu Gia River is generally low, ranging approximately from 2 thousands to more than 9 thousands cell/l. The density and biomass of phytoplankton is lower in Bung upstream as compared to Vu Gia downstream.

The density distribution among species is different in each river section. In the sections 1, 2, 3 and 4, several genera of Bacillariophyta phylum (*Melosira, Diatoma, Fragillaria, Synedra*) often dominated in density of the phytoplankton community. Chlorophyta was the dominating group in section 5.

In biomass composition, multi-cell algae of genera *Oscillatoria, Lyngbia* (Cyanobacteria) and *Spyrogyra* (Chlorophyta) dominate the biomass of phytoplankton. However, the abundance of species changes both over the annual cycle, as well as along the river.

Table 5. Density and biomass of phytoplankton at the different sampling stations, see **Figure 5.**

Sampling station	Density (cell/l) and biomass (mg/m3)							
	Total density		Bacillariophyta		Chlorophyta		Cyanobacteria	
	Dens.	Biomass	Dens.	Biomass	Dens.	Biomass	Dens.	Biomass
Dak Oc	4,628	197	2,519 (54.4)	133 (67.5)	220 (4.7)	45 (22.8)	1,890 (40.6)	20 (10.1)
Dak Ring	7,352	215	3,704 (51)	90 (42)	685 (9)	95 (44)	2,963 (40)	30 (14)
Ta Vin	4,900	205	2,049 (42)	135 (66)	2,851 (58)	70 (34)	0	0
Bung river HSt	2,633	273	1,967 (75)	196 (72)	667 (25)	76 (28)	0	0
Khe Vinh	4,224	153	1,889	63	78	82	2,204	9
Bung river dam	3,222	314	1,269	96	1,667	184	259	33
Bung river Ta Lo								
Sonh Thanh	7,111	248	2,963 (42)	108 (44)	1,556 (22)	114 (46)	2,593 (36)	26 (10)
Cai river	9,191	334	2,697	243	418	82	6,076	9
Ta Hong	2,149	172	1,038 (48)	117 (68)	0	0	1,111 (52)	55 (32)
Vu Gia Ha Nha	2,075	162	1,297 (63)	71 (44)	778 (37)	92 (56)	0	0
Vu Gia Ai Nghia	4,767	429	2,767 (58)	302 (70)	1,999 (42)	128 (30)	0	0
Vinh Dien	8,586	361	1,881 (22)	92 (35)	0	0	6,704 (78)	270 (75)
Cau Lau	6,029	262	1,622 (27)	86 (33)	0	0	4,407 (73)	176 (67)
Cau Do	6,367	479	3,033 (48)	282 (59)	3,333 (52)	197 (41)	0	0
Hoi An	3,604	252	1,657 (46)	88 (35)	822 (23)	98 (39)	1,124 (31)	66 (26)

5.2 Periphyton

5.2.1 Species composition in the periphyton community

The functional ecological group called periphyton, are in this study defined as including attached algae, mosses, fungi and bacteria that grow on the stream bottom. Twenty-two species of Bacillariophyta were determined out of a total of 47 species of algae in the periphyton samples collected from rapids of the Bung River. This shows that benthic diatoms are the most abundant component of periphyton in Bung River.

However, filamentous algae belonging to green algae (Chlorophyta phylum) such as *Spirogyra ionia*, *S. azygospora*, and *S. prolifica* are also major components in the biomass of periphyton.

In river sections 1, 2 and 3, the periphyton constitutes the tiny film growing on stream-bed rocks and stones (making the stones slippery), or sometimes as a film of filamentous algae on stable sandy bottom. It ranges in colour and forms from bright green "clouds" of filaments to thin slimy films on stones. The colour of this film can be from grey-yellow to shiny black or brown-whitish. This community is a very important component of the stream ecosystem as it forms the plants (primary producers) of the food chain.

A tiny diatom cover is on all stones in rapids of all stations such as Dak Oc (Bung Upstream), Ta Vinh, and Khe Vinh (reservoir area). In small tributaries (streams) with moderate flow, more green algae could be found, also filamentous, on rocks, stones and boulders, which indicate more nutrient rich conditions.

In streams with stagnant or slow flowing waters, long green filaments could be seen, e.g. in Dak Ring and in Song Cai at Thanh My. The green filaments are attached to the surface of stones, boulders, and in some places, filamentous algae can cover the entire bottom area of the stream. Many algal groups can live in such algal association, e.g. *Chlorophyta, Bacillariophyta,* and *Cyanophyta*.

In the lower reach of the river (section 4-5), diatom cover on stones was still important, but there was a larger contribution from filamentous green algae.

Moss communities were observed mainly on the surface of big stones in small streams with high humidity. Mosses are small leaf-bearing plants, mostly restricted to headwaters, attached to stone. Mosses intermingled with algae are a source of food and a habitat for a wide range of aquatic insects, snails and crustaceans.

5.3 Zooplankton

5.3.1 3.1. Species composition

In the samples collected from the Vu Gia River system including Bung River, Thanh River, Cai River and Vu Gia River in February 2006, 40 species of zooplankton belonging to 15 families were recorded (see the Annex of the report). Among the different groups of zooplankton, Cladocera had most species (19 species, constituting 47.5% of the total number of species). Generally, most zooplankton species are widely distributed in the area.

Typical species of freshwater zooplankton included Cladocera and Copepoda-Cyclopida which were mainly distributed in stream-river. Copepoda-calanoida (*Allodiaptomus rappeportae*) is a characteristic species for waters in the central area of Vietnam.

In the river section 5, four typical brackish water species of copepoda belonging to Copepoda-Calanoida, namely *Schmackeria curvilobata*, *S. bulbosa, Acartia pacifica*, and *A. clause* were found. Sections 4 and 5 were the most diverse in species composition. Section 1 (the upstream areas) had the lowest number of species.

Table 6. Observed zooplankton taxa in Song Bung River February 2006

Taxon	Family		Species	
	Number of family	Percentage	Number of species	Percentage
Cladocera	5	35.7	19	47.5
Copepoda	4	28.6	14	35.0
Rotatoria	3	21.4	4	10.0
Harpacticoida	1	7.1	1	2.5
Ostracoda	1	7.1	2	5.0

5.3.2 Quantitative distribution

The density of zooplankton was generally low, ranging from approximately 20 to more than 200 individuals/m^3. Copepoda was dominant in density of zooplankton and constituted 57-89%. These values were of similar density as found for zooplankton community of other streams and rivers in the central area of Vietnam. Drifting insect larvae constituted a considerable portion of the zooplankton in the river sections 1, 2, and 3. The component of insect larvae in river zooplankton is often referred to as "drift", i.e. individuals that are torn loose from the bottom by the current, or they have gone into the current voluntarily, to provide transportation to downstream areas. Very few insect larvae live truely planktonic. The *Chaoborus* midge is one of the few. Fish-eggs and fish-larvae were also found in the zooplankton samples from river section 5. The density of zooplankton varies in the different parts of Vu Gia river system, see Table 7, the highest density being recorded in sections 4 and 5, and the lowest densities were found in the upstream sections.

Table 7. The density of zooplankton of Vu Gia-Thu Bon river system during the field work in February 2006.

No.	Station	Total conc.	Copepoda	Cladocera	Rotatoria	Insecta larvae	Mollusc larvae	Fish egg-larvae
		Ind./m3	Ind./m3 (%)	Ind./m3 (%)	Ind./m3 (%)	Ind./m3 (%)	Ind./m3 (%)	Ind./m3 (%)
1	Dak Oc	19	12 (63,16)	4 (21,05)		3 (15,79)		
2	Dak Ring	95	54 (56,84)	35 (36,84)		5 (52,63)		
3	Stream	17	9 (53)	3 (17,9)		5 (29,4)		
4	Song Bung Tavin	23	20 (86,96)	3 (13,04)				
5	Khe Vinh	91	56 (61,53)	35 (38,46)				
6	Song Bung HSt	80	61 (76,25)	16 (20,0)		3 (3,75)		
7	Song Bung dam side	85	64 (75,3)	19 (22,3)		2 (2,3)		
8	Song Bung Ta Lo	75	55 (73,3)	19 (25,3)		1 (1,3)		
9	Tranh river	121	69 (57,02)	52 (42,96)				
10	Cai river	67	45 (67,16)	15 (22,3)		7 (10,45)		
11	Vu Gia Ta Hong	76	60 (78,95)	16 (21,05)				
12	Vu Gia Ha Nha	124	94 (75,81)	23 (18,55)	4 (3,22)	2 (1,61)		
13	Vu Gia Ai Nghia	122	71 (58,19)	48 (39,34)	1 (0,82)	2 (1,64)		
14	Cau Lau	159	91 (57,23)	60 (37,74)	7 (4,4)	1 (0,63)		
15	Vinh Dien	151	135 (89,40)	16 (10,6)				
16	Cau Do	239	170 (71,13)	63 (26,36)	3 (1,26)	4 (1,67)		
17	Hoi An	124	106 (85,48)	14 (11,29)			1 (0,63)	2 (1,63)

Table 8. Density of zooplankton in the Bung river in 2004 (data from July 2004, Ho Thanh Hai et al., 2004)

Station	Total Conc. Ind./m3	Copepoda Ind./m3 (%)	Cladocera Ind./m3 (%)	Rotatoria Ind./m3 (%)	Ostracoda Ind./m3 (%)	Insecta larvae Ind./m3 (%)
Song Bung Upstream1	41	12 (30,0)	12 (30,0)		17 (40,0)	
Song Bung Upstream2	128	35 (27,58)	44 (34,48)			49 (37,93)
Song Bung reservoir1	37	19 (50,0)	16 (44,4)	2 (5,5)		
Song Bung reservoir2	48	31 (64,58)	12 (25,0)	2 416		3 (6,25)
Song Bung Downstream1	53	33 (61,54)			20 (38,46)	
Song Bung Downstream2	67	46 (68,65)	19 (28,35)		2 (2,98)	

5.4 Zoobenthos

In the samples collected in the different river sections of Sung Bung River in February 2006 it was observed 48 taxa of zoobenthos (bottom dwelling animals). These consisted of 10 species of crustaceans, 19 species of molluscs, and 19 families of insect larvae. Primary data are given in the annex of the report.

Most of the species found are widely distributed over large parts of SE-Asia, but some species are confined only within the mountainous region of central Vietnam, e.g. the crustacean species *Potamon frustorferi, Vietopotamon aluoiensis, Atya moluccesis* . Some species of shrimps, such as *Macrobrachyum sp.1, Macrobrachyum sp.2, and Macrobrachyum sp.3* have not been found in Vietnam before, and may be new species for science. These will be checked for endemicity.

In the report on aquatic life of the Bung River by Le Trinh et al., (2005), some zoobenthic species such as the shrimp species *Macrobrachyum dienbienphuense, M. vietnamense*, and the snail of *Brotia (B) binodonsa subgnobiosa* were recorded. These zoobenthic species were, however, not found in this study. Some information on the number of taxa of Crustacea and Molluska found during the field work 2006 is given in Table 9.

Table 9. Taxa of Crustacea and Mollusca found in the 5 river sections in February 2006

Taxon	Family		Genus		Species	
	Number of family	(%)	Number of genus	(%)	Number of species	(%)
Crustacea-Macrura	2	16.7	3	15.0	7	24.2
Crustacea-Brachyura	2	16.7	3	15.0	3	10.3
Gastropoda	5	41.6	9	45.0	11	37.9
Bivalvia	3	25.0	5	25.0	8	27.6
Total	12	100	20	100	29	100

Most of the shrimps were belonging to the genus Macrobrachium. Only one crab species, *Somanniathelphusa sinensis*, was found. Several mollusc genera such as *Brotia; Pila; Sinotaia, and Angulyagra,* were found, which all are being exploited as important food for local people, but they are also sold at fish markets in Thanh My, Ai Nghia to give cash income.

The abundance of different snails ranged from 20-70 individuals/m^2 in some streams of sections 1 and 2. The abundance of different insects is much higher than for snails, reaching to hundreds of individuals per m^2. Communities of *Ephemeroptera* and *Plecoptera* are diverse in species composition and abundant in quantity at the head stream in reaches with moderate flows and clean water.

5.5 Fish and fishery

5.5.1 Species composition

Based on different ways of information gathering during the field work in February 2006, such as interviewing local residents, analysis of fish samples collected ourself from the Khe Vinh stream (tributary to Bung River in the section 2), as well as market surveys along the Vu Gia river, the team identified 107 species of fish belonging to 31 families of 9 orders occurring in the Vu Gia river system (see annex for complete species list).

Among them, the Cypriniformes order had 59 species, constituting 55.1 % of total amount of species. Among the 5 river sections, section 4 (upstream and middle Vu Gia river) had the highest number of fish species (90 species). In the sections 1, 2, 3 of the Bung river the number of species were much lower, ranging from 34 species in the uppermost (sect 1) to 38 species in the lowermost part (sect 2).

Brackish species of fish are only found in the river section 5 and consist of: *Clupanodon thrissa, Liza seheli, Gerres filamentosus, Chanda gymnocephala, Sillago sihama, Pisodonophis boro, Strongylura strongylura, Mystus gulio, Eleuthronema tetradactylum, and Nibea soldado.*

Among the fish species of Vu Gia River system, 4 species are listed as threatened in the red data book of Vietnam (2000) : *Clupanodon thrissa, Anguilla marmorata, Bangana lemassoni, and Tor tambroides Bleeker.*

In the fish species composition revealed in the study, there were 7 escaped “fish farm species species” that have been introduced from China, India, Africa and America, and 3 other species that have been introduced from the Red River and from the Mekong Delta.

Table 10. Occurance of fish taxa in Sung Bung – Vu Gia River

No	Order	Number of families	%	Number of species	%	Number of VN Red Book
1	Clupeiformes	1	3. 2	1	1	1
2	Osteoglossiformes	1	3. 2	1	1	
3	Anguilliformes	2	6. 4	2	1. 8	1
4	Characiformes	1	3. 2	1	1	-
5	Cypriniformes	3	9. 7	59	55.1	2
6	Siluriformes	6	19. 4	14	13.1	
7	Synbranchiformes	2	6.5	3	2. 8	-
8	Beloniformes	2	6. 5	2	1. 9	-
9	Perciformes	13	41. 9	24	22.4	-
	Total	31	100	107	100	4

In the Vu Gia river basin, according to the knowledge of local people, fishes are generally distinguished into two kinds: black fish and white fish.

- Black fish: fish species often survive the dry season in the bottom layer in the wet mud among vegetation. Often found in rice fields, as well as in sluggish parts of rivers and streams. Mostly carnivorous and detritus feeders. This group includes the families of *Channidae, Clariidae, Anabantidae.* Most of the species have dark colour.

- **White fish**: this group includes *Cyprinidae*, and catfishes belonging to the families of *Pangansiidae, Siluridae*, etc.

5.5.1.1 Measurement of some fish species collected from the Bung River at Pa Di village and Thon Two during the field work in February 2006

Anguilla marmorata Quoy & Gaimard: 1 individual with W = 4,000 g.
Spinibarbichthys denticulatus (Oshima): 1 individual with SL = 630 mm, W = 6,500 g.
Tor stracheyi (Day): 2 individuals with SL = 580- 660 mm, W = 3,500- 6,000 g.
Hainania serrata Koller: many individuals with SL= 50-78 mm, W = 2.4-6.4 g.
Pseudohemiculter dispar (Peters): 1 individual with SL= 74 mm, W = 6 g.

5.5.1.2 Measurements of 13 fish species collected from Khe Vinh stream:

The sampling site was close to where the road 14B crosses the stream. This part of the stream will be inundated by the future Song Bung 4 reservoir. The collected fish were small in size, their weight ranged from less than 1 g to 85 g/individual. Most of these fish species are used as food by the local residents. There are no migration barriers from the sampling site and down to the confluence with Song Bung which means that these fish are also present in Song Bung. The following fish were caught in the test fishing:

Poropuntius deauratus (Valenciennes): 2 individuals with SL = 80-95 mm, W = 13.7- 22.5g
Puntius semifasciolatus (Gunther): 1 individual with SL = 50 mm, W = 4.6 g.
Opsariichthys bidens Gunther: 20 individuals with SL= 35 -110 mm, W = 1.2-13 g.
Rasbora sumatrana (Bleeker): 6 individuals with SL = 47-56 mm, W = 2.6-4.1 g.
Glyptothorax interspinalum Mai: 1 individual with SL = 84 mm, W = 9.2 g.
Pseudecheneis sulcatus (McClelland): 4 individuals with SL = 48-70 mm, W = 2.2-6.6 g.
Annamia normani (Hora): 4 individuals with SL = 65-73 mm, W = 3.6-5.5 g.
Schistura caudofurca (Mai): 2 individuals with SL = 74-78 mm, W = 7-8 g.
Pterocryptis cochinchinensis (Valenciennes): 2 individuals with SL = 96-113 mm, W = 9.2-16.5 g.
Channa gachua (Hamilton): 9 individuals with SL = 80-163 mm, W = 9-85 g.
Papuligobius uniporus Chen & Kottelat: 1 individual with SL = 75 mm, W = 8.2 g.
Sewellia lineolata Valenciennes: 3 individuals with SL = 38-55 mm, W = 1.8-4.8g.
Brachygobius sua (Smith): 3 individuals with SL = 1 – 3 mm.

5.5.1.3 Measurements of some fish species collected from Thanh My market

We were told from the fish traders that these fish were mainly caught from the Cai River, Thanh river, and Vu Gia River. However, as it is close to the area where these rivers meet Song Bung, and there is no migration barrier encountered, the same species will be present in the downstream part of Song Bung.

Bangana lemassoni : 6 individuals (one small fish SL = 137 mm, W = 72.6 g), maximum W = 1.2 kg with SL = 450 mm.
Barbodes altus = *Puntius foxi*: 2 individuals with SL= 135-142 mm, W = 46.6-49 g.
Cirrhinus miolitorella : SL 45 Cm, W = 1 kg
Culter flavipinnis 2 individuals with SL = 175-207 mm, W = 54-92,5 g.
Elopichthys bambusa : 1 individual with SL = 45 cm, W = 1.1 kg, sometime to catch specimens with weights to 3 kg.
Hemiculter leucisculus: 3 individuals with SL = 140-167 mm, W = 30.6-72.8 g.
Hypsibarbus malcolmi = Puntius daruphani:1 individual with SL= 150 mm, W = 71 g.
Megalobrama terminalis : 1 individual with SL = 205 mm, W = 166 g.
Spinibarbichthys denticulatus : 1 individual with SL = 160 mm, W = 121.6 g. Maximum specimens with weight 3 kg may be caught.

Garra bourreti: 1 individual with SL = 120 mm, W = 40 g.
Onychostoma ovale: 2 individuals with SL = 120-170mm,W = 38-125 g.
Onychostoma ovalis rhomboides: 1 individual with SL= 120 mm, W = 38 g.
Opsariichthys bidens: 1 individual with SL= 110 mm, W = 1.2 g.
Paraspinibarbus macracanthus: 2 individuals with SL = 132-140 mm, W = 56-59 g.
Schistura caudofurca : 1 individuals with SL = 74 mm, W = 7 g.
Cranoglanis henrici : 2 individuals with SL= 130-170 mm, W = 29-71.5 g. Common species in this area with SL = 17 - 35 cm, W = 0.07– 0.5 kg
Cranoglanis bouderius : 1 individual with SL= 165 mm, W = 67 g.
Monopterus albus : 1 individual with SL 260 mm, W = 16 g. Maximum 60-70 cm, W = 150 -200 g.
Mastacembelus armatus: 12 individuals with SL = 117 -204 mm, W = 5.8 – 30.7 g.
Channa gachua : 14 individuals with SL = 80-163 mm, W = 9-85 g.
Channa striata : 1 individual with SL= 140 mm, W = 50 g. Common species in this area with SL = 40 -60 Cm, W = 0.3-1.0kg

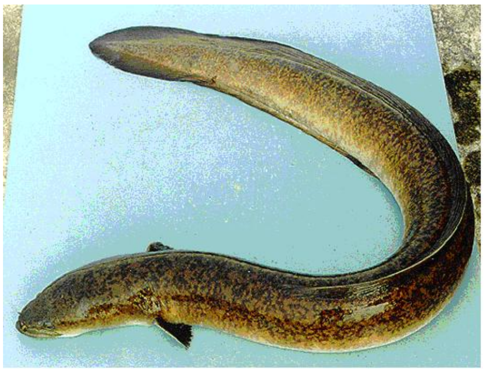
5.5.2 Some information on the ecology of important species

Clupanodon thrissa (Chinese gizzard shad)

The species belongs to the family Clupeidae (herrings, shads, sardines). This species often lives pelagic in coastal waters, and in estuarine waters. Many places they are exploited in commercial fisheries. The size is 20-30 cm. They migrate annually upstream for spawning. Spawning grounds are flowing area, and they have floating eggs. Research results on this species in the Red River System in northern Vietnam, shows that the spawning ground may be in Lo river (Phu Tho), Da river (Thac Bo, Hoa Binh). Now, prior to the regulation, there are no migratory barriers in Vu Gia river. The spawning season is from March to May. Each female can spawn 20,000-50,000 eggs. They eat different species of algae belong to Bacillariophyta such as *Pinnularia, Coscinodiscus, Asterionella, Suriella, Amphora, Cymbella*, and some small custaceans, and organic detritus as well.

Anguila marmorata (Giant mottled eel)

The species belongs to the family Anguillidae (freshwater eels). This species often live in upstream areas of large rivers or freshwater lakes having connecting channels to sea. They live in rock caves with thick mud layer in bottom. Their length ranged from 50-70 cm, even to more than 1m with normal weight from 0.6 to 2 kg. The highes recorded weight is 20.5 kg. They can become very old, up to 40 years.



Reproduction: This species is catadromous, it grows in freshwaters, and when reaching maturity, they migrate to the deep sea for spawning. After hatching of the eggs, leaf-shaped larvae are drifted to the shore by sea currents and the juveniles swim upstream rivers to live there until they become mature. By interviews, it was confirmed that the eel also live far upstream in the Song Bung 2 area, but in low numbers and its size is small. At the moment, prior to the regulation, there are no natural migratory barriers in Vu Gia river.

Nourishment: This species is carnivorous, eating invertebrates, including crustacean, oligochaete, mollusk larvae, and small fishes, even small amphibians. The eel often finds food at night.

The eel is exploited mainly in the spawning season which occurs in the rainy season, extending from September to March. Biological characteristics of this species are not studied in detail.

Bangana lemassoni (No English name)
This fish belongs to the family Cyprinidae (Minnows or carps). Maximum size is 30 cm. The species is distributed in upstream and middle part of the river. Adult females at two years of age can start to spawn. Spawning season often extends from December one year to February next year. Spawning grounds are often located to flowing waters with bedrock, boulders, cobbles and gravels. When spawning they congregates in shoals with high density.

Their main food is periphyton including diatom, green algae, organic detritus, and several invertebrates. Their bowel is many times longer than the body length. In this survey, the team collected females of this species with gonads in the maturity stage IV.

Bagarius yarrelli (English name Goonch)
This fish belongs to the catfish family Sisoridae. Maximum recorded size is 200 cm and weight 20 kg. This species often distributes in the upstream and middle part of the Bung River. It occurs in large rivers on the bottom, even with swift current. They do not enter small streams. Found among boulders, often in the white water of the rapids where it apparently is indifferent to the strong current.

Reproduction: They are mature after 3-4 years of age. They migrate from the downstream to the upstream and middle part of the river for spawning. They migrate often in schools. Spawning grounds are moderate flowing water with bedrock and low depth. Spawning season extends from March to June, or even later.

Nourishment: They are carnivorous fish species, their main food are insect larvae such as Ephmeroptera, Trichoptera, Hemiptera, Coleoptera, Odonata, Diptera, and shrimps, as well as small fishes.

Cranoglanis henrici (No English name)
This fish belongs to the family Cranoglanididae (Armorhead catfishes). Maximum size is 30 cm. The fish lives benthopelagic, and is widely distributed from the middle of the river to downstream areas in the Vu Gia River system.

Nourishment: Their food is diverse, and includes leaves, crustaceans, mollusks, zooplankton, oligochaeta, worms, insect larvae and human waste and organic detritus.

Reproduction: Spawn eggs in holes in rocky bottoms. There is scarce information on the biological and ecological features of this species.

Notopterus notopterus (Bronze featherback)

This fish belongs to the family Notopteridae (Featherbacks or knifefishes). Maximum recorded size is 60 cm (FishBase).

This species is mainly confined to the lower basin of Vu Gia – Thu Bon from Thanh My to the mouth of the river. It lives both in fresh water and brackish waters. Their food is diverse including small crustaceans, small fish, and insect larvae. Spawning season falls in flooded months with high water level. The female spawns eggs in nest in bottom and eggs are protected by the male.

This fish is exploited both in aquaculture, as well as in commercial and subsistence fishery.

Found in clear streams and enters brackish waters. It inhabits standing and sluggish waters of lakes, floodplains, canals, rivers and ponds. Breeding takes place in stagnant or running waters in the rainy season. Eggs are laid in small lumps on submerged vegetation. A female measuring 21-25 cm usually lays 1,200-3,000 eggs. The fish is relished both in fresh and dried state.

Barbodes altus or Puntius foxi (Red tailed tinfoil)

This species belongs to the family Cyprinidae (Minnows or carps). Maximum size is 20 cm (FishBase).

This is a common species, distributed in Bung River, Tranh river, and Cai river. Their food consists of small invertebrates and plant detritus, and organic human detritus. They congregate in colonies of some tens individuals. There is scarce information on biological and ecological features of this species in Vietnamese rivers.

Importance according to FishBase: fisheries: minor commercial; aquaculture: commercial; aquarium: commercial.

Biology description in FishBase: Occurs at midwater depths in large and medium-sized rivers and floodplains. It feeds on various plant and animal matter. Commonly found near villages where it feeds on organic detritus disposed of by humans. Reported to be occasionally poisonous, causing vomiting, due to the fruits it eats. Colonises inundated forests and adults migrate back to the river in October. Young of the year follow thereafter when the water levels recede. Large-sized fish are marketed fresh while smaller ones are used to make prahoc (fermented fish) and nuoc mam. Popular fish in the aquarium trade where it is sold under the name of "tinfoil barb". It is captured from the wild for the ornamental fish trade in Thailand. It is cultured in floating cages in Viet Nam.

Spinibarbichthys denticulatus (No English name is given)

The species belongs to the family Cyprinidae (Minnows or carps). Maximum size in Song Bung is up to 10 kg. This species distributes in upstream and middle river of the Vu Gia river with speedy flow. Big fish is living in deep pools of rivers and streams.


Nourishment: This species eat higher plants such as grass, and fruits. Young fishes eat algae, invertebrates, and insects. Adults eat mainly plants. Therefore, the length of bowel gradually increases to 3-4 times longer than the body length.

Reproduction: This species is mature at 3-4 years of age. Females with body length of 60-70 cm have 14,000 eggs with the length of 100 cm have more than 100,000 eggs. There are two spawning periods being February-April and july-October. Juveniles are living in the littoral waters of tributaries, after this stage, they move to larger and deeper waters. It is an important fish both in commercial and subsistence fisheries.

Megalobrama terminalis (Black Amur bream)

This fish belongs to the family Cyprinidae (Minnows or carps). Maximum size is 60 cm corresponding to 3 kg (FishBase). Lives benthopelagicly in rivers.

No picture available

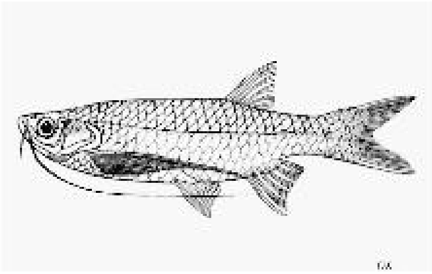
This species is distributed in the middle Vu Gia river and lower Song Bung. Their food consists of aquatic plants, plant detritus, algae, invertebrates, and insects. The bowel of this species is long, approximately two times longer than body length. Reproduction: This species often migrates to upstream or middle part of the river for spawning. Spawning grounds are in littoral waters with slow flows. Spawning season ranges from May to July. Juveniles and young fishes are drifting downstream by the flow. It is an important fish both with respect to commercial and subsistence fisheries.

Opsariichthys bidens

This fish belongs to the family Cyprinidae (Minnows or carps). Maximum size is 16 cm (FishBase).

This species is found anywhere from upstream at Khe Vinh with gravel and rock substrate to downstream close to the river mouth. It prefers rapidly flowing stretches of large rivers. The diet consists of insect larvae, especially Odonata. There is limited information on biological and ecological features of this species.

Esomus longimanus (Mekong flying barb)
This fish belongs to the family Cyprinidae (Minnows or carps). It is a small fish and the maximum size is given to be 8 cm in the FishBase.



This species is widely distributed in flooded rice- paddies, canals, ditches, and tributaries in downstream of Vu Gia River. Their diet includes zooplankton, and insects. There is limited information on biological and Ecological feature of this species.

Description in FishBase: Usually found in ditches, canals and ponds often in areas with extensive growth of submerged aquatic plants. It is encountered mainly in stagnant water bodies including sluggish flowing canals as well as in medium to large rivers of the middle Mekong. It feeds on zooplankton and insects. Sometimes sold fresh and used to make prahoc (fermented fish).

Poropuntius deauratus (No English name)
This fish belongs to the family Cyprinidae (Minnows or carps). There is no information on maximum size.

This species is often distributed in upstreams reaches of Song Bung (sections 1, and 2). They eat algae, organic detritus and chironomids. There is scarce information on biological and ecological feature of this species. In the FishBase they are recorded as endemic to an area of Vietnam south of Hue.

Puntius brevis (No English name)
This fish belongs to the family Cyprinidae (Minnows or carps). Maximum size is given to 12 cm (FishBase).

This species is distributed in floodplains, canals, ditches, and streams with slow flows. They eat algae, plankton, small crustaceans and tubuficid worms (Oligochaeta). It moves into newly inundated land during flood season and spawns there. There exists little information on biological and ecological feature of this species.

Carassioides acuminatus (No English name)
This species belongs to the family Cyprinidae (Minnows or carps).

This species is often distributed in the lower basin of Vu Gia – Thu Bon river system, where they live benthopelagicly. They eat zooplankton, insect larvae, Oligochaeta, chironomids, and organic detritus. There is scarce information on the biological and ecological features of this species. According to FishBase there is a commercial fishery on the species many places.

Onychostoma ovale (No English name)

This fish belongs to the family Cyprinidae (Minnows or Carps). It is a small fish and the maximum size is given to be 10 g (FishBase), but seems to get bigger in the Vu Ghia – Song Bung river system.

This species is often distributed in flowing waters in the upstream reaches. They eat periphyton, zooplankton, insect larvae, and organic detritus. Females of 2 years of age are mature. They spawn sticky eggs in stone caves. The spawning season extends from December to February.

Mastacembelus armatus Zig-zag eel (local name: lau)

This fish belongs to the family Mastacembelidae (Spiny eels). Maximum size is given to be 90 cm (FishBase).

This species is frequently distributed in stone caves in fast flowing waters. They eat worms, insects, small shrimps, even small fish. The bowel of this species is short, equals 50-60% of body length. Females of 1 year of age get mature. Spawning season ranges from April to June. Spawning locations are stone caves near the river bank. It can also live in brackish water.

Big fish are often concentrated in deep pools, confluent waters between stream and river. By interviewing local residents, some locations along the Bung River such as Khe Rang, Khe Bnau, khe Lang and Khe Vinh are feeding grounds of this fish species.

Biology description given in FishBase: Usually found in streams and rivers with sand, pebble, or boulder substrate. Seldom leaves the bottom except when disturbed. Also occurs in still waters, both in coastal marshes and lakes. Sometimes stays partially buried in fine substrate. It enters flooded forest. Reported to occur in areas with rocky bottoms in the Mekong mainstream during the dry season, but enter canals, lakes and other floodplain areas during the flood season. It forages at night on benthic insect larvae, worms and some submerged plant material. It is common during the summer months. Marketed fresh and frequently seen in the aquarium trade.

Elopichthys bambusa

This species belongs to the family Cyprinidae (Minnows or carps). It is a big fish and maximum published size is given to be 200 cm (Fishbase) which indicates a weight up to 15-20 kg. It is a potamo-droumous fish that lives benthopelagicly in large rivers. It is a popular food fish for humans.

Very little information is published about the biology and ecology of this species. In adult sizes it is a fish eating predator.

5.5.3 Fish migration

The Vu Gia – Thu Bon river system is a continuous water body without fish migration barriers. In such a system the fish community will always be comprised of many migratory populations. With respect to migration habits the fish community can be divided into

1. Anadromous species	=	Species that live in the sea and which goes up into the river for spawning
2. Catadromous species	=	Species that live in the river and which migrate to the sea for spawning
3. Potamodromous species	=	Species that perform annual migrations withing the river system, either for spawning or for feeding purposes
4. Stationary species	=	Species that live in the same area of the river all their life

An example of an anadromous migrant in Song Bung is the *Clupanodon thrissa* (Chinese gizzard shad), which is important in coastal and estuarine fisheries. By means of interviews with local people, we were told that small gizzard shad (*Clupanodon thrissa*) can migrate up to the Vu Gia upstream for spawning. Exactly how far up it can migrate was not clearified, but it seems to migrate not further than to the junction between Song Bung and A. Vuong, probably not even so far. During the field work in February, many small gizzard shads were caught along Vu Gia and sold in Thanh My market and other markets along the Vu Gia. This species was not available in the Thanh My market during our field visit in January, indicating that the fish had not started the migration by then.

A representative for the catadromous species is the important and highly priced (up to 250 000 VND per kg) *Anguilla marmorata* (Giant mottled eel). This species migrate all the way to the Song Bung 2 area, and also from there it migrates to the sea for spawning. Downstream spawning migration of mature adult *Anguila marmorata* occurs in rainy season extending from September to March. On this migration it is frequently caught by fishermen.

Many fish species migrate within the river system, both for spawning and for feeding. These are called potamodromous species. Their migration distance can be both long and short, depending on the species. Other species live more or less in the same area of the river all the time (stationary species).

In addition to the time of ther year, the hydrological regime is a major factor in steering the timing of the fish migrations. The migrations are trigged by seasonal rise and decline of water level and water flow. Upstream spawning migration of adults generally starts at the beginning of the rainy season, when the flows increase and water levels are rising. Typical representatives for potamodromous species with upstream spawning migration are *Bangana lemassoni and Bagarius yarrelli*, which both are important food fish for humans in Song Bung.

According to local fishermen along the downstream part of Song Bung, several species migrate downstream to the flooded lands around the the junction canal between Vu Gia and Thu Bon. These are species that spawn in flooded vegetation, see Figure 18. The common carp (*Cyprinius carpio*), and other big cyprinids were said to perform this migration every rainy season.

Many species also migrate in the small rainy season, which is confined to May- June. In this period the water level is not high enough for those species that spawn in flooded vegetation. However, the water is turbid, which gives the fish shelter and the feeling that it is safe to migrate. Those who migrate in this period often spawn floating eggs which are hatching while drifting downwards. The current speed is moderate in this small rainy season which gives time enough for hatching before the eggs are reaching the sea. The juvenliles of these species are swimming upstream and are found over the different river sections. Other upstream spawners have eggs that stick to stones, rocks, bushes, etc. The juveniles of these species are performing downstream feeding migrations. During the dry season, when the water level is dropping, especially in the Bung upstream and the Vu Gia upstream as well, adult fish migrate to deep pools which are important refuges during this often critical period.

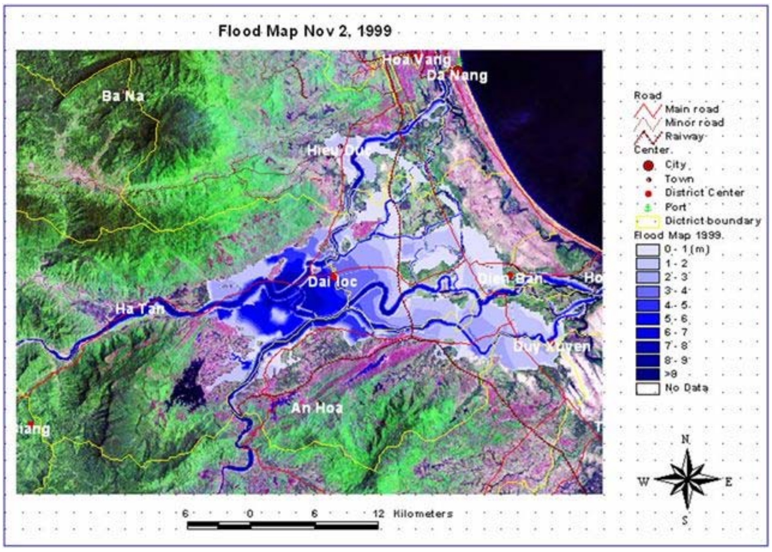


Figure 18. The lowland area of the Vu Gia – Thu Bon River System where there is flooded areas every rainy season is an important spawning area of many fish species, also down-migrating from Song Bung (simulated model picture from the high flood in Nov 1999, Basberg 2006).

The fish migrations in the Vu Gia – Thu Bon River System are not studied, and are only partly understood. **Table 11** shows some data about spawning migrations of some species from the river system.

Table 11. Migration and spawning season of some main fish species in Vu Gia – Thu Bon river

No	Scientific name	Spawning time	Spawning place	Migratory type
1	*Anguilla marmorata* Quoy & Gaimard,	September to March	Deep sea	katadromous
2	*Anabas testudineus* (Bloch)	April-June	Paddy rice field	
3	*Bagarius yarrelli* Sykes	March to June, may be later	rapids	potamodromous
4	*Bangana lemassoni* (Pellegrin & Chevey)	December- February	rapids	potamodromous
5	*Barboides gonionotus* (Bleeker)	September-December	Anywhere waters	
6	*Channa striata* (Bloch)	April-July	Wet land, paddy rice field	
7	*Cirrhinus microlepis* Sauvage	June-July		potamodromous
8	*Cirrhinus molitorella* Valenciennes, 1844	May-September, mainly from June-August	Upstream	potamodromous
9	*Cyclocheilichthys enoplos* (Bleeker)	May-June		
10	*Mastacembelus armatus* (Lacepede)	April to June	stone caves near bank	
11	*Notopterus notopterus* (Pallas)	May to July	in nest in bottom	
12	*Osteochilus salsburyi* Nichols & Pope	October-November	Undulated field	
13	*Clupanodon thrissa* (Linnaeus)	March-May	Riverine mouth, in brackish waters	anadromous
14	*Trichogaster trichopterus* (Pallas)	April-May	Paddy rice field	
15	*Wallago attu* (Schneider)	spawning peak September-November	Undulated fields	
16	*Hainania serrata* Koller	April-July	Small streams	potamodromous

5.6 Fishing activities

So far there is no official statistic on fresh water fishery in Nam Giang district. The information given here is gathered during the field work in February 2006 by the freshwater ecology team, supplemented with some information from the household survey team. The main description of fish catch and its meaning for local population will be given in the reports from the social team.

5.6.1 Aquatic products that are used

Local people are utilising several water living anaimals:

- Fish
- Mussels
- Snails
- Shrimps
- Crabs
- Frogs
- Turtles

Among these fish is the most important. The series of pictures in Figure 19 show some of the aquatic products that are exploited.

Large fish

Small fish

Shrimps

Frogs


Snails


Mussels


Turtles


Crabs (section 5 estuary)

Figure 19. Some aquatic animals which are utilised as food by the local residents. Some of the species are also being sold to provide cash.

By interview, Mr. Bui Cong Luong (Department head of economy of Nam Giang district) said that there are about 10 boats catching fish in Nam Giang. Each boat can catch 5-30 kg of fish/daily. He confirmed, though, that most of them are not professional fishermen.

We were also told that the expected number of professional fishermen (their occupation being fishermen) at the Thanh My town region ranged from 3 to 5 persons, and 20 persons at the Ai Nghia town. Each fisherman often catches from 1kg to 5 kg of fish per day. However, many days they don't catch any fish.

Fish price varied depending on the type of fish. The price of eel can reached about 200,000 VND/kg, turtle: 250,000-300,000 VND/kg. Price of other fish is lower, ranging from 10,000 to 30,000 VND/kg.

According to information of many residents who were interviewed, the fish resource was reduced to about 50% compared with previous catches 10-15 years ago. Eels (Giant mottled eels - *Anguilla marmorata*) and *Bagarius yarrelli* are now rarely found as compared to 10 years ago. These species were caught by hooks or gillnets. Some residents living in the reservoir area told that fishermen in earlier days often caught eel of more than ten kilograms, whereas today they catch only eels up to 3-4 kg.

Some species have more or less disappeared, as for example the *Onychostoma spp*., which which used to be a common fish species. Now it has become very rare. However, several big sized fishes are still caught by local residents, such as *Bangana lemassoni, Cirrhinus molitorella, Cyprinus carpio, Elopichthys bambusa, Spinibarbichthys denticulatus, Bagarius yarrelli, and Anguilla marmorata,* with a weight more than 1kg/ individual.

Some common fish species in the Bung River such as *Barbodes altus, Barbodes gonionotus, Onychostoma ovale, Paraspinibarbus macracanthus, Cranoglanis henrici, Mastacembelus armatus, Carassius auratus, Hainania serrata, Clarias fuscus, Monopterus albus, Channa striata, Glossogobius giuris*, are often used for food by local residents in the basin.

5.6.2 Fishing methods

The local people along the river use several kind of fishing gear to catch fish:

- Gillnet (standing and drifting)
- Seine net
- Landing net (Hand net)
- Dredge net (for mussels and snails)
- Indian Krimmer (net on a rod, 4-5 m long)
- Cast net
- Lift net
- Bamboo traps
- Spear fishing
- Electric fishing gear (both from boat and from land)
- Single line with one hook
- Baited long line with many hooks
- Shrimp traps (bundles of wood, bamboo tubes)
- Weirs
- Hand catching

All these types of fishing gear are in active use in the Song Bung – Vu Gia River and they were all observed during the field work in February 2006. The habit of fishing is different at different river sections. In **Figure 20** we have shown picture of some of the meothods used. A few pictures are not from this river system (marked), but are included to show the principles of the methods).

Gillnet with mesh size of 10 cm vitnesses about big fish

Gillnets are cleaned and dried between each use. Use of gillnet is the most common way of fishing, in the catchment, mostly standing nets, but also drifting nets are used..

Seine-netting. NB: Not from Song Bung, but included to show the principle.

Men are practicing the difficult and heavy technique of cast-net. Both fish and shrimps are caught with cast nets. (NB. Picture not from Song Bung, but included to show the principle)

Small fish are often caught by hand-nett (or landing-net) when they are shoaling. Women often practice this method.

Spear-fishing. Photo not from from Song Bung, but included to show the principle.

Baited line are used both in swift waters ad quiet waters, both as long line with many hooks and single line with one hook (photo from Bird et al 2005)

Bambu traps.In the wide end there is an inward directed funnel.Branches are placed around the rim of the funnel. The fish swims in between the branches and into the small hole in the centre of the funnel. It cannot find its way out.

A boy with electric fishing gear that is made for operating from land

Practicing electro-fishing from land. The boy to the left is carrying the catch

Bamboo boat equipped both with a gillnet and electric fishing gear.

Practicing electro-fishing from boat.

Mud is taken up in bamboo sievs. The mud is washed through and mussels and snails are retained.

Catch of snails and small mussels in Vu Gia

In the lower Vu Gia small fish are caught in lifts nets. The net is placed on the bottom by a system where the corner poles are tilted inwards. One man operates the whole system by a manual winch

During fishing and transport the fish need to be kept alive to prevent rotting in the warm climate. Living fish hanging behind in a loosly voven polyethen bag.(Photo: Jeremy Bird 2005)

Figure 20. Some fishing methods practiced in Song Bung - Vu Gia River System

5.6.3 Aquaculture

By the interviews carried out at the Zuoih commune, we were told that pond aquaculture has been conducted by local residents over many years. However, it was done only in a primitive way where surplus of fish catch from the river was put into the pond and fed until it was needed as food. In 2003 the authorities of Nam Giang district started a training course for farmers in aquacultural methods. Each of the fish farming families was supplied with 100 fish larvae including four species, namely:

- *Cyprinus carpio (Common carp),*
- *Oreochromis mossambicus (Tilapia),*
- *Ctenopharyngodon idellus (Grass carp),*
- *Hypophthalmichthys harmandi (Silver carp)*.

The residents were also trained in fish cultural techniques. Total area for aquaculture ponds of the Zuoih commune is roughly estimated to about 19,900 m^2.

Cyprinus carpio (Common carp)

Information on Common Carp from FishBase: Maximum published length is 120 cm SL, max. published weight: 37.3 kg, max. reported age: 20 years.

Common carp occur at a temperature range of 3-35°C. Hardy and tolerant of a wide variety of conditions but generally favors generally large water bodies with slow flowing or standing water and soft bottom sediments. Common carp thrives in large turbid rivers. They are omnivorous, feeding mainly on aquatic insects, crustaceans, annelids, mollusks, weed and tree seeds, wild rice, aquatic plants and algae; mainly by grubbing in sediments. Spawn in spring and summer, laying sticky eggs in shallow water vegetation. A female 47 cm in length produces about 300,000 eggs. Young are probably preyed upon by several predatory species. Adults uproot and destroy submerged aquatic vegetation and therefore may be detrimental to duck and native fish populations. Utilised fresh and frozen.

Oreochromis mossambicus (Tilapia)
Biology description given in FishBase: Maximum reported length 39.0 cm SL; max. published weight: 1,130 g; max. reported age: 11 years. Most common in blind estuaries and coastal lakes. Also found in

warm weedy pools of sluggish streams, canals, and ponds. May form schools. Omnivorous, feeds on almost anything from algae to insects. Can be reared under hyper-saline conditions. Marketed fresh and frozen. Juveniles are carnivorous, adults tend to be herbivorous. Exhibits considerable plasticity in its feeding habits as well as in its reproductive biology.

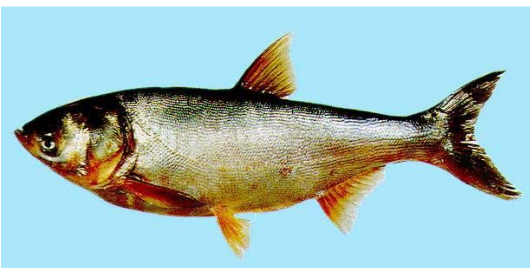
The reproduction potential is enormous. They spawn around the year almost in a continuous manner. The males define and defend territories on the bottom, and form a nest by cleaning a circular area 20 to 30 cm wide. In areas with soft bottoms the nest is excavated 5-8 cm deep by digging with the mouth 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. The large reproduction potential often results in dense populations with very small specimens when stocked into reservoirs.

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.

Ctenopharyngodon idellus (Grass carp)
Biology description given in FishBase: Occurs in lakes, ponds, pools and backwaters of large rivers, preferring large, slow-flowing or standing water bodies with vegetation. Tolerant of a wide range of

temperatures from 0° to 38°C, and salinities to as much as 10 ppt and oxygen levels down to 0.5 ppm. Feeds on higher aquatic plants and submerged grasses; as well as on detritus, insects and other invertebrates. One of the world's most important aquaculture species and also used for weed control in rivers, fish ponds and reservoirs. Spawns on riverbeds with strong current. Utilised also fresh and eaten steamed, pan-fried, broiled and baked. Considered as a pest in most countries because of the damages it makes to submerged vegetation.

Hypophthalmichthys harmandi (Silver carp).



Information on Silver Carp from FishBase: Maximum recorded length 105 cm TL; max. published weight: 50.0 kg. Requires stagnant or slow-flowing conditions such as in impoundments or the backwaters of large rivers. Feeds on phytoplankton and zooplankton. In its natural range, it migrates upstream to breed; eggs and larvae float downstream to floodplain zones. The silver carp is an active species well known for its habit of leaping clear of the water when disturbed. Swims often just beneath the water surface. Utilised fresh for human consumption and also introduced to many countries where its ability to clean reservoirs and other waters of clogging algae is appreciated even more than its food value. It is among 3 or 4 species of cyprinids whose world production in aquaculture exceeds 1 million tons per year.

Beside of the above mentioned species, which were brought in from lowland aquaculture, two species caught in Bung River (mainly in September) were also introduced into the pond aquaculture. These species are *Mystacoleucus marginatus and Probarbus jullieni* - indigenous fish caught in the Bung River.

Mystacoleucus marginatus (No English name)

Information from FishBase. Maximum reported size 20 cm. Found at bottom depths of rivers and streams. Inhabits areas with sand or pea-gravel from small streams to large rivers. Usually found in streams with clear and moving waters.

Breeds when water levels begin to rise, but whether it leaves areas with permanent water or not is unknown. Occasionally seen in markets.

Probarbus jullieni (Isok barb)

Information from FishBase. Maximum size: 150 cm SL; max. published weight: 70 kg. The species inhabits mainly the mainstream of large rivers, with sand or gravel substrates and abundant mollusks populations. Occurs in deep and slow reaches. Feeds on aquatic plants, insects and shelled mollusks. Spawns in winter (late December-early February) in big riverine deltas over sand and gravel substrate with water current of 1 m/sec. Undertakes spawning and trophic migrations in the Mekong basin. Trophic migrations occurs throughout its occurrence range which takes place mainly at the onset of the flood season and are mainly undertaken by juveniles and subadults. Upstream spawning migrations take place between October and February from Kompong Cham in Cambodia to Chiang Khong in Thailand. At Chiang Khong fishermen reported that *Probarbus* moves up the tributary Nam Ta in Laos to breed in March-April. Three *Probarbus* species were also reported to migrate together, but spawn separately, in January-February at Sungkom, Nong Khai Province in Thailand. Egg is buoyant, yellow and 2 mm in diameter. Hatching occurs within 32 hrs at 23°C. An excellent fish for human consumption, sometimes consumed raw, but rather scarce so it fetches a high market price. Eggs are particularly priced. Used to be cultured commercially in Thailand. May be caught individually or in small numbers of any size incidentally with gillnetting and other fishing activities, at virtually any time or place in the Mekong mainstream, but mostly caught during November-January spawning migration, when it is by far the most important species in fisheries catch. In the Mekong this important fisheries species is under serious long-term decline. The decline is evidently basin wide and the most obvious (but not necessarily only) reason is overfishing with gillnets during the reproductive migrations and spawning periods. The isok barb attains 70 kg or more, but mostly marketed size nowadaysis 5-20 kg.

Table 12 below shows the area of the pond aquaculture in Zuoih Commune.

Table 12. The area of culture ponds in the Zuoih commune

	Pa Rum A	Pa Dhi	Thon 2	Pa Rum B
Number of culture ponds	16	36	17	21
Area (m2)	12,426	4,247	1,872	1,418

About 20-60% of the cultured fish were for selling, the remaining for own food or offering their families as gifts. Among the villages in the reservoir area, the farmers of the Thon 2 village have better aqua-cultural knowledge than the others. In generally, aqua-culture products constitute important food sources for the local residents, especially in the dry season when it is difficult to catch natural fish from the Bung River.

However, the aquaculture initiative by the authorities has only had limitied success. The main problem is to get new juveniles to stock the ponds. The villagers have to pay 1000-2000 VND per small fish, which often was found too expensive. The fry brought in was also stressed during transport and had high mortality. The lack of safe delivery of stocking fry, pollution problems and lack of piped water to compensate for evaporation loss in the dry season, as well as diseases, were mentioned as main constraints to aquaculture in the area.

5.7 Assessment on aquatic biodiversity

5.7.1 An overview on diversity in freshwater ecosystems of Vietnam

In the national report on the status of biodiversity in Vietnam, it is stated that freshwaters of Vietnam are endowed with a rich diversity of flora and fauna including algae, aquatic macrophytes, aquatic invertebrates, insects and fish.

Freshwater algae

1,402 species of algae are recorded, belonging to 259 genera, and 9 phyla.

Aquatic invertebrates

In Vietnamese freshwaters 794 species of aquatic invertebrates are identified. Many of these species are firstly described in Vietnam. These comprise 21 species, and 1 genus of zooplankton, 7 genera and 33 species of shrimps and crabs, 3 genera and 43 species of mollusk, which are considered as endemic to Vietnam or the Indochine region.

Freshwater fish

In the inventory of freshwater fish in Vietnam 546 fish species are described, belonging to 228 genera, 57 families, and 18 orders. However, Nguyen Van Hao (2001) has indicated that the expected real number of freshwater fish species for Vietnam can be more than 700 species. The Cyprinidae family has 79 species, belonging to 32 genera and 1 subfamily that are endemic for Vietnam. Of them, 1 genus and 40 species and subspecies found in the inventories, were new to science. These species mainly live in the head waters of mountainous areas.

5.7.2 Aquatic biodiversity in the Vu Gia river system

There is scarce information on fish fauna in the Vu Gia River system prior to this study. Previous surveys were conducted only in some tributaries belonging to the Vu Gia river system such as Thu Bon River (Nguyen Huu Duc, 1995), Tranh River (Nguyen Xuan Huan et al., 1999), and Avuong River (Ho Thanh Hai et al., 2003). Nguyen Huu Duc (1995) identified 85 species of fish occurring in the Thu Bon River.

Kottelat, 1994; H.H.Ng and J. Freyhof, 2001; Jorg Freyhof and Dmitri V.Serov, 2001) identified 34 fish species in the Tranh River (tributary of Vu Gia-Thu Bon river system).

In the report of the co-operative survey on fish between IEBR and the New York Natural History Museum (USA) that was carried out from 29 March to 4 April 1999, Nguyen Xuan Huan et al., identified 53 species of fish belonging to 10 families occurring in the Tranh River (Tra My district).

Nguyen Huu Duc (1995) in the survey on fish fauna of central Vietnam recorded 85 species of fish in Thu Bon River.

There is also some information on other trophic levels of aquatic ecology in the Vu Gia-Thu Bon river system. In the report on aquatic life of the A Vuong River, Ho Thanh Hai et al., (2002) identified 12 species of phytoplankton, 14 species of zooplankton, 10 zoobenthic species and 21 fish species. In the report on aquatic life of the Bung River conducted by Le Trinh et al., (2005), 54 species of phytoplankton, 21 species of zooplankton, and 24 zoobenthic species were recorded.

The fish survey of this study involved analyses of fish samples collected from Bung River, and interviews with riparian residents along the Vu Gia river system both upstream and downstream. This survey identified 107 fish species belonging to 31 families and 9 orders occurring in the Vu Gia river system. In comparison with previous research results on freshwater fish fauna in the central of Vietnam of Nguyen Huu Duc, 1995; Nguyen Thi Thu He, 2000, the number of fish species of Vu Gia river system is much higher than other rivers of the central Vietnam (Ve river-34 fish species, Con river-43 species, Ba river- 50 species).

The aquatic survey of this study identified 78 phytoplankton species belonging to 26 families, 45 algal species and 4 moss species in the periphyton community; 40 species of zooplankton belonging to 15 families; 48 zoo-benthic taxa. Among them, some species of shrimps are not yet identified and may be new species to science. The true number of aquatic species of Vu Gia-Thu Bon river system is obviously larger that what has been revealed through this rapid study.

5.8 Environmental threats (other than hydropower regulation) to the aquatic life of Song Bung – Vu Gia River system as addressed by local people and fishermen during the interviews

5.8.1 Over fishing

The human population is growing and so do the fishing pressure. The use of monofilamentous nylon gillnets has increased tremendously the last 10-20 years. In addition, catching fish by electric shock has become widespread in Vu Gia river system, especially in the Bung upstream, where bedrock and stones make it difficult to use nets efficiently. Increased fishing pressure, including the destructive fishing practice of using electric fishing gear by fishermen of all riparian villages along the Vu Gia River, is the main reason for decreasing fish populations.

5.8.2 Gold exploration

Exploitation of mineral gold in upstream of Bung River, Than River, and several other tributaries are occurring daily. This activity increases turbidity and sediment load, as well as the dredging disturbes the aquatic habitats physically. Besides, this activity involves use of some toxic chemicals such as mercury and cyanide used in separation of gold from the mineral. The toxins can represent a stress to aquatic life and fish.

5.8.3 Sand and gravel exploitation

Exploitation of sand and gravels for construction purposes in Thanh River near Thanh My and on Vu Gia river (Dai Loc district) causes increasing turbidity and changing flows, as well as disturbing the structure of the riverbed. This may hamper aquatic life.

5.8.4 Destruction of riparian forest

A considerable amount of the protected forests in the headwater basin are impacted and have declined both in area and quality. The first trees to be cut, are those along the river as floating on the river is the main mean of transportation. Big overhanging trees are very important for fish and aquatic life (create shadow and nutritious litter fall).

6 Anticipated impacts on water quality and aquatic life during the contruction phase

In this phase the water flow will be approximately as it was prior to the construction. As there has been no damming yet, and the river is still passable for fish, there will be almost no upstream impacts in this period. During the construction phase, the following activities can affect the water quality and aquatic life negatively.

- 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
- Erosion due to accidental water releases
- Sedimentation in the slow flowing river stretches, with shallowing of deep pools
- Reduced primary production due to siltation of periphyton producing substrates, as well as due to reduced light penetration of the water column from increased turbidity.
- 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
- Dry-ups during the initial filling of the reservoir

6.1 Erosion products from natural soils

The flora and fauna of the Bung River are adapted to considerable variations in the concentration of particles. Whereas pure and clear water type of rivers are very susceptible to large inputs of erosion material from construction work, the Song Bung – Vu Gia type of river can tolerate considerable amounts. Many activities in the construction phase, the digging, filling, deposit and clearance activities, will give rise to very high concentrations of suspended sediments in the river, much higher than what is the case to day. Particularly high concentrations can occur as a result of sudden rainshowers. 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. The submerged vegetation will get reduced light conditions. 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.

The erosion matter will settle to the bottom in quiet river stretches, particularly if the river is loaded with particulate matter during the dry season. The important deep pools of the river can then be filled in with sediments, and become shallower. These pools are very important fish refuges during the dry season, particularly for the big sized fish species. According to fishermen in the villages there are many such pools in Song Bung between Khe Vinh and the confluence with Song Cai. In the undisturbed river, the content of particles is very low during dry season, but can be fairly high during the wet season. During the wet season the flow is, however, so strong that the pools are not filled with sediments. On the contrary, the strong currents during this period will clear the pools for sediments. These special currents are made by the curvature of the river, or the rapids just upstream. If such a pool has been made shallower due to settling of erosion material during the construction phase, it may be that such excavating currents are not formed in the new shallow situation, and the pool may be gone for ever.

In a river, the bottom dwelling animals are normally the most important sources for fish food. Most of the bottom dwelling animals in quiet stretches of a river lives like the earth worm (i.a., oligochaeta, chironomidae, some trichoptera). They are feeding on the surface sediment and digesting what is of nutrient containing organic material. In a normal river the sediment consists of a mixture of organic and inorganic material. However, after a river has been exposed to heavy loads of erosion material, the sediment are converted to inorganic sands and silt (like a desert) of low nutritional value for the bottom animals. As a result, the production of fish food is often drastically reduced. This kind of desertification of the bottom sediments of a river takes many years to restore.

Therefore, appropriate actions should be taken to try to reduce erosion during the construction phase. Particularly erosion prone areas are recently denuded soil-areas, like roads, roadsides and parking places, camp sites, fills and soil deposits.

6.2 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.

6.3 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 at 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, or in large rivers during low flow.

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

6.4 Sanitary runoff from construction workers camp

Hydropower projects often gather several thousands workers who normally live in temporary camps near the river in barrack colonies. If the sanitary discharge enters the river, it may cause a health problem for the people living downstream (drinking water, irrigation water etc.). Construction workers are often coming from other districts, and can bring new waterborne diseases to the area. Untreated sanitary effluents should not be discharged into the river.

6.5 Oil and chemical spills

Construction of hydropower plants, including dams, spillways, 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, and cars. 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.

6.6 Accidental water releases and dry-ups

Accidental floods and dry-ups are known to happen during the construction of hydropower dams. Such events can do considerable damage the aquatic life. They are relatively easy to avoid by taking care and do all construction steps properly, perform the necessary testing in time, etc.

Construction includes most often building of a coffer-dam, which is a small dam used to divert the water into the bypass tunnel, to allow for water free building zone for the construction of the real reservoir dam. Normally the coffer-dam contains only a small volume of water. However, as this dam is only of temporary character, it is often not very solidly constructed. It happens that it breaks during flood periods, which gives extra peaking of the flood downstream. At such events the river is already flooding and a small addition due to a cofferdam break can be critical, and can cause considerably damage downstream.

Filling the reservoir for the first time takes often long time. Large dams take often more than a year to fill. In this period the river is often more or less closed. This can make large damage to the aquatic life, and fish, particularly if the river is closed in the dry season. Initial filling should be done mainly in the wet season, and always letting a minimum release (Env. flow) passing the dam.

Accidental floods due to malfunctioning of spillway gates have also happened during test-running of the dams and power stations. All the equipment should be tested properly before the reservoir is being filled with water.

7 Anticipated impacts on water quality and aquatic life during the operation phase

In this phase it is necessary to devide the impacts into

- Downstream impacts – These are the impacts downstream the dam and all the way to the sea.
- Upstream impacts – These are the impacts in the inundated area (the reservoir) and the upstream river.

7.1 Downstream impacts

7.1.1 Short description of the impact on the hydrological regime

The way they will operate the SB4 and A Vuong power station will be the main decisive factor for the water flow in the Song Bung down to the confluence with Song Cai. It is most likely that the power production will be adjusted according to the need for electricity in the society and hence be operated in a peaking mode. That means high production during day time (16-18 hrs), and low or no production during night time (6-8 hrs). However, the final decision on the operation mode of the powerplants (SB4 and A Vuong) is not available when this report is written.

If no compensation flow is released, the stretch beween the dam and the confluence with A Vuong will be dry in the driest periods of the year. As the runoff from the remaining catchment downstream the dam in SB4 and A Vuong is small (Table 13), the flow will be very low all the way down to Song Cai if both power plants are switched off during night time.

Table 13. Average natural flow in Song Bung in areas downstream the dam, and the contribution of runoff from the un-regulated remaining catchment.

River Section of Song Bung	Natural Flow Conditions in Song Bung (m^3/s)	Cumulative inflow from local tributaries downstream of A Vuong and SB4 (m^3/s)	
	Annual Mean	Annual Mean	Estimated Minimum
SB4 dam site to confluence with Song A Vuong (ca 3.5 km)	72	< 0.5	0
Song A Vuong to SB4 power station (ca 2 km)	106	4	< 0.2
SB4 power station to A Vuong power station (head of SB5 reservoir) (ca 8 km)	108	6	< 0.3
SB5 dam site to confluence with Song Cai (ca 10 km)	112	10	< 0.5

In the river streches downstream of the tailrace of SB4 power plant, and the A. Vuong powerplant 2 km downstream of that again, the water level and flow will fluctuate considerably over the diurnal circle. Table 14 shows the maximum daily water level fluctuations at different places in the downstream river sections when SB4 is operating in a peaking mode (Alt 1) and when both SB4 and A Vuong are operating in a peaking mode (Alt 2).

Table 14. Maximum expected daily water level fluctuations from peaking in Song Bung 4 (alternative 1) and from peaking in both Song Bung 4 and A Vuong (alternative 2)

Location	Alternative 1		Alternative 2	
	Water level fluctuation (m)	Time from max to min (hours)	Water level fluctuation (m)	Time from max to min (hours)
Downstream Song Bung 4 HPP	1.5	2	1.5	2
Downstream A Vuong HPP	2.0	3-6	3.2	3
At Song Bung 5 dam site	1.9	3-6	3.1	3-6
At Hoi Khach	0.6	6	1.0	6
At Ai Nghia	0.13	>6	0.20	>6

7.1.2 Impact on erosion activity

Hydropower regulation schemes affect many of the erosion processes taking place in a watercourse. Often the erosion activity increases, and the river water becomes more turbid. However, in the long run the reservoir will trap sediments, which means that the water coming out of a reservoir after 5-10 years will contain less erosion material than the river water did at the same point before the regulation. The operation mode of the power plants can, on the other hand, give more erosion in downstream stretch of the river, e.g. through diurnal flow variations.

7.1.2.1 Erosion in the reservoir area

In the first period after the regulation several erosion processes will take place. The sides of the reservoirs will be eroded. The sediment binding roots will be killed by the inundation, and the soils will be prone to erosion from waves and varying water levels. Much of this erosion material will end up in the reservoir bottom, but considerable amounts of fine silt and clay fractions will be transported downstream and make the water turbid. This erosion will create downstream problems only during the first 5-10 years of the operation, depending on the soil texture in the reservoir area.

7.1.2.2 Erosion due to diurnal water flow fluctuation

The diurnal variation of water flow and water level will cause erosion in a long stretch of the downstream river. The impact will be most significant during the dry season.

A likely operation mode (fitted to the society need of power) will possibly be full production during 16-18 hrs and closed down during 6-8 hours during night time. The water level variations will be half a meter and more according to the hydrodynamic modelling study. If both Song Bung 4 and A Vuong will be operated in this manner, the diurnal water level fluctuations will be more than 1 m (up to 3 m). This will increase shoreline erosion and thereby make the water more turbid.

The mechanism behind this type of erosion can be described as follows: The dry season up-and-down movement of the water surface, combined with differences in flow speeds, will create erosion in the lower part of the river bank, making this steeper, and causing slides, etc. When the water level is high for 18 hrs the river bank will be soaked with water until the equilibrium between the water pressure inside the bank and the external pressure exerted by the river water is achieved. When the power plant is switched off, the water level will drop rapidly. The external water pressure will disappear whereas the internal pressure is still present. This will cause rapid outward directed water movements in the bank, loosing up the soil structure in the bank surface. When the flow is increasing again when the power plants are switched on, the scouring forces of the current will easily dig out some cm of this loose bank zone. This will in the long run dig out the lower part of the river bank causing slides, tree-fall, bamboo-fall, and important riverbank stabilising roots will eventually disappear. The river bank will be more vertical, and will be prone to large scale erosion during flood periods. The increased steepness, and inorganic character of the changed river bank, will make it less suitable for river bank gardening than it was before. Figure 21 shows river bank gardening inVu Gia.

Figure 21. River bank gardening in Vu Gia

It should be noted that even though the water level fluctuations in the central and lower part of the downstream river will be low, the erosion material from the erosion further up will be transported downstream, and will settle in the deep pools in the dry season. Slowly, these deep pools will become shallower, and their important ability to serve as dry season fish refuges will be reduced.

Therefore, it will be important to minimise these diurnal water level fluctuation as much as possible, particularly in the dry season.

7.1.2.3 Erosion due to increased human activity

A large scale hydropower development, as is planned in the Vu Gia Catchment, normally results in permanent increase in human activity in the area. Several of these activities give rise to increased erosion, such as building of several roads with erosion prone road sides, residential areas, agricultural activities, and deforestation.

7.1.2.4 Erosion due to sudden spillway releases

In a hydropower systems life there will be situations where it is necessary to release water through the spillway. This is often done during the rainy season, when the dam is approaching full level. If a heavy rain then is forecasted, it may be necessary to release large amount of water through the spillway. In addition to the rain driven river swelling you will have an additional rise due to release of earlier collected water. In this way some stormflows can be stronger than before. These sudden and powerful floods will create large erosion in unconsolidated and root-free river banks.

7.1.2.5 Sediment flushing of the reservoir

In the beginning of the rainy season, when the reservoir is drawn down to minimum operation level, it is possible to flush out some of the accumulated sludge in the reservoir by letting the first part of the monsoon flow to flush through the reservoir. This activity results in extremely high turbidity in the downstream river, which can have large impact on the aquatic life. This sediment flushing can also contribute to fill in the deep pools in the river channel, which are important dry season refuges for several fish species. However, it should be noted that sediment flushing is not planned in any of the Song Bung reservoirs.

7.1.3 Impacts on water quality

7.1.3.1 Turbidity

In the first period after the regulation the water will be more turbid. This will however, not be a permanent situation. After the initial erosion from the reservoir sides is over (approximately 5-10 years) the reservoirs will be net sinks of particulate matter.

If sediment flushing of the reservoirs is practiced in any of the regulations, the turbidity will be very high in the beginning of the rainy season. This will create problem both for human use of the water as for the river biota. No sediment flushing is planned for the Song Bung Reservoirs, but this may be an option at a later stages.

However, diurnal water flow and water level variations can create river bank erosion along the Song Bung and thereby cause turbidity problems also further downstream.

7.1.3.2 Coliform bacteria and hygienic pollution

The upper part of the Song Bung River has only low density of people. It is therefore not likely that the river will be hygienically contaminated by domestic sewage water, and runoff from livestock animals, to any extent of concern. However, the river water should not be drunk without pre-boiling. The reservoirs will reduce the content of coliform bacteria in the river water, due to sedimentation and the fact that several planktonic organisms eat bacteria. The longer the water residence time is in the reservoir, the more efficient is the reduction in the bacteria numbers. From a drinking water perspective, this is a positive impact. However, planktonic algae in the reservoir can reduce the suitability of the water for drinking purposes.

In the area downstream of the Song Bung 4 dam, and upstream the confluence with A Vuong, there can in periods be very low flow, and the river can be susceptible to local discharges. This is, however, not expected to be a problem due to the low density of people in the area.

7.1.3.3 Impact on downstream eutrophication

Eutrophication is the result of over-fertilisation of the water with plant nutrients, first of all phosphorus. The sources are normally discharges from domestic wastewaters and runoff-losses from different agricultural activities.

In the first years after the construction of dams, the reservoirs often get eutrophic due to release of nutrients from decomposition of organic material in the inundated terrestrial catchment. They can then develop blue green algal blooms that, in special cases, can contain toxic algal species. The reason why they develop toxicity in some instances, are not well known. After 5-10 years this initial eutrophication will end. In the long run, reservoirs always causes oligotrophication of the downstream stretches due to trapping of nutrients in the reservoirs.

The power plant is abstracting water from the deep layer of the reservoir. In the first years after the regulation this water will contain little oksygen, and will contain a relatively high concentration of bioavailable phosphorus. This will fertilise the downstream river, a process which is called eutrophication. This will create high periphyton growth on the stones in the river in a transitional phase of approximately 5 years. This can mean more food for some periphyton eating fish, but, in such attached algal growth, it may occurr problem-species of algae. One such species is *Lyngbya woolei*, which can give "burning itchiness" after bathing (often called fireweed). It can also be toxic to fish, and animals and humans when drinking. This species blooms more or less always in the warmest and most sunny period of the year. After the first 5 years, when most of the nutrients from the decomposing terrestrial litter are leached out, it is not likely that the dam will cause any eutrophication problems in the downstream river. There is too little human settlements and agriculture activities in the the upper catchment to feed the reservoir with the required amounts of nutrients to keep it eutrophic in the long run. See chapter on upstream impacts where the situation in the reservoir is treated more thoroughly.

7.1.3.4 Downstream temperature

The water is withdrawn from the deep water of the reservoirs. The temperature can be approximately 3 degrees centigrade lower than normal just downstream of the reservoir, but will attain average air temperature on the way down to the confluence with Song Cai. This is not expected to create any notable problems. There may be some small impacts on the hatching period of fish eggs in the upper reaches. In Scanidinavian reservoirs this has given notable effects of this kind in the downstream river, but there the difference between deep water temperature and surface water temperature can be as much as 8-10 degrees centigrade in periods.

7.1.4 Impacts on aquatic life

7.1.4.1 Impact on the the growth of attached algae

Algae growing on stones, sediments, on macrophytes, on branches of trees, on mosses, are the most important primary producers in river. A large number of bottom animals (fish food) are subsisting on periphyton, and some fish species are eating periphyton as part of their diet among them several of the cyprinids and pangasid catfishes. When the water gets more turbid, less light penetrates to the bottom where the periphyton grows, and the production of periphyton is reduced.

Sedimentation of erosion material onto the algal cover (siltation) is also impeding the primary production, as well as making it more difficult for the periphyton grazers to utilise the periphyton as food. The periphyton will be intermingled with inorganic, indigestible material.

Diurnal water level fluctuations will kill lot of the shallow water periphyton just by drying them up every day. The release of nutrients from the decaying terrestrial litter in the reservoir will keep up the periphyton production in the first years, but in the long run downstream periphyton production will decrease.

7.1.4.2 Sight problems for the carnivorous fish and other water animals

Several carnivorous fish and other water animals are depending on their eyes when hunting. Reduced visibility is a constraint to their hunting ability, making the hunt less efficient. It requires more energy to get the same amount of food as before, which leads to reduced growth rate of the single fish, and reduced production for the fish population.

7.1.4.3 Makes the bottom sludge inorganic

The bottom sludge, or sediment, in the slow flow stretches of natural rivers consists of a mixture of organic and inorganic material. Many populations of bottom dwelling animals are living in this sediment in the same manners as the earth worm. They eat the surface sediment and digest the organic material it contains. These animals are very important fish food. When the erosion material, which is more or less totally inorganic, settles in the slow flowing stretches, the sediments are converted to inorganic sands and silt like in a dessert. The production of the bottom animals are strongly reduced in such sediments.

7.1.4.4 Impacts on fish migration

The dams will create migration barriers. Several fish species are migrating far up the rivers, for feeding, spawning and nursery purposes. This may be species that in other periods of their life cycle stay in other areas of the river system. It is possible to build fish bypass systems for some fish species. This has been partly successfully done for Atlantic Salmon (*Salmo salar*) and brown trout (*Salmo trutta*) in Europe and America, at least for lower dams. However, for the fish of SE-Asia river systems the knowledge on efficient fish bypass systems is very limited. For such a high dam as in Song Bung 4, the fish elevator is likely the best bypass system.

The water flow pattern is also an important aspect with regard to fish migration. For many species it is the first flow increase in the beginning of the rainy season that triggers the migration. These triggering flows are often delayed, or have disappeared in a regulated river with reservoirs. The first part of the rainy season is used for filling the reservoirs. In several regulations in Norway, and in other European countries, the Power Companies are obliged as part of the concession to release triggereing floods for salmon.

Some small (often step-like) falls are only passable by fish when the flow is above a certain size. The filling of the reservoir may delay the reaching of this flow size by considerable time, weeks to months, and the fish is not able to reach their destination in time, e.g. an adequate spawning ground.

7.1.4.5 Impact on fish spawning and nursery

As described above, the spawning migration is often hampered by lack of triggering flow, or by too low flow throughout the migration period, for the fish to reach their spawning ground.

Spawning areas may be tributaries, flooded wetlands or forest, rapids in the river. These areas must be accessible, and they must be wetted for a sufficiently long period of time to allow the eggs to hatch, and to provide suitable living conditions for the first life-stage of the fish larvae. The filling of the reservoirs in the first part of the rainy season are often a major reason why spawning conditions are not reached in regulated rivers. It may be lack of flooding, or that the flooding comes too late, or the flood does not last long enough to allow for nursery of the young-of-the-year fish.

Erosion can be a problem for some spawners, eg. those who are having their eggs in gravels in rapids. Settling of erosion material between the stones reduces the oxygen concentration in the gravel bed which can be a problem for getting the necessary oxygen supply for the eggs and larvae.

7.1.4.6 Impacts on the production of fish food and fish feeding

The production of fish food is often strongly reduced in a regulated river. There are many reasons for this:

- Periphyton is reduced due to siltation and low light due to turbid water
- Frequent water level fluctuations destroy the periphyton, macrophytes, and bottom fauna in the shoreline area.
- The increased sedimentation in the deep areas makes the sediments of inorganic character that contains little digestible food for the bottom animals.
- Reduced flooding of forest and wetlands prevent feeding migrations into these areas.
- The dams also make barriers hampering feeding migrations
- The altered flow pattern also makes problems for feeding migrations
- The trapping of nutrients in the reservoirs leads to oligotrophication, which also results in less fish food production

- The erosion of the river banks reduces the overhanging trees and riparian vegetation, which consequently reduces the organic litter fall (leaves, insects, etc) to the water.

7.1.4.7 Impacts on dry season refuges – the deep pools

Song Bung is known to have many deep pools, which are important refuge areas for those species that are staying in the river also in the dry season. Some of the pools, we were told by the villagers, are as deep as 10 m and more at dry season water level. All activities that increase the content of soil in the water (erosion process), particularly those that contribute to suspended sediments in the dry season, will contribute to the filling of the deep pools. Filling of these pools will cause a great loss in fish abundance and species richness. Diurnal flow variation in the dry season is most likely a bad thing in this respect. In the swollen river, the physical forces of the current are so strong that they do not allow net sedimentation in the river channel itself, only in the floodplains areas in lower Vu Gia.

7.1.4.8 Impact on aquatic biodiversity

Hydropower regulations are known to be the biggest threat to aquatic biodiversity in Asian rivers to day (Dudgeon 2002). Almost all rivers are poorly studied with respect to biodiversity, and new species are discovered all the time. Also in this study of Song Bung – Vu Gia several individuals were observed that was impossible to find in the taxonomical literature, and which most likely are new to science. There is no doubt that the planned regulation schemes in Song Bung will lead to eradication of several species of fish and other water living organisms in Song Bung River. For example the catadromous long distance migrant *Anguilla marmorata*, which is the most important commercial fish in middle and upper Song Bung, will disappear totally upstream the dam. Downstream the dam it will be considerably reduced.

In such species rich systems as the SE-Asian Rivers, the ecological niches are very narrow, and only small physical encroachments can wipe out several species. There is insufficient knowledge concerning the requirements of all these organisms with respect to water flow, water level, water quality, etc., to enable adequate management of the different populations in the new regulated river situation. The only way of trying to save as many species as possible is to try to keep these parameters as close as possible to the natural conditions.

7.1.5 Impacts on human water use

These impacts are more thoroughly treated in the reports (in prep) from the team describing the terrestrial impacts and the socio-economic impacts, so here is only given a brief overview.

7.1.5.1 Drinking water

In the first years after the regulation increased content of suspended sediments (erosion material), and possibly algae produced from nutrient released by decomposing terrestrial litter in the reservoirs, will cause problems with respect to the use of the water as untreated drinking water. After 5-10 years, the initial erosion will be over, and the reservoirs will trap sediments and nutrients, and the water of Song Bung will clear up.

In the long run, with respect to algae content and bacteria content, the concentrations in the downstream Song Bung will be lower than before, because the reservoirs will trap nutrients, bacteria and suspended sediments.

However, in the stretch between the dam and the outlet from the power plant, the water flow will be very low, and the water quality will be vulnerable to discharges. For this reason, it can be risky to take unboiled drinking water from this low flow stretch. The population density is low in this area, and the problem is expected to be minor.

7.1.5.2 Swimming and bathing

It is not expected that human activities like swimming and bathing in the downstream part of the river will be impacted negatively by the Song Bung 4 regulations.

7.1.5.3 Washing

In the first years after the regulation the increased turbidity of the water will give some reductions in the suitability of the water for washing, but after 5-10 years the river water will be of the same turbidity as now, or better. However, large diurnal water flow variations may cause long lasting increased turbidity in the downstream areas.

7.1.5.4 Navigation

For many of the local people living along the downstream part of the Song Bung, the river is the main road. Most families have a boat that they use for transport across the river and along the river. The transport along the river is risky due to rapids with submerged rocks. When the water becomes more turbid in the first years after the regulation, the rocks will be more difficult to see for the boat driver, and accordingly the boat transport will be more risky. However, after some years the turbidity is not anticipated to be much impacted.

Water level is also important for the use of boats, particularly in the dry season. The normal type of regulation undertaken in Vietnam, result in higher water flow in the dry season, and thus the boating should be facilitated in this period. If the power plants are run in a peaking mode, boat transport may be dangerous around the time when the turbines are turned on and off (morning and late evening). Local residents need to be informed about these activities.

7.1.5.5 Irrigation

In the stretch from the dam and down to the outlet from the power plant it may be impossible to get enough irrigation water for local people living along the river, particularly in the driest season. However, in this stretch, very few people are living. As A Vuong also will be regulated, there will be practical problems with irrigation water for those living in the river crossing area. Further downstream there will be water enough, but modified water intakes fitted to the new water level and water flow situation have to be built. The socio-economic report will provide more information on this.

7.1.5.6 Fishing

The planned regulation scheme in Song Bung can very easily give large negative impact on the fish stock in the downstream part of Song Bung. The mechanisms behind the impacts on the fish populations are described earlier in this chapter. Here we describe the impacts on the fishery.

- Reduced fish catches due to reduced stocks
- Reduced fish sizes due to shift in species composition, but also due to reduction in growth rate
- Some species will more or less disappear
- The fish will get another spatial distribution and it will be necessary to fish in other places than to day.
- Fishery may be particularly poor in the dry season if the fish will migrate out of the river in their search for dry season refuge
- It may be necessary with stricter fish management rules than today.
- More dangerous boating due to turbid water and rapidly shifting flow
- Increased danger of loss of fishing equipment due to sudden releases of water
- Reduced catch will send the fish buyers to Vu Gia downstream because of unreliable delivery from the Song Bung fishermen
- The local residents cannot subsist only on fish as protein source, they have to use more livestock animals as food, or develop aquaculture

7.1.5.7 Impact on downstream fish yield

The downstream river can be divided into 3 different stretches

1. The area between the dam and the outlet from the power plant
2. The area from the outlet of the power plant to the confluence with Song Cai
3. The area downstream of the confluence with Song Cai

In the first of these three areas the fish productivity will be very low or none if there is no minimum release of water from the dam (compensation flow).

In the stretch downstream of the power plant outlet the water is back in the river again. In this reach the water flow and water level will fluctuate considerably over the diurnal circle. The water level variations will be half a meter and more according to the hydrodynamic modelling study. If both Song Bung 4 and A Vuong will be operated in the same likely peaking manner (not yet decided), 16-18 hrs on and 6-8 hrs off, the diurnal water level fluctuations will be more than 1 m (up to 3 m). This will increase shoreline erosion and thereby make the water more turbid. This will reduce the efficiency for the fish in finding their food. More importantly, is that the frequent water level variations and dry-ups will reduce the production of the periphyton (the tiny algal layer on the stones) which is the most important primary (plants) producer in fast flowing rivers. This reduction will reduce the productivity in all the following levels in the food chain (bottom animals and up to fish). On gentle bottom slopes the periodical withdrawal of water will kill a lot of bottom animals as they cannot move fast enough to cope with the retreat of the water when the turbines are switched off. For these reasons it is very likely that there will be a considerable reduction in the fish productivity also on this stretch.

In the stretch downstream of the confluence with Song Cai, the water flow and water level variations will be less. According to the hydrodynamic modelling study, the diurnal water level fluctuations will be around 20 cm. Such small variations do not create much harm to the water ecosystem, even if they occur every day. However, the detoriation of the Song Bung river stretch from the confluence and upstream, including the dam, deprives the migratory fish of spawning and feeding grounds. This applies also to the migratory fish living in downstream reaches, i.e., those making periodically upstream migrations either for spawning or for feeding. The Vu Gia – Thu Bon river system is a continuous water body without fish migration barriers. In such a system the fish community will always comprise many migratory populations. These can comprise of long distance migrants, like the important and highly priced (up to 200 000 VND per kg) *Anguilla marmorata* that migrate all the way up to the Song Bung 2 area, and which migrate to the sea for spawning. Another species, which is important in coastal and estuarine fisheries, the *Clupanodon thrissa*, migrate up the rivers for spawning. The migratory, downstream living fish populations, that use Song Bung for migrations will be reduced. These populations will after the regulation only have the left branch of the river system to migrate to (Song Cai/Song Than).

I have been asked to estimate how large the reduction will be in the fish yield (for local people fisheries) in the downstream river stretch (Song Cai-Vu Gia). It is not possible to give exact estimates for yield at the present state of knowledge of the fish community of the Vu Gia – Thu Bon river system. However, a minimum estimate of the impact can be put forward in the following way: Let us anticipate that the lower reach of the river consist of 50 % migratory and 50 % stationary fish species. The stationary populations will be very little impacted, if at all. The Bung river regulation deprives the migratory fishes of about 50 % of their available migration routes (only the left branch Song Cai/Song will remain). This will reduce the migratory fish populations living in the downstream part by approximately 50 %. Based on this reasoning, including the unaffected stationary fish, the lower stretches will get a reduction in fish biomass of about 25 % compared with the present situation.

However, it is most likely that the impact on downstream fishery yield will be greater than this estimated 25 %, as people are also fishing on migratory species that live upstream: fishing when the fish pass the river stretch that people use. It may therefore be anticipated that the Song Bung regulations will reduce the yield of the fisheries downstream of the confluence with Song Cai approximately 30 % compared with the present yield.

However, it should be noted that there is no scientific basis for this estimate. It should be regarded as a "professional judgement".

Table 15. Anthicipated reductions in fish yield in different downstream stertcehs of Song Bung - Vu Gia river after the Song Bung 4 hydropower regulation (based on experience and professional judgement).

Downstream River Reach	% reduction of fish yield	
	With minimum Resease from the dam	Without minimum release
Between the dam and the outlet from the power plant	90	100%
Between the outlet of the power plant and the junction with Song Cai	70	80
Downstream the junction with Song Cai	30	30

When all the planned hydropower development projects in the Vu Gia – Thu Bon river system are conducted, the impact on also the downstream stretches will be much more profound, even estuarine and coastal fisheries will be negatively impacted.

7.1.5.8 Some information of Dam's impacts on estuarine fishery resources

Among fish populations living in estuarine brackish waters, the Small gizzard (*Clupanodon thrissa*) represents an important species. This species often distributes in coastal waters and migrates upstream in spawning season. In the survey of March 2006, this species was found in Vu Gia river from river mouth area to Thanh My.

Unfortunately, there are no official statisticcal data on the catch of this species in the Vu Gia-Thu Bon River. On the sections 4 and 5 of the Vu Gia River, local fishermen often use gill-nets to catch Small gizzard. We anticipate that about 5-10 kg of Small gizzard are sold daily in Ai Nghia market which is somewhat less than in Thanh My market.

From the Red River delta there exist statistics on the fishery on this species, and the history indicates that there might be a connection between the decline in the population size of this fish and the hydropower regulation in the catchment. The small gizzard used to migrate up Red River and into Da River and Lo-Gam-Chay River to spawn. The first large hydropower regulation on the Red River system was the Thac Ba Reservoir on Chay River, which was finalised in 1963. In 1969 started the work on another large dam, the Hoa Binh on Da River. This dam was finalised in 1984.

Table 16. The catch of Small gizzard (*Clupanodon thrissa*) exploited on spawning migration in the Red River (tons/year).

Locations \ Year	1964	1965	1966	1967	1979
Viet Tri (Phu Tho)	1.5	1.6	1.5	1.5	-
Hanoi	40.0	67.7	32.5	23.5	-
Hwng Yen	300.0	100.0	14.0	6.5	-
Tan De (Thai Binh	15.0	14	62.0	6.5	-
Total	356.5	183.3	62.0	38.0	40.0

Source: Ho The An, 1979

The statistic shows that for all years before 1964, the annual catch of Small gizzard exploited from Red River was very high, for some years it reached to 600-800 tons. After that, production of Small gizzard clearly declined. In 1982, the production of Small gizzard in Hanoi was only 50-60 kg, and now, the annual catch of this species is very low, and is not included in any catch statistic any more (Ho The An, 1979; Vu Trung Tang, 1989, 1996).

Besides over-exploitation, many have blamed the construction of large dams on the Red River system such as Thac Ba, and Hoa Binh to be a main reason for the decline in the population of small gizzard. There is no doubt that some spawning grounds of *Clupanodon thrissa* and other migrating fishes were lost when these reservoirs were completed and put into operation. However, the inherent mechanism of this influence is still unclear and needs to be further studied, but the concurrence in time is a strong indicator.

There has been a decline in most fish yield in the Red River delta region (Western Tonkin Gulf) over the last 30 years. Tran Duc Thanh, Do Dinh Chien (2005) estimated that Hoa Binh dam had contributed to reduce 42,665 tones of fish of the estuary coastal waters.

All experience points to that an extencive hydropower damming scheme like the one planned in the Vu Gia- Thu Bon river basin, will give large negative impacts to the river fisheries and the estuarine and coastal fisheries in the Da Nang – Hoi An area as well. The fish populationas are adapted to the rivers rhythm through several thousands of years. The reasons are many:

Creating migratory barriers preventing fish from doing their spawning and feeding migrations.

Trapping of nutrients. The reservoirs will trap nutrients like phosphorus and organic material that will reduce the productivity downstream.

Reduced flooding. Several fish species are spawning in flooded areas. The reduced flooding will reduce the spawning areas.

Catching sediments. The dams will catch sediments and prevent the flood lands of settling of the nutrient rich sediments. This will reduce the condition for fish nurserey.

Altered timing of floods. The filling of the reservoirs in the rainy season will reduce/delay the first migration-triggering flow increase. This may result in that the spawning migration takes place too late, and the eggs will not have enough time to hatch before the water is retreating again. The flooded period may also be too short to develop eggs and fry to the size needed for successful survival of the young-of-the-year fish populations.

Altered salinity pattern in the estuary. The increased flow in the dry season will reduce the salinization of the water in this period, whereas the reduced flow in the wet season will increase the salinization of the water in this period. The shift in salinity in the waters is also believed to be important with respect to triggering fish migrations.

However, not only the fishery yield will decline due to decline in the fish population. Also the fish biodiversity will decline considerably (MRC. 1997).

7.2 Upstream Impacts

This chapter deals with the impacts on water quality and aquatic life upstream the dam.

The damming will result in loss of 30 km of river fish habitats (mainstream Song Bung River and tributary rivers). These previous river ecosystems are now transformed into a lake ecosystem. This is a major shift which will result in a considerable loss in aquatic biodiversity in the reservoir area as only few of the river species will adapt to a life in a lake ecosystem. The following items will be looked into in the following sections:

- Hydrological changes
- Erosion
- Oxygen
- Impacts from mining
- Eutrophication
- Aquatic life and biodiversity
- Fish production and potential for development of reservoir fisheries.
- Emissions of methane and other green house gasses

7.2.1 Hydrological changes – formation of the Song Bung 4 Reservoir

The Full Supply Level (FSL) of the reservoir will be at El. 222.5 m that will create a lake with an area of 16.5 km^2 and store a total volume of water of 493 million m^3. The drawdown of the reservoir to the Minimum Operating Level (MOL) at El. 195 m will be 27.5 m. At the MOL the area would be 7.8 km^2 and the volume of water some 173 million m^3. The volume of water to be used for electricity generation, between FSL and MOL, would be 320 million m^3. This equals approximately 14 % of the mean annual inflow volume to the reservoir. The inundated area at FSL and MOL is shown on the map in Figure 22.

The reservoir will be operated for seasonal regulation of the inflow, generally, the reservoir will be filled-up to the FSL during the wet season, from September to December, and be drawn down to the MOL during the dry season. A typical variation of the reservoir water level during the year and the monthly average inflow is given in Figure 23.

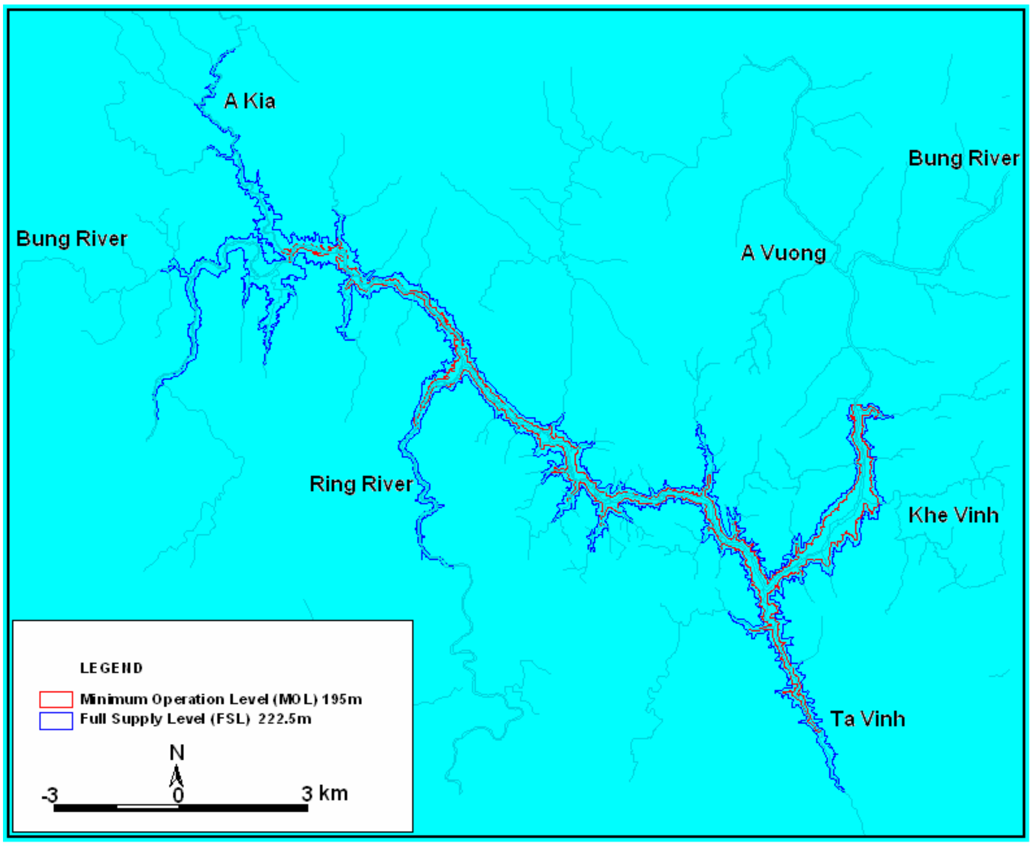


Figure 22. Reservoir-area inundated at MOL and FSL

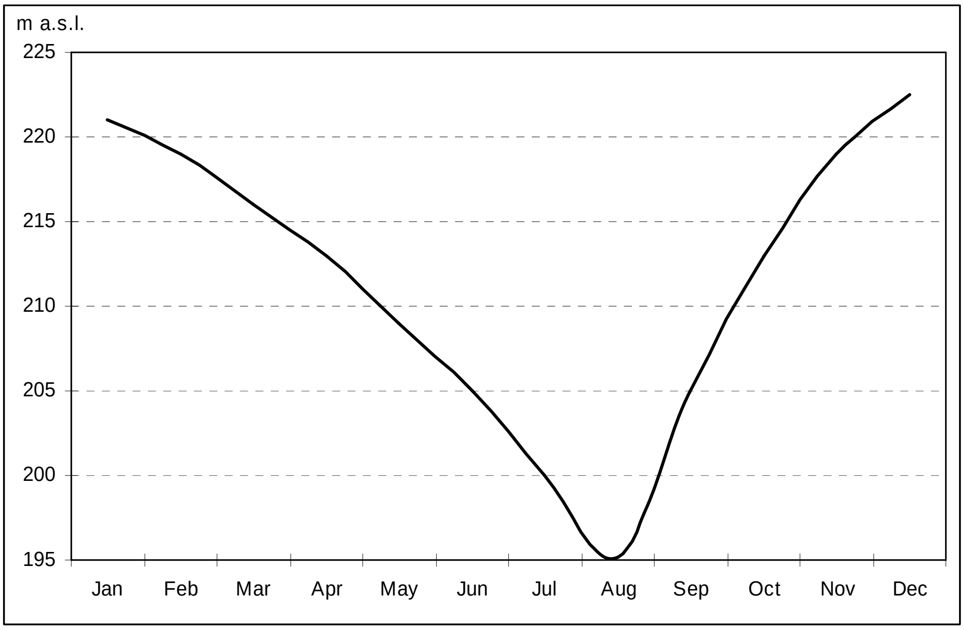


Figure 23. Typical annual water level variation in the reservoir

7.2.2 Reservoir Erosion

In the first period after the regulation several erosion processes will take place. The sides of the reservoirs will be eroded. The sediment binding roots will be killed by the inundation, and the soils will be prone to erosion from waves and varying water levels. Much of this erosion material will settle in the reservoir bottom, but considerable amounts of fine silt and clay fraction will during the first years after the regulation be transported downstream and make the water turbid. This erosion will create downstream problems only during the first 5-10 years of the operation, depending on the soil texture in the reservoir area.

All the organic material, and fine silt material, of the littoral zone will be washed away from the regulation zone, rendering back after some years an inorganic dessert where very few organisms can live. Much of the inorganic material that has been eroded from the littoral zone will settle in the hypolimnion, making the sludges there also of inorganic character. The profundal bottom living animals is mainly living like the earth worm, eating sediments and digesting what is in it. When the sediment after several years of regulation has become inorganic due to sedimentation, they will be of low productivity for bottom animals.

If the vertical extention of the regulation zone is being greater that 10 m, the littoral type of life will not be functioning.

After 5-7 years the erosion activity within the reservoir will be low. The water quality in the reservoir will clear up, and the water coming out of the reservoir will be clearer than the water coming into the reservoir. It will be a net trap of sediments.

7.2.3 Oxygen in the reservoir

When the reservoir is filled for the first time, a lot of organic material from the terrestrial forests will be inundated. This material will decompose under the consumption of oxygen. When the oxygen is consumed it will continue to decompose anaerobically.

In the hydrodynamic study it was run temperature simulations in the reservoir, it came out that the reservoir would be tratified parts of the year. The surface temperature could be as high as 28 degrees while the temperature at the bottom could be 20-21 degrees. Oxygen has not been simulated for the reservoir, i.a. due to lack of wind data, but the modeller anticipate that the there will be no oxygen in the water withdrawn from the turbines in periods.

The upperrmost 8-10 m of the water column in the reservoir will at all time be well oxygenized, both due to incoming rivers and contact with the atmosphere, but mostly because oxygen is being produced by the planktonic algae in the photosythesis which takes place down to approximately 10 m depth. During the reainy season, with the flooding rivers, most likely the stratification will be broken and the reservoir water will be mixed. Oxygen is then brought down to all strata in the reservoir water column. When the weather is being more warm and sunny, the surface layers become heated (down to approximately 10 m depth). Below this depth the temperature will stay low from the last part of the rainy season. Warm, ligter water will then be lying on top of cold and heavy bottom water. This creates stability in the water column, and the deep water will be sealed off from receiving new oxygen until the next rainy season. From April throughout August the deep water can be very low in oxygen, in eutrophic reservoirs the deepwater is often anaerobic every year in this period, whereas oligotrophic reservoirs are not. In the first years after the damming, most tropical reservoirs have anaerobic deepwater 5-10 years after the damming. When the inundated terrestrial litter is decomposed, oligotrophic reservoirs will again have oxygen in the deep waters.

Tropical reservoirs that have large human activity in the catchment, many people with sanitary discharges, agricultural activities, aquaculture, etc., will often become permanently eutrophic, and have anaerobic hypolimnion in all future. This is bad in many ways, nutrients may be released from the sediments making the situation even verse, create toxic blue green algae, cause release of methane and other gasses with greenhouse effect, etc.

The Song Bung 4 reservoir will be oligotrophic (see below), and it is therefore likely that the reservoir will only suffer from oxygen deficiency only the first 5-10 years after the damming. After that period, the reservoir will not be anaerobic to any notable extent. The better vegetation clearance there will be done in the reservoir area prior to the filling of the reservoir, the better will the oxygen conditions be in the future reservoir.

7.2.4 Eutrophication

The Song Bung is lying in a forested area, with few people living in the catchment, and no intensively driven agricultural areas. During the National Hydropower Plan it was estimated by the frequently used and internationally recognized Vollenweider eutrophication model (Vollenweider 1976), that the Song Bung 4 reservoir would get an algal biomass of 0.7 µg Chla/l as an average in the epilimnion over the growth season. This is indeed an oligotrophic level. Control estimations using the more precise data from this EIA study still gives that the reservoir will be oligotrophic.

It is not expected algal problems in the Song Bung 4 reservoir. In the first 3-5 years, after the damming nutrient rich water (withdrawing deep water) can cause some algal growth in the downstream river, but it is not expected to an extent that will create problems.

7.2.5 Impacts from mining

The study on impacts from mining showed that water, sediments and fish were only little impacted by mercury and other heavy metals from the mining activity in the catchment.

When the terrestrial areas will be inundated the break down of the organic matter will create low oxygen in the bottom layer whith formation of methane. The methanogenic bacteria have also the ability to form methyl mercury, which is much more bioavailable as the metallic mercury that is present in the sediment to day. Therefore, it may be that the mercury contamination of the fish will increase somewhat. However, most of the goldmining areas will disappear due to the inundation, and this will reduce the use of mercury in the catchment in the future. It is not likely that mining activities will create any conflicts with the hydropower plans in the Song Bung Catchment.

7.2.6 Aquatic life and biodiversity

The transforming of a long stretch of river habitats into lake habitats will create large changes in aquatic life in the reservoir area. The lotic aquatic system are energy wise driven by periphyton-bottom animals, while a lentic aquatic ecosystem is much more driven by phytoplankton – zooplankton. Per unit area the first has often a higher specific productivity, but as the water suface area increases considerably by a damming, the total aquatic protein production in the area can be greater after a regulation as compared with the situation before.

Since the early 1960s construction of reservoirs has increased in Vietnam. According to statistics, there are about 3,000 reservoirs with various sizes in Vietnam. All reservoirs, generally, have developed fisheries, and these make a significant contribution to overall freshwater fish production.

In most cases the productive fisheries in the reservoirs are based on the native fish biodiversity of the impounded river. These fisheries include larger table-fish and some cases small pelagic species. The results from the studies on fish fauna of reservoirs show through comparison of pre—and post-impoundment conditions that the number of fish species always has decreased significantly, (e.g. by 38% in Tri An reservoir, 51% in the Thac Ba reservoir). On the other hand the fish catch has increased significantly (e.g. an increase of 958 tones/year in Tri An reservoir and 423 tones in Thac Ba reservoir) and fishery employment in the area has increased by many times.

Often the species that are used in pond aquaculture, and in floating cage aquaculture escape and inhabit the reservoirs. Some of these can be very numerous. One of the new-comers is the tilapia *Oreochromis mossambicus*. They often become very numerous (over-populated) and the population often consists of small sized specimen. Figure 24 shows a fish catch of small tilapia from a tropical reservoir that has been over populated by escaped aquaculture fish. The fish is so small that it is on the edge of being suitable as human food.

Figure 24. Tilapia catch from a tropical hydropower reservoir in the Dominican Republic (Lago de Rhincon), that has been populated by escaped aquaculture tilapia (Berge et al 2003)

The reason for the decline in the biodiversity is partly that migratory species disappear because thay are not able to pass the dam, but the main reason is that only a few species of the former river species are able to adapt to a lake life. Many of this species are still living in the tributaries, as well as in neighbouring rivers. But some species will disappear from the upstream catches. One of the highly priced fishes that will disappear from all upstream rivers is the gian mottled eel. Several other species, which we don't have the total overview of at the moment, are likely to disappear to the level of almost extinction.

The possiblitities of utilising the fish production potential in the reservoir will be discussed under the mitigation cahapter 9.5.

7.2.7 Emission of greenhouse gases from the Song Bung 4 reservoir

7.2.7.1 Man made reservoirs – a source of greenhouse gas emissions

The World Commission on Dams (established by the World Bank and the IUCN) undertook by far the most comprehensive and indipendent review yet done of the world's dams, and in their final report (WCD 2000) *Dams and Development: A New Framework for Decision Making*, they address that recent research indicates that dams and their associated reservoirs are globally significant sources of emissions of the greenhouse gases carbon dioxide and, in particular, methane. They recommend that comparisons of the costs and benefits of different development options should include assessment of the net greenhouse gas emissions from dams. Emissions from tropical reservoirs are typically between 5 and 20 times higher per unit of area flooded than those from reservoirs in temperate and boreal regions (McCully 2000). The worst tropical reservoirs can contribute many times more to global warming than coal fired power plants generating the same amount of power (McCully 2000 "the IRN-report", Fearnside 2002, 2004, 2005, St Louis et al 2002, Duchemin et al 2002, Rosa et al 2002, 2004).

A growing body of evidence shows that hydropower is not as climate friendly as believed earlier. However, the item is still controversial. There are great disagreements on how to calculate the emission budget (gross or net) for a reservoir, and studies from different tropical reservoir have given large differences in emission results. The reasons for these differences are still poorly understood, but it has to do with the organic load of the reservoir, the oxygen regime, the autochtonous production (eutrophic or oligotrophic), the morphometry, the wind fetch, the water residence time, etc.

When the dam is constructed and filled for the first time, large amount of terrestrial forest biomass is inundated. When this biomass is being degraded it consumes oxygen and creates other gases, $C0_2$, H_2S, N_2O and CH_4. Of these, CO_2, and in particular the last one, methane, is the worst of these gases and is 21-23 times more powerful as greenhouse gas as CO_2. It is produced when organic material is decomposed under anaerobic conditions. In deepwater of tropical reservoirs high concentrations of methane are often formed (up to 10 mg/l and more). When water level in the reservoir is lowered during the dry season, methane starts to bubble off through the reservoir surface. But more important is the release over the turbines and the spillways (Galy-Lacaux et al 1997, 1999, Fearnside 2005). The sudden fall in pressure when the water comes out results in quick release of methane and carbon dioxide, see Figure 26. The downstream heating of the water (reduces gas solubility) also results in methane and carbon dioxide release to the atmosphere.

The phenomenon of greenhouse gas release from reservoirs is mainly studied in Canada (St. Louis et al 2000, Duchemin et al 2002) and Brazil (Fearnside 2000, 2002, 2004, 2005, Rosa et al 2002, 2004). The first study that in a way discovered the problem of the main release of methane being from the turbines and spillway, and not from the reservoir surface as hitherto believed, was done in French Guyana (Petit Saut Dam) by a French team (Galy-Lacaux et al 1997, 1999).

A first attempt at calculating the global contribution of reservoirs to climate change was made by a team of Canadian researchers headed by Vincent St. Louis of the University of Alberta. The research was published in the scientific journal Bioscience in 2000 (St. Louis et al 2000). They estimated that reservoirs of all types and sizes worldwide release 70 million tons of methane and around a billion tons of carbon dioxide annually. These figures equal about one-fith of the estimated methane emissions from all other human activities, see Figure 25. It should be noted that only 25 % of these reservoirs are hydropower dams, the other being for irrigation and drinking water purposes. According to Eric Duchemin of the University of Quebec at Montreal (Duchemin 2002), accounting for reservoir emissions could increase Canada's estimated greenhouse gas output by around three percent and the country's electrical sector emissions by around 17 percent. As gas releases from reservoirs in tropical areas are many times higher than in Canada, accounting for this contribution, for example in Brazil with 400 tropical hydropower reservoirs producing 90 % of the conuntry's electricity (Rosa et al 2004), would have a large impact on the greenhouse gas emission budget.

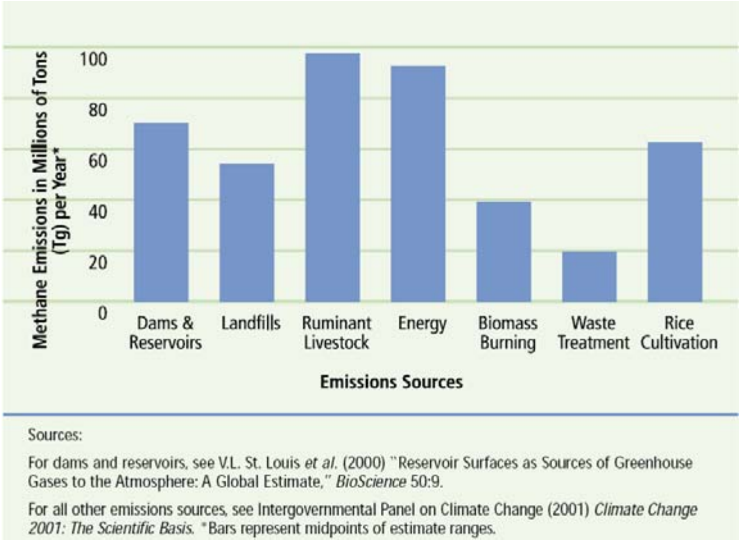


Figure 25. Estimated methane releases from major anthropogenic sources (after McCully 2000)

The UN's Intergovernmental Panel on Climate Change (IPCC) has given recommendations for the countries to include release of greenhouse gases from reservoirs, but as it is still not included in the mandatory guidelines of the Kyoto Protocol, an accounting for this contribution is still not done.

Figure 26. Hypolimnion spillway release in the Tucurui dam, Brazil (Fearnside 2002). The ski-jump fashioned release of the spillway was constructed to effectively oxygenate the water. But, at the same time it is efficient in stripping off the methane and carbon dioxide content of the reservoir deep water.

7.2.7.2 The greenhouse gas release from Song Bung 4 Reservoir

How much greenhouse gas will be released from Song Bung 2 reservoir, and how large is this emission compared with the emissions from the production of the same amount of electricity by means of gas fired thermal power (the most climate friendly thermal power) and oil fired thermal power, would be interesting to know. As mentioned above, the results from the studies of reservoir emissions in tropical reservoirs in Brazil and French Guyana (emissions results from about 12-15 reservoirs) vary greatly, constituting from 20 % to 400 % of the emissions from an equivalent oil fired power plant. The latest study being from 2004 (published in the journal Mitigation and Adaptation Strategies for Global Change in 2005, Fearnside 2005) is from the Curua-Una Dam in the Amazonian part of Brazil. The study was performed 13 years after the filling of the reservoir. The emission of greenhouse gases from this reservoir was 3.6 times the amount of CO_2 that would have been emitted by generating the same amount of electricity from oil. Most often there is a peak in the emissions the first 2-3 years after the filling of the dam, but some reservoirs continue to emit high amounts of methane throughout the lifetime of the reservoir.

There is not developed any clear cut model on how to estimate the emission from a reservoir prior to its construction. A very rough approximation can, however, be achieved by using average emission numbers from other tropical reservoirs. The previously cited Canadian group led by Eric Duchemin (Duchemin et al 2002) looked into this question. They found that average emissions from tropical reservoirs range from 200 to 3000 grams of CO_2 per kilowatt-hour (kWh). The power potential of SB4 is calculated to 538 x 10^6 kWh per year. The emission of greenhouse gases (as CO_2 equivalents) from SB 4 will then be between 108 000 tons CO_2 and 1620 000 tons CO_2 per year.

If these el-production is accomplished by the cleanest natural gas power plant technology (Combined Cycle = 0.5 kg CO_2 per kWh) an electricity production of 538x10^6 kWh will emit approximately 269 000 tons of CO_2. This means that the release of greenhouse gases from the SB4 reservoir will be between 40% and 600 % of what have been released by production of the same amount of electricity by gas fired thermal power plant. Comparison with oil fired thermal power (average 806 g CO_2 per kWh (Van de Vete 1996)) gives that the greenhouse gas emission from SB4 reservoir will be between 25 % and 276 % of this CO_2 equivalent. These estimates are gross estimates, i.e. it is not corrected for the greenhouse metabolism that takes place in the terrestrial areas that are going to be flooded. These ares can both be sinks and sources for greenhouse gases.

It is not possible in advance to give a more precise estimate on the emissions of green house gases from SB 4 reservoir, other than stating that it will not be very much better than gas fired thermal power. According model calculations, the SB4 reservoir will in the long run be oligotrophic. This will imply that the hypolimnion of the reservoir will not be anaerobic more that in a short initial phase of 2-5 years. After that there will not be favourable conditions for methanogenese in the sediments. If all the timber is removed from the reservoir area before the inundation, the SB4 reservoir will most likely be in the lower end of the span of greenhouse gas emissions found in the tropical South American reservoirs. The only way of getting a better quantification of the greenhouse gas emissions from SB4 reservoir is by monitoring.

But it is a growing scientific evidence that tropical hydropower reservoir is not climate friendly as they often produce more greenhouse gases than if the same amount of electricity was generated by fossile fuels.

8 MITIGATION MEASURES DURING THE CONSTRUCTION PHASE

8.1 Measures against erosion

8.1.1 Roads and road sides

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.

8.1.2 Reccomended 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 degradeable 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, relevant enforcement should be made to prevent erosion.

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

8.1.3 Parking lots, camp areas and construction sites

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

8.2 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 ammonium-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.

In the low flow period, 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. In the wet season, the ammonia discharge will not be big enough to harm the river biota.

8.3 Soil deposits and spoil rock deposits

In the first period after a major tunnel and hydropower construction work the spoil rock deposit is normally 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 location is important, the water handling is important, and the final termination is important.

8.3.1 Location 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 always easy to find 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 (i.e. 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 pond 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.

8.3.2 Final termination of the spoil rock deposit

When there is no more interest for using the spoil rock deposit it should be leveled and formed 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.

8.4 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. Preferentially, the camps should be placed in areas where there is good infiltration capacity in the ground. In such areas standard pit latrines may serve the intention of preventing hygienic pollution of entering 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 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 service, and at large sports arrangements. These can be emptied every day/every second day at the sewage system of the nearest town, or at a safe infiltration site.

8.5 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 important to secure that such compounds are not allowed to enter the Song Bung River.

The storage and fuel filling should take place on paved area, which is water-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.

8.6 Measures against accidental water releases and dry-ups

The coffer dam should be built so strong that it will withstand all floods, and the by-pass tunnel should have capacity to take all flood sizes known to can occur in the river. This to prevent coffer dam breaks.

The initial filling of the reservoir should be done only in the wet season with bypass of an amount of water at least corresponding to 10-15 % of average annual flow at the dam site. In the dry season, the normal low flow should be allowed to pass the dam. It is important that the river is not allowed dry up at any time.

The functioning of the spillway gates should be tested out properly with respect to both opening and closing before filling the reservoir.

9 MITIGATION MEASURES DURING THE OPERATION PHASE

9.1 Introductory remarks

The operation phase is the period after the construction is completed, the initial filling of the reservoir is finished, everything is tested properly, and the power plant is put into normal operation. The operation phase has a lifespan of 50 – more than 100 years in most hydropower plants.

The changes in hydrology are often the main reason for the environmental damage that follows a hydropower development scheme. The aquatic life has over thousands of years adapted to a certain hydrological regime which is relatively predictable from year to year. In the summer the monsoon rain is causing the rivers to swell, which again triggers the spawning migration of a large number of fish species. The floodplains are flooded and the farmers are planting their rice in the paddy fields. In November-December the water levels goes down in the onset of the dry season. Fish migrate back to the larger rivers, the farmers harvest the rice, etc. Every year, approximately the same cycle is repeated, with a few deviating years now and then. These deviating years are also important to prevent certain species from developing too strong and dominating populations.

The hydropower schemes interrupt this normal hydrological cycle that both the aquatic life and the human use have adapted according to. The dams, and any dry stretches, break the ecological continuum of the river, and prevent fish of reaching their spawning grounds, feeding grounds, nursery areas, etc. The changes in hydrology often bring increased erosion activity, which gives water quality problems, siltation problems, and sedimentation problems.

The key measures in Song Bung 4 HPP with respect to protect water quality and aquatic life is

1. Compensation flow downstream of the dam
    - Minimum relase from the dam
    - Downstream Flow Adjustments
2. Consider building fish bypass system over the dam
3. Keep the water level fluctuations in the reservoir within 4 m (FSL-MOL)
4. Let the reservoir establish fish stocks based on indigenous species
5. Consider establishing fish stocking programmes of the reservoir
6. Development programmes for teaching local people how to run aquaculture in floating cages.

9.2 Establishment of a compensation flow downstream the dam

The compensation flow will in this case consist of 2 items:

1) Minimum release of water from the dam
2) Flow adjustments to trigger fish migrations / secure enough water for fish migration

9.2.1.1 Compensation flow proposal from the Hydrodynamic Modelling Study

Considering all historical low flows and studies of salinity intrusion in the delta we suggest to use 10% of mean annual flow as the compensation flow requirement for all hydropower developments in the Vu Gia Thu Bon basin. The requirement is reasonable considering the historical low flows in the basin. Using 10% mean annual flow is the same as recommended by WCD, and MONRE uses the same recommendation as guideline for setting compensation flow in Vietnam (Basberg 2006). Currently work are undertaken to establish guidelines for environmental flow in Vietnam by MONRE, but these are not ready yet.

Table 17. Calculated common compensation flow and suggested value (from the Hydrodynaqmic modelling study (Basberg 2006) *Unit: m³/s*

	A Vuong	SB2	SB4	SB5	SC	D1	D4	STr	Hoi Khach	Ai Nghia	Giao Thuy
10% of Mean Flow	3.0	1.6	7.2	11.2	1.0	3.9	9.6	11.0	26	30	29
P-90%	4.9	3	14.1	21.7	0.5	7	14.6	13.6	49	53.5	31.8
Q3020Y	0.9	0.9	5.7	7.9	0.1	3.3	7	4.6	24.3	24.8	10.6

This study gives a recommendation of a minimum release from the Song Bung 4 dam of 7.1 m^3/s.

9.2.1.2 State of the Art in Assessment of Environmental Flow

In the first stage of water management planning 30 years ago, assessment of minimum flow solely took into consideration the needs of water use interests, and often only the most important of these. As the water use sectors had voices that clearly mediated their requirements for water flow, and water level, the environment was voiceless. Environmental authorities were introduced to communicate the requirements of the environment. Gradually it became clear that many of the human water uses are dependent of a well functioning aquatic ecosystem, to give the humans so-called “ecological services”. Therefore many countries have now included in their Water Act, or water legislation, the requirement of a minimum flow downstream dams, and diversions. In Norway the Water Resources Law set requirement for a minimum flow of “common low flow”, which is approximately equal to 10% of average flow. Other countries have adopted more sophisticated requirements, as for example South Africa, where the South African National Water Act (No. 36 of 1998) introduces the concept of ecological reserve which it describes like this: “The ecological reserve relates to the water required to protect the aquatic ecosystems of the water resource. The reserve refers to both the quantity and quality of the water in the resource.” The Department Water Affairs and Forestry gives a description of different methodologies for assessing the ecological reserve in South African rivers (DWAF 1999). The methodologies varies greatly with respect to the amount of work needed to assess the environmental flow; from one day desk stop evaluations to 8 month studies with several months of field work.

As environmental flow methodologies have evolved, there has been a move away from a “minimum flow” concept (Stalnaker 1990) to recognition of the importance of variability in the flow for the structure and functioning of riverine ecosystems (Richter et al 1997).

The World Bank has made a series of 4 Technical Notes which deal with environmental flows in rivers (Davis and Hirji 2003). Here they divide the methods of assessing environmental flow into four categories:

1. Hydrological index methods (e.g. Richter et al 1997). These are mainly desktop approaches relying primarily on historical flow records to make flow recommendations for the future. Little, if any, attention is given to the specific nature of the considered river or its biota.
2. Hydraulic rating methods (e.g. Gippel and Stewardson 1996). These methods use the relationship between the flow of the river (discharge) and simple hydraulic characteristics such as water depth, velocity, or wetted perimeter to calculate an acceptable flow. A variety of this method is often referred to as the habitat simulation methodologies (e.g. Milhouse at al 1989) which use suited river bottom area instead of wetted perimeter. These methods are an improvement compared to the hydrological index methods, since they require measurements of the river channel, and so are more sensitive than the desktop approaches to differences between rivers. However, judgement of an acceptable flow is still based more on the physical features of the river rather than on known flow-related needs of the biota.

3. Expert panel method. Expert panels use a team of experts to make judgements on the flow needs of different aquatic biota at different sites of the river.
4. Prescriptive holistic approaches (e.g. Arthington 1998). These methods require collection of considerable river specific data and make structured links between flow characteristics of the river and the flow needs of the main biotic groups (fish, vegetation, invertebrates).

A more recent methodology belonging to the prescriptive holistic approaches is evolving in South Africa (O'Keefe et al 2002). The method, which is called the "Flow stressor response model", guides the evaluation of the ecological consequences of modified flow regimes, based on the principles of ecological risk analysis (Suter 1993), using an index of flow related stress on the in-stream biota. The method is still under development. So far it concentrates on water quantity requirements, but a parallel process is being developed to assess ecological stresses in relation to water quality.

In the EU Water Framework Directive it is recognised that a physically altered river (regulated flow, dammed, or other physical encroachments) it is not possible to reach good ecological status, which is the requirement in normal rivers. The goal in these rivers is to achieve good ecological potential. This is still not finally defined, but the meaning is somewhat in the direction of "to create the best possible environmental condition within the constraints set by the physical regulation". The EU Water Framework Directive set as minimum requirement that in no regulation you are allowed to break the ecological continuum. This means that there should be at least a minimum release downstream the dam, but no figure is given for the size of this. The environmental goals in regulated riverr are in other words less strict than in non-regulated rivers. There is for example a clear connection between how much electricity you take out of a river and how much environmental quality you loose.

The present methodology of assessing environmental flow, take into account mainly the needs for the in-stream biota. The needs for the different human use categories are not included. Neither have they made the recognition that a regulated river always will loose some of its environmental qualities, as e.g. recognised by the WFD cited above. In addition the holistic approach methods are too laborious to be used for predictive purposes in new regulations. The data needed are simply not present in most cases, and it will take years to collect them. The new methodologies, e.g. recommended by the World Bank, can be however, be very useful in adjusting the concession conditions in old regulations, where experience on the consequences are gained, and monitoring data are gathered over years. But for the assessment of Environmental flow in the Song Bung 4 HPP the methodologies cannot be applied with the present state of biophysical knowledge of the river.

Therefore the less sophisticated minimum release from the dam to be proposed from the SB 4 reservoir should be called "compensation flow" and not environmental flow.

9.2.1.3 Proposal for compensation flow downstream of Song Bung 4 Dam and Hydro-power Plant

The distance from the Song Bung 4 dam to the outlet of the power plant is approximately 5 km. Two km upstream of the power plant enters the A Vuong tributary, but this is dry during the dry season, as the water enters via the A Vuong Powerplant approximately 7 km downstream of Song Bung 4 power plant, see Figure 27. In the future Song Bung 2 reservoir will reach 2 km upstream of the tailrace from the A Vuong Power plant. There is no minimum release or environmental flow requirements in the A Vuong regulation. That means that in the dry season the flow in the old A Vuong River will be more or less zero.

Several fish species in the Vu Gia – Song Bung Rivers are upstream spawning migrants, and migrate to the dam area of Song Bung 4 and further upstream. The spawning migration is an inherent instinct in most species, which means that there will be spawning migrations also after the regulation, even though it will easily become considerably disturbed. For example those who spawn floating eggs, need as long river stretch as possible to secure the eggs of hatching before drifting to the sea (or to the reservoir). In the future the river stretch up to the Song Bung 4 dam will be an important spawning stretch for fish in the Song Bung 5 reservoir. In addition, the river stretch will be important water source for wildlife and livestock in the dry season, particularly since there is not planned any minimum release in the A Vuong River. If it will be feasible in the future to create a fish bypass system over the dam, it is important to have a living river continuum. Therefore, based on these arguments, including the strong recommendations from the World Commission on Dams, The World Bank, and the European Union Water Framework Directive, MONRE, as well as the judgements made in the Hydrodynamic Modelling Study of this project, <u>it should be established a minimum release from the dam</u>.

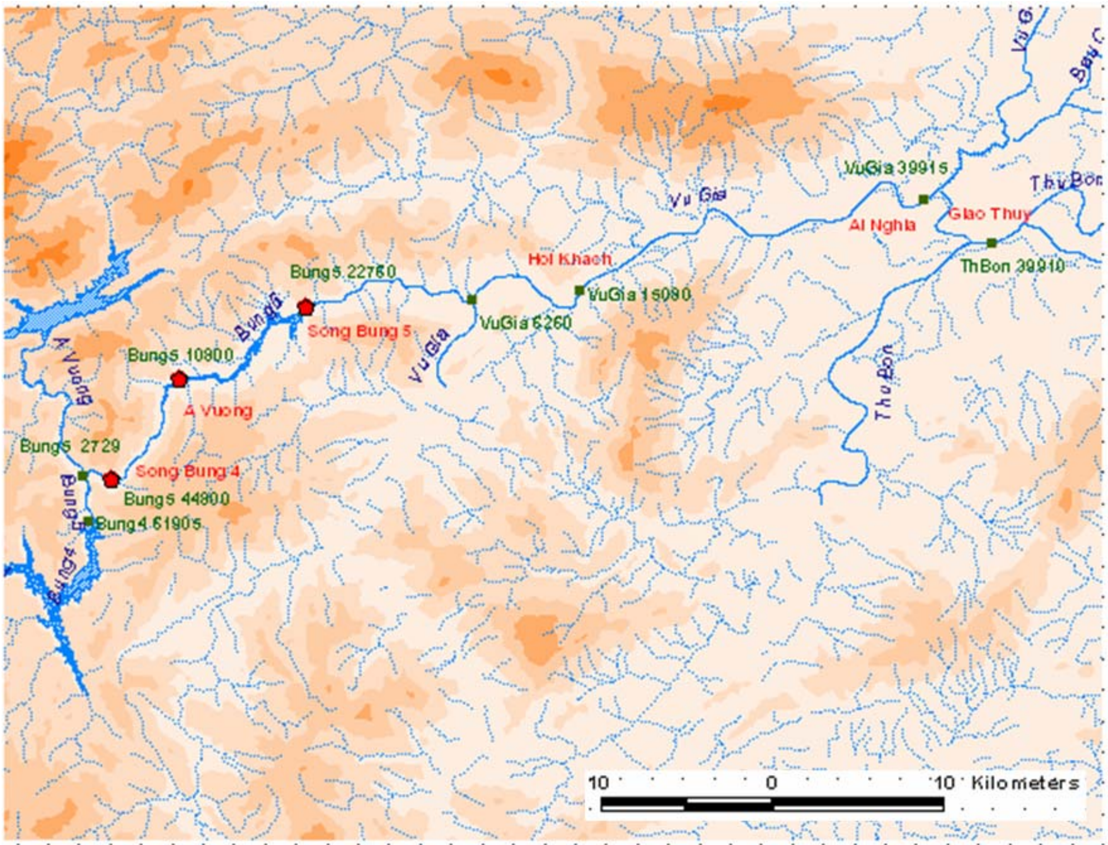


Figure 27. The Reservoirs, power plants and stretches where minimum release of water is necessary (from Basberg 2006)

The Hydrodynamic study ended up with a proposal for a compensation flow defined as minimum flow at all sites which should be 10 % of average flow at the site, or bigger. This is in accordance with most international reccommendations for a static minimum release. At the Song Bung 4 damside this equals 7.2 m^3/s. The average monthly minimum flow at the dam site is for most years 25 m^3/s or more, but for particularly dry years the minimum can be as low as 5 m^3/s. The minimum release should not at any time be less than this figure.

In the Word Bank recommendations, Environmental Flow is a much more dynamic term that just a static minimum release. As far as possible they recommend that the release should follow the same rhythm as the natural river. But, if you take away 90 % of the water at all times (letting 10% back), it would be very little water back in the driest days of the year. Therefore, during the driest period the proportional release needs to be greater than in other periods. However, there is not enough information available from Song Bung to try to assess an Environmental flow in a highly sophisticated manner, as e.g. some of The World Bank Methods cited in the previous chapter.

However, in addition to taking care of the river continuum, which is covered by a static minimum release, the release could be varied a little to try to take care of some of the increased needs during spawning migration. There is two large spawning migration periods in the Song Bung, and they are both triggered by flow increase in the river, in addition to time of the year (gonad development). One is in the small rainy season (May-June) and the other in the large rainy season (Sept-Nov).

Our proposal for Compensation Flow will be a release from the Song Bung 4 dam as given in Table 18.

Table 18. Proposal for an Environmental Flow released from the dam in different months of the year (values in m^3/s)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5	5	5	5	8	8	5	5	9	11	9	7

This release corresponds to 6.8 m^3 /s in average, which constitute 9.4 % of annual mean flow, a little less that what was proposed by the Hydrodynamic study (Basberg 2006).

It can be built in a small turbine in the damfoot which can produce electricity on the minimum release. In such a high dam as in Song Bung 4, this will give a significant amount of electricity.

9.3 Consider building of fish bypass systems

Several fish species migrates far upstream Song Bung River to day as the river does not seem to have any physical barriers. The highly priced *Anguilla marmorata* is one example of such a long distance migrant. As hydropower development is recognised as the greatest threat for freshwater biodiversity in SE-Asia (Dudgeon 2002) it has been more and more focus on developing fish bypass systems for letting the fish pass the dams. Such systems are of three types:

- Canals
- Ladders
- Lifts

Which systems will be best fitted here, needs to be considered very carefully with expertise on the fish species present. Since it is a faily high dam, a lift system may be most feasible. However, there exists little experience with fish bypass systems in the region, and therefore it is premature to give concrete recommendations for building these now. But these technologies will develop in the future, and it is therefore important to have permanent flow all the way from the dam.

9.4 Fish stocking programmes

If the reservoir fails to be self stocked by river fish that adapt to the lake life, and the recruitment failure seem to be due to spawning or nursery problems, it should be considered to establish a fish stocking programme. This can not be decided upon until some years of experience are gained.

9.5 Possibilities for fish production in the Song Bung 4 reservoir

9.5.1 Introductory remarks

The Song Bung 4 dam will convert a long river stretch of Song Bung from a river ecosystem into a lake ecosystem with a surface 16 km^2 at full supply level. We have been asked to give an evaluation about the possibilities to have good fish production in the reservoir based on experience from other regulations, preferable from Vietnam. In that connection we have gathered information about fishery yield and aquaculture from Vietnamese reservoirs, both irrigation and hydropower reservoirs. As fish production and fish yield is not studied quantitatively in relation to the operation mode of the hydropower reservoirs in this region, we have also brought in experience from European regulations. The principles of how regulations impact freshwater ecosystems are the same all over the world.

Since the early 1960s construction of reservoirs has increased in Vietnam, both for irrigation purposes and for hydropower. According to the statistics, there are now approximately 3,000 reservoirs with various sizes in Vietnam. In all the reservoirs there have been developed fisheries, and these now make a significant contribution to the overall freshwater fish production in the country. In most cases the reservoirs develop productive fisheries based on the native fish biodiversity of the impounded river. These fisheries include both larger table-fish and some cases small pelagic species. Comparative studies on pre—and post-impoundment fish catch, show that the biodiversity of fish species decreases significantly after an impoundment (e.g. by 38% in the Tri An reservoir, and by 51% in the Thac Ba reservoir). On the other hand, the impoundments result in an overall significant increase in the fish catch (e.g. an increase of 958 tones/year in the Tri An reservoir and 423 tones in the Thac Ba reservoir) and fishery employment increased by many times.

The fish yield of a reservoir comprises both exploitation of natural fish stock trough traditional fisheries but also several kinds of aquacultural activities. Most common is aquaculture in floating cages, which often utilise different kinds of carps, as well as tilapia.

9.5.2 Fishing production and fish productivity

Small and shallow irrigation reservoirs are normally more productive than large and deep hydropower reservoirs. In a study on fishery in reservoirs of Vietnam, Nguyen Van Hao (1994) devided the fish yield of the different reservoirs like in Table 19.

Table 19. Fishery yield in small and large reservoirs

Relative reservoir size	Fishery yield
Small reservoirs	111-215 kg/ha
Medium sized reservoirs	52-73 kg/ha
Large reservoirs	16-28 kg/ha

Several data of fishery yield and aquaculture production of some reservoirs in Vietnam are represented in Table 20 and Table 21.

Table 20. Fishery yield and aquaculture production of some reservoirs in Vietnam

No.	Reservoir Name	Area (ha)	Aquaculture		Fishery on wild fish		Total		Year and Authors
			Ton	kg/ha	Ton	kg/ha	Ton	kg/ha	
1	Thac Ba (YenBai prov.)	19.000-23.500	100	5,0	463	24	563	30	(1993), Nguyen Hu Nghi, 1995
2	Cam Son (Bac Giang)	2.300	37	18	58	25	96	41	(1993), Nguyen Hu Nghi, , 1995
3	Phu Ninh Quang Nam)	2.400-3.200	60	25	35	15	95	40	(1993), Nguyen Hu Nghi, 1995
4	Liet Son (Quang Ngai)	180	12	67	10	56	22	122	(1993), Nguyen Hu Nghi, 1995
5	Nui Mot (Binh Dinh)	600-1.200	40	6	24	40	64	107	(1993), Nguyen Hu Nghi, 1995
6	Dac Uy (Dac Lac)	300	15	50	5	7	20	67	(1993), Nguyen Hu Nghi, 1995
7	Suoi Hai (Ha Tay)	600						28,33	(1965), Nguyen Van Hao, Thai Ba Ho, 1983, 1985
8	Quan Son	350						28,57	(1965), Nguyen Van Hao, Thai Ba Ho, 1983, 1985
9	Dong Tranh	41						48,8	(1966), Nguyen Van

									Hao, Thai Ba Ho, 1983, 1985
10	Dai Lai (Vinh Phuc)	275					13.5-29.7	21,6	(1967,1968), Nguyen Van Hao, Thai Ba Ho,, 1983, 1985
11	Van Truc (Vinh Phuc)	172					11.6-69.7	40,7	(1967,1968), Nguyen Van Hao, Thai Ba Ho,, 1983, 1985
12	Da Nang	300					15.4-34.7	22	(1965, 1969) Nguyen Van Hao, Thai Ba Ho,, 1983, 1985
13	Dong Ngu (Thanh Hoa)	60						30	(1969), Nguyen Van Hao, Thai Ba Ho, 1983, 1985

Soures: MOF (1996), Aquatic resources of Vietnam.

According to the official statistics, the fishery yield of reservoirs in Vietnam is four times greater than the aquaculture production in the reservoirs, see Table 21.

Table 21. Area, production and productivity of reservoirs in Vietnam in 1993

Regions	Number of reser-voirs	Total area (ha)	Area for natural exploit-ation (ha)	Fishing on wild fish		Aquaculture		Total production	
				Tons	kg/ha	Tons	kg/ha	Tons	kg/ha
Middle land and moun-tainous area of northern Vietnam	797	63.665	52.129	886	17,0	370,4	7,11	1.256,4	24,1
Northern Central part	121	20.784	18.321	324	17,7	92	5,02	416	22,7
Southern Central part	196	11.196	2.479	70	28,2	192	77,45	262	105,69
Tay Nguyen plateau	189	12.424	2.299	155	67,4	59,5	25,88	214,5	93,3
Eatern Nam Bo	100	73.105	63.816	2.618	41,0	314	4,92	2.932	45,95
Total	1.043	181.174	139.044	4.053	29,2	1.028	7,39	5.081	36,55

Soures: MOF (1996), Aquatic resources of Vietnam

Annual Fish production of two large reservoirs (Hoa Binh and Tri An) is presented in Table 22 and Table 23.

Table 22. Annual Fish production and fishing effort in Hoa Binh Reservoir (Hoa Binh, Son La)

	1989	1990	1991	1992	1993	1994	1995
Catch (tons)	120	135	150	180	296	332	300
Number of fishermen	240	270	300	360	740	920	1200
Number of fishing boats	120	135	150	180	370	460	600
Yield per fisherman	0.5	0.5	0.5	0.5	0.4	0.36	0.25
Yield per boat	1	1	1	1	0.8	0.72	0.5

Source: MRC, (1997), Large dam fisheries of the lower Mekong countries: Review and Assessment. Database. Project on Management of Reservoir Fisheries.

Table 23. Annual Fish production and fishing effort in Tri An Reservoir (Dong Nai prov.)

	1991	1992	1993	1994	1995
Catch (tons)	1275	1070	1136	902	1323
Number of fishermen	4200	4170	3990	3000	3600
Number of fishing boats	1400	1390	1330	1000	1200
Yield per fisherman	0.30	0.26	0.28	0.30	0.37
Yield per boat	0.91	0.77	0.85	0.90	1.10

Source: MRC, (1997), Large dam fisheries of the lower Mekong countries: Review and Assessment. Database. Project on Management of Reservoir Fisheries.

Some studies on fish fauna of Tri An reservoir have been carried out by Tran Truong Luu et al., (1990). The results indicated that during the first year after inundation, most original riverine fish species appeared to be dominant, but the second year showed that Chinese carp (eg. silver carp, and big head carp) were well suited to the new environment, especially in the open and pelagic zones. After one year these cultured fish were 8-10 kg per individual.

9.5.3 Aquaculture in reservoirs

Generally, since the yearly 1970-1980s, reservoirs were stocked with fry and juveniles of both indigenous and exotic species. However, since the reservoirs have often complicated forms, long and steep, etc., it is often complicated to manage the fish resource in a cost effective way. Therefore the stocking programmes have decreased and gradually become replaced by aquaculture in floating cages.

Some indigenous fish species that are often stocked into the reservoir or cultured in floating cages in Vietnam reservoirs are presented below in Table 24 and Table 25.

Table 24. List of fish indigenous species stocked directly into the Vietnamese reservois, or cultured in floating cages.

Common name	Lating Name
Common carp	*Cyprinus carpio*
	Hypophthalmichthys harmandi
Mud carp	*Cirrhinus molitorella*
Snakeheads	*Channa striatus*
Snakeheads	*Channa micropletes*
	Channa lucius
Eel	*Anguilla marmorata*
	Mystus nemurus
Bong tuong	*Oxycleotris marmoratus*

Table 25. Some exotic species of fish often stocked directly into Vietnamese reservoirs or utilised in floating cage aquaculture in the reservoirs

Common name	Latin name
Silver carp	*Hypophthalmichthys molitrix*
Bighead carp	*Aristichthys nobilis*
Grass carp	*Ctenopharyngodon idella*
Mrigal	*Cirrhinus mrigala*
Rohu	*Labeo rohita*
	Catla catla
Mozambique tilapia	*Oreochromis mossambicus*
Nile tilapia	*Oreochromis niloticus*
	Tilapia sp.

Source:
Tran Truong Luu, 1992. Some aspects of aquatic aquaculture in the Mekong delta.
Luong Van Thanh et al., 2004. Environmental status of Tri An reservoir. Unpublished document of Institute of water resources at South Vietnam.

Some information on aquaculture in floating cages in some reservoirs in Vietnam are presented in Table 26.

Table 26. Some data on floating cage aquaculture of some reservoirs in Vietnam

Year	Hoa Binh		Thac Ba		Tri An		Dau Tieng	
	Number of cages	Cage production (tons)	Number of cages	Cage production (tons)	Number of cages	Cage production (tons)	Number of cages	Cage production (tons)
1992	100	50					2	2
1993	105	53	2	0.9	300	150	30	30
1994	105	53	30	13.5	400	200	150	150
1995	90	45	45	21	470	235	120	150
1996	80	40	20	9	600	300	35	70
2001					832	no data		
2002					879	no data		
2004					677	no data		
		Grass carp		Grass carp		Snakehead		Snakehead

Source:
MRC, (1997), Large dam fisheries of the lower Mekong countries: Review and Assessment. Database. Project on Management of Reservoir Fisheries.
Luong Van Thanh et al., 2004. Environmental status of Tri An Reservoir. Unpublished data from Institute of Water Resources at South Vietnam.

In the recent time, the water quality of Tri An reservoir has become seriously deteriorated due to over-development of floating cage aquaculture. The number of cultured cages peaked in 2002 with 879 operative cages. Since 2004, the local authority has required a decrease in the number of cultured cages in this reservoir, and fishermen living on floating cages have been removed to the land for agriculture.

Beside cage culture, local residents have developed another type of aquaculture called “fish culture in small straits” of reservoir. In these areas, in rainy season, local residents set up a fence across a strait and introduce juvenile fish which are harvested in dry season when the water retreat. In 2000 this type of aquaculture comprised 184,000 fish, in 2001-237,000, in 2002-688,000; in 2003-1,022,000. To day, the local authorities have prohibited this aquaculture activity in the Tri An Reservoir to protect natural habitats and develop natural aquatic resources.

9.5.4 What fish productivity can be anticipated in Song Bung 4 Reservoir?

Song bung 4 reservoir will be long and narrow with steep sides. This means that the productive shallow areas will be small. The reservoir is lying in relatively unfertile soils with oligotrophic waters coming from the catchment. The population in the catchment is low, and agricultural areas very restricted. This indicates that the fish productivity of the reservoir will be low. In many cases, the Song Bung 4 reservoir will be of the Hoa Binh type, and not of Tri Ahn type. This last one is a large shallow reservoir lying in productive agricultural landscapes of the lowland in Dong Nai Province in South Vietnam. From Table 22, it can be seen that the fishery yield in Hoa Binh has varied from 120 tons per year to 300 tons per year. If this is devided by the 200 km^2 surface of the reservoir it gives a fishery yield of 8-15 kg/ha. This fish productivity is very low, and even lower than the lowest categrory given in Table 19. So, as Song Bung 4 is a smaller reservoir than Hoa Binh, let us say that the fish productivity of the Song Bung 4 reservoir will be 20 kg/ha per year.

The surface area equals 1600 ha, and by multiplaction the total fish production of the reservoir will be 32 000 kg per year. An adult person subsiding on fish needs at least 100 g (average including children) fish per day, which is 36.5 kg/year. This means that the reservoir will supply a population of 1000 persons with annual protein need if fish is the only protein source. If they eat fish every second day, the reservoir fisheries can supply proteins for 2000 persons with protein.

We saw from Table 21 that on average for Vietnamese reservoirs, utilization of natural fisheries gave 4 times as much yield as aquaculture. If this is also anticipated to apply for Song Bung 4 reservoir, the reservoir can provide approximately 40 000 kg fish meat per year with developing both fisheries and aquaculture. This means that it can supply a population of 1250 persons with protein if fish is the only source. If they eat fish every second day the reservoir can supply proteins to a population of 2500 persons.

9.5.5 The impact of water level fluctuation on fish yield

The fishery yield statistics from Vietnamese reservoirs has not been analysed in relation to water level fluctuation. They have, however, been systemised with respect to size of the reservoirs, stating that small reservoirs have higher fish productivity than larger reservoirs (Nguyen Van Hao 1994). In fact water level fluctuation is a decisive factor in determining the fish productivity of reservoirs.

The shoreline area (or the littoral zone) down to approximately 10 m depth is the most important zone in a lake with respect to fish production. Here the bottom receives light, which create conditions for the growth of rooted plants, benthic algae, coarse organic debris from overhanging trees, stones, old logs, varied habitats, bottom animals, hiding places, etc. Normally in lakes, 60-90 % of the fish food is produced here. If this zone is destroyed by periodically dry ups due to regulation, the plants are killed and the organic material, and inorganic sludge are washed away. The zone are transformed into more or less a stony dessert where it is very little food to find even in the period of the year it is covered with water, see Figure 28.

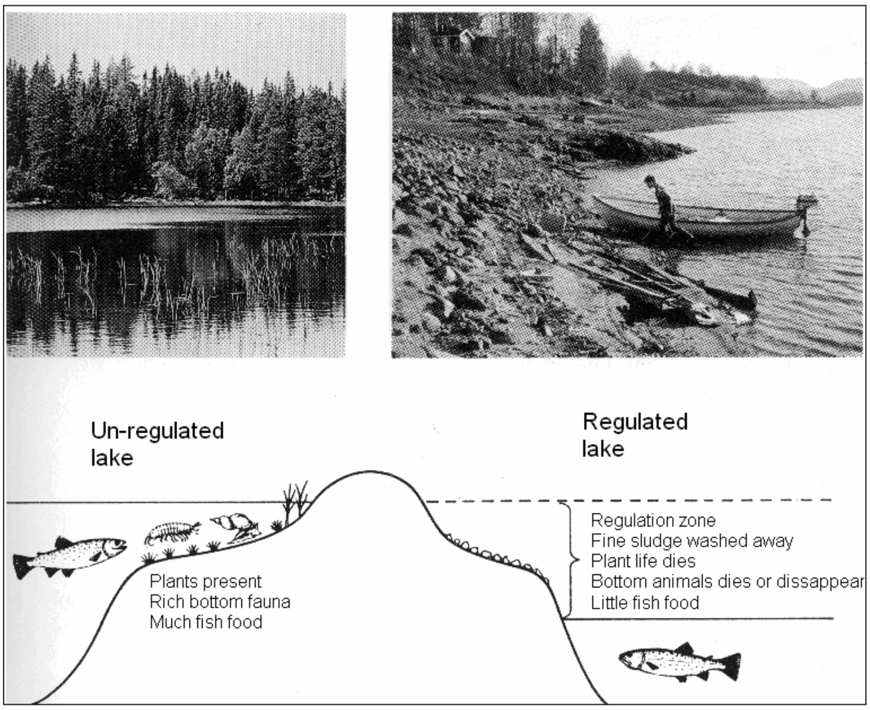


Figure 28. High water level fluctuations kill the important littoral zone in regulated lakes, and reduces fish food production and fish habitat (from Økland 1995).

The erosion material from the regulation zone settles for a large part within the deep part of the reservoir making the sludge here inorganic. Most of the profundal bottom animals, which are the most important fish food in the deep water area of a reservoir, lives from eating and digesting sludge (like the earth worm). When the sludge becomes inorganic due to sedimentation of erosion material, the production of bottom animals declines. In this way also the central deepwater part of the reservoir gets low productive with respect to fish food production. Figure 29 shows an example on the impact water level fluctuation on the production of bottom animals in Lake Blåsjøen, a hydropower reservoir in Sweden (Grimås 1961).

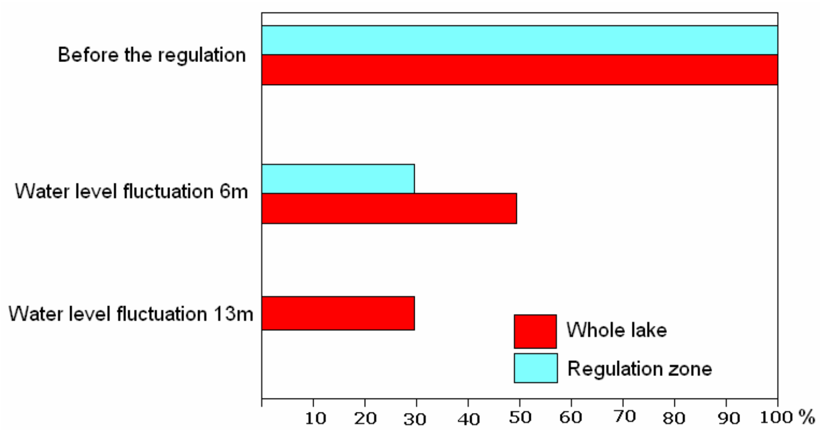


Figure 29. Impacts of water level fluctuation on the production of bottom animals (important fish food) in Lake Blåsjøen in Sweden (Grimås 1961).

In the Norwegian reservoir Stolsmagasinet the impact of water level fluctuation on fish yield is studied, see Figure 30 (Garnås and Gunnerød 1981). It was found a direct correlation between the water level fluctuation and the fish yield.

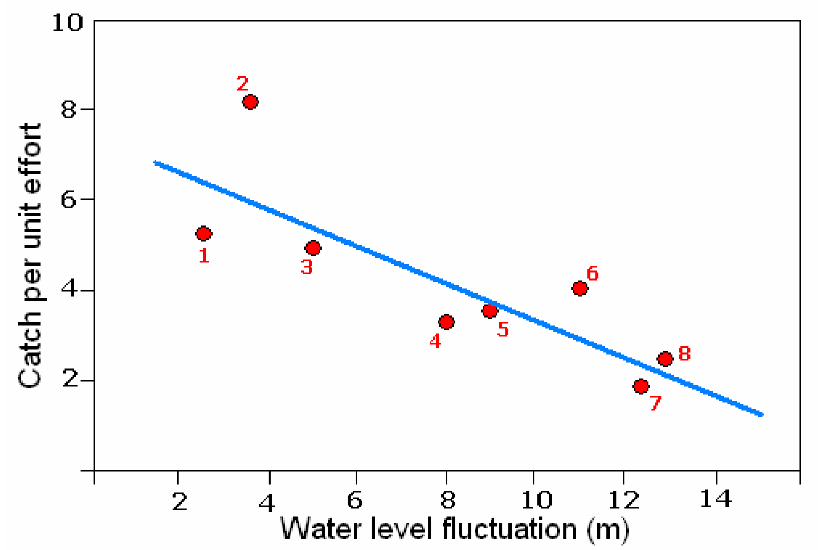


Figure 30. Fish yield (catch per unit effort) in parts of the Stolsmagasiner hydropower reservoir system with different water level fluctuations (after Garnås and Gunnerød 1981)

In a regulated lake with high water level fluctuations, the planktonic food web is the most important. However, plankton animals are small and fast swimming, and it cost a lot of energy for the fish to catch them. The plantivorous fish often become small in size, and are difficult to catch. The production is much lower than in lakes with only small water level fluctuation (living littoral zone). In a short transitional phase after the regulation, however, the fish productivity can be good despite large water level fluctuations. This is due to good food availability from the inundated terrestrial organic material. This will be decomposed after few years.

As a general rule in the long term perspective, it can be said that if the water level fluctuations are less that 3-5 m it can be good fish production in a reservoir, and it is impossible to have good fish production if the water level fluctuations are greater than 10 m. If the reservoir is of the clear water type the fish productivity can tolerate higher water level fluctuation than if the water is of the turbid type. To have good fish production in Song Bung reservoir, the water level fluctuations should not be more than 4 m. With water level fluctuation means the difference between maximum supply level and minimum operation level.

The fish productivity of the Song Bung Reservoir is based on empirical data from other Vietnamese reservoirs, which all have higher water level fluctuation than 10 m. Base on the Norwegian experience cited above, it is likely that the the fish productivity of Song Bung reservoir will be 3 times greater with a water level fluctuation of 4 m instead of 27 m.

9.5.6 Recommended fish enhancement actions in the reservoir

Based on the analyses of fish production, fishery and aquaculture data from Vietnamese reservoirs given in the sections above, the following fish enhancement actions are recommended:

Keep the water level fluctuation in the reservoir within 4 m (FSL-MOL). According to the hydrodynamic modelling study this will only reduce the electricity production slightly.

Let the reservoir be populated with indigenous fish species. The species that thrive in the lake environment will establish very fast, and there should not be a need for stocking with exotic species.

If local people want to, and are allowed to, still live along the reservoir, they should be tought how to run aquaculture in floating cages. This should be planned as part of the livelihood programme. Preferentially the aquaculture should be based on indigenous species. Several non-indigenous species are already introduced into aquaculture in Suoui Commune, and it may be that some of these have escaped and are present in viable stands in the reservoir area of the river.

10 MONITORING

A monitoring programme should be launched both in the construction phase, as well as in the operational phase.

10.1 Monitoring in the construction phase

The monitoring programme in the construction phase should be aimed at controlling that the work is complying with the regulations set (so called Compliance Monitoring), which is not part of the aquatic life study. For our part it is relevant to monitor the water quality upstream and downstream of the construction area. That means 2 monitoring stations with location:

1. Upstream the dam site
2. Downstream the planned tail-race entrance

The sampling frequency should be once a month.

The parameters should be:

- Water flow downstream
- pH
- Conductivity
- Turbidity
- Suspended sediments
- Oxygen
- Ca
- Mg
- Total Phosphorus
- PO4-P
- Total Nitrogen
- NO_3
- NH_4
- Coliform bacteria
- Mineral Oil

If the recommendations on measures given in the mitigation chapter are followed during the construction work, it is not anticipated any damage to the river life downstream. Therefore it is not relevant with any biological monitoring in the construction period. However, there should be established some control, combined with awareness programme, to prevent the construction workers go fishing with dynamite, as this often is the most damaging impact on river life in a construction period.

10.1.1 Costs of the water quality monitoring in the construction phase

The budget is based on that the power company does the sampling and brings the samples to the laboratory. The budget covers the analysis and the expences confined with treatment of the data and reporting.

Costs of water quality monitoring in the construction phase

Activity	Costs (VND)
Field work (done by the hydropower company, not included in the budget)	0
Bringing the samples to Da Nang (done by the hydropower company, not included in the budget)	0
Analysis (14 parameters, 2 stations, 12 observations per year)	21000000
Treatment of data and writing the report (20 days of specialist work a 300 000 VND per day)	6000000
Total per year	27000000

27 mill VND. The sum is exclusive VAT.

10.2 Monitoring in the operation phase

This chapter deals with the monitoring of water quality and aquatic life in the operational phase. That is after the reservoir is filled and the power plant has started its operation. Very shortly, the monitoring should cover the following items:

1. Water quality
2. Fish meat mercury content
3. Fish yield and fish species composition
4. Algal species composition in the reservoirs
5. Release of greenhouse gases from the reservoir

10.2.1 Water quality monitoring

Water quality should be monitored with sampling 4 times a year (Jan-Apr-Jul-Oct) at the following stations:

1. Song Bung upstream the reservoir
2. Reservoir just upstream the dam
3. Minimum release water just downstream the dam
4. Tailrace from the power plant
5. Just upstream the outlet from A Vuong Power Plant
6. Hoi Khach (just after the merge with Song Cai)
7. Ai Ghia (just upstream the connection canal between Vu Gia and Thu Bon)

The sampling should be coordinated with the sampling for the monitoring of the greenhouse gas release.

The general WQ-parameters should be (at the “running water” stations 1,3,4,5,6,7 in the list above)

- Temperature
- Oxygen
- TOC
- pH
- Turbidity
- Chlorophyll-a
- Total Phosphorus
- PO4-P
- Total Nitrogen
- NO_3
- NH_4
- Arsenic
- Iron

As the pollution from mining showed up to be of minor importance, heavy metals are not included in the parameter list for water quality.

In the reservoir the samples should be taken over the reservoir's deepest point, which is just upstream of the dam (sampling point - approximately 200-300 m upstream). The samples will be taken in 5 different depths. The depths will vary from time to time depending on the filling degree of the reservoir. At each of the 4 samplings, the depth should be decided as follows: The shallowest sample at 1m depth and the deepest one 5m above the bottom, one sample at the turbine intake depth, and one midway between 1 m and the intake depth, and one midway between the intake depth and the bottom.

The samples should be analysed for the same parameters as above, and in addition the 1 m sample should be analysed for algal species composition.

Costs of Water Quality Monitoring (VND/year ex VAT)

Activity	Costs (VND)
Field work fee (2 persons x 2 days x 4 obs per year x 100000)	1600000
Field work travel (300 km x 5000 VND/km x 4 obs)	6000000
Field work per diem (2 pers x 200000 vnd/d x 2 days/obs x 4 obs)	3200000
Chemical analysis river stations (13 parameters x 6 stations x 4 obs/year)	27000000
Chemical analysis reservoir station (1 stations, 5 depths, 14 parameters, 4 obs/year)	22000000
Analysis of algal species composition (4 samples per year x 300000 per ana)	1200000
Treatment of data and writing the report (30 days of specialist work a 300 000 VND per day)	9000000
Miscellaneous, printing costs, meetings with client, etc	7000000
Total per year	77000000

10.2.2 The Greenhouse gas monitoring

The green house gas monitoring will not be done with the aim of assessing the total amount of greenhouse gas emission, i.e. 1) the diffusion of gas from the reservoir surface and 2) the breakdown of the above-water biomass, will not be included. The release through the turbines, (spillway, if the deep water type is chosen), as well as through the minimum release, will be monitored. This will be done by measuring the concentration of methane and carbon dioxide in the reservoir at the same station and depth as in WQ-monitoring in the reservoir. At the same time the corresponding concentration will be measured in the 3 effluents (turbine, spillway, minimum release) and the river downstream. The differences in concentration will indicate how much has stripped off into the atmosphere by pressure fall combined with turbulent mixing and heating. It should be noted that taking samples of supersaturated gasses in water is tricky, as they start to "bubble off" as soon as the sample is brought to the surface and pressure falls (like removing the cap from a Cola-bottle).

To measure the surface diffusion of the gases from the reservoir and from the above water degradation of organic material, is regarded as a too big task for this monitoring programme. The degree of super saturation of methane and carbon dioxide in the deepwater of the reservoir will tell a lot of the total emission potential from the reservoir, and how it develops.

Cost of greenhouse gas monitoring (VND/year ex VAT)

Activity	Costs (VND)
Field work coordinated into the Water Quality monitoring programme, no extra expences	0
Analysis (Methane and CO2 analysis)	10400000
Treatment of the data and reporting (13 days x 1 man x 300000 per day)	3900000
Miscellaneous, printing costs, meetings with client, etc	2000000
Total per year	16300000

10.2.3 Fish monitoring

This monitoring consists of

1) Fishery yield monitoring,
2) Fish species monitoring, and
3) Mercury concentration in fish meat.

No 3 is made current by the potential methylation of mercury in the reservoir sediments, which will make the mercury remains from the gold mining much more bio-accumulative than the metallic mercury that is present prior to the damming.

All these 3 monitorings will utilize material from the same sampling in the fish yield monitoring. The fish yield monitoring will be organized in the following way:

It will be elaborated a photo album of the 107 fish species identified during this EIA study. Fishermen, or families that fish more or less every day, will be contracted to report their catch of the different species every day (or fishing tour) both with respect to numbers, species, and weight. The photo album will be their identification literature, to help them getting the correct Latin names on the different species. Such a group will be mobilized in the upstream area, the reservoir area, area between the reservoir and Song Cai, and the part of Vu Gia upstream of Ai Ghia. Data will be collected every month. The group will take samples of big specimen of fish for mercury analysis. These samples will be preserved with formalin or ethanol. The groups must get some payment for the job as it will imply extra work in their daily fishing.

Costs of the fish monitoring (VND/year ex VAT)

Activity	Costs (VND)
Preparing photo album and species identification literature for the local fishermen	8000000
Field work fee establishing the fishermen groups as well as training them (2 persons x 10 days x 300000) + per diem and travel	10000000
Costs for the 7 fishermen groups to do the monthly fish catch registrations (3000000 VND/group/year x 7 groups)	21000000
Treatment of the data and reporting (30 days x 1 man x 300000 per day)	9000000
Miscellaneous, printing costs, meetings with client, etc	5000000
Total per year	53000000

Cost of the fish meat mercury monitoring (VND/year ex VAT)

Activity	Costs (VND)
Field work coordinated into the Fish monitoring programme, no extra expences	0
Analysis (10 fish at each of the 7 stations x 200000 VND/ana)	14000000
Treatment of the data and reporting (10 days x 1 man x 300000 per day)	3000000
Miscellaneous, printing costs, meetings with client, etc	2000000
Total per year	19000000

11 TOR for a Study of the Aquatic Resources in the Vu Gia River system

A study to improve the knowledge of the aquatic resources in Vu Gia River basin

Terms of Reference

Draft by Dag Berge, Oct 4, 2006 Revised after comments from Jeremy Bird

11.1 Introduction

During the Phase 1 scoping study for the Song Bung 4 Hydropower Project, the scoping team felt that a project by project approach will have a limited ability to assessing the cumulative impacts on aquatic life and fish resources in the whole Vu Gia River system (basin level). One important reason is because the fish fauna consist of many migratory species (long distance and short distance migrants). Not only will migration routes be blocked by dams, but living and spawning habitats will easily be destroyed for many species in parts of the rivers. Such a study will be necessary to enable sound recommendations for future protection and management of aquatic habitats of locally important species.

The elaboration of the TOR for such a study was included in the terms of reference for the aquatic ecologist in the Song Bung 4 Phase 2 study.

11.2 Scope of Work

11.2.1 Work done in the Song Bung 4 EIA

The Song Bung 4 Phase 2 study has identified 78 phytoplankton species belonging to 26 families; 45 algal species and 4 moss species in the periphyton community; 40 species of zooplankton belonging to 15 families; 48 zoo-benthic taxa. Among them, some species of shrimp are not yet identified and may be new species to science. The survey identified 107 fish species belonging to 31 families and 9 orders occurring in the Vu Gia – Song Bung River system. The true of number of aquatic species of Vu Gia-Thu Bon river system are larger than what has been identified through this rapid study. Several species are listed in the Vietnamese Red List Book, but not so many are on the IUCN red list.

11.2.2 Items in the new study

Most species in the lower systematic groups, Phytoplankton, Periphyton, Zooplankton, Insectlarvae, etc. do not have migratory barriers within this restricted area. They are spread by spores, resting eggs, by birds, by flying upstream (insects), etc. The Song Bung 4 study contained also a few sampling stations in Song Cai / Song Than. Therefore, it is not necessary for the new study to comprise all the systematic groups that normally is included in an EIA.

However, there is a great need for more information on fish, and other organisms that people utilise for their livelihood in the basin. The study should comprise the following organism groups (or communities):

- Fish
- Shrimps
- Crabs
- Mussels

To be able to assess the importance of the communities, as well as to assess the impacts, design mitigation measures, protection of special habitats, elaborate efficient management plans, etc., the following information (item list) is important for these 4 organism communities:

"Item list"

1) Abundance of the different populations
2) Species composition in each of the four communities
3) Size structure of the specimen in the different populations
4) Living habitat of the different populations
5) Food and feeding habits of the different populations
6) Migration behaviour of the different populations
7) Spawning habitat of the different populations
8) Identify rare and endangered species (red-list status)
9) Human use of the different populations
10) Identify natural and existing man-made migratory barriers
11) Identify ongoing human activites that can harm the different populations

11.2.3 Study area (river sections)

The study shall be restricted to the Vu Gia River system. That means that Thu Bon River shall not be included, even though the two rivers are interconnected in the lower parts. Figure 31 shows an outline of the Vu Gia River system with main tributaries. Thu Bon River system is located to the south of Vu Gia.

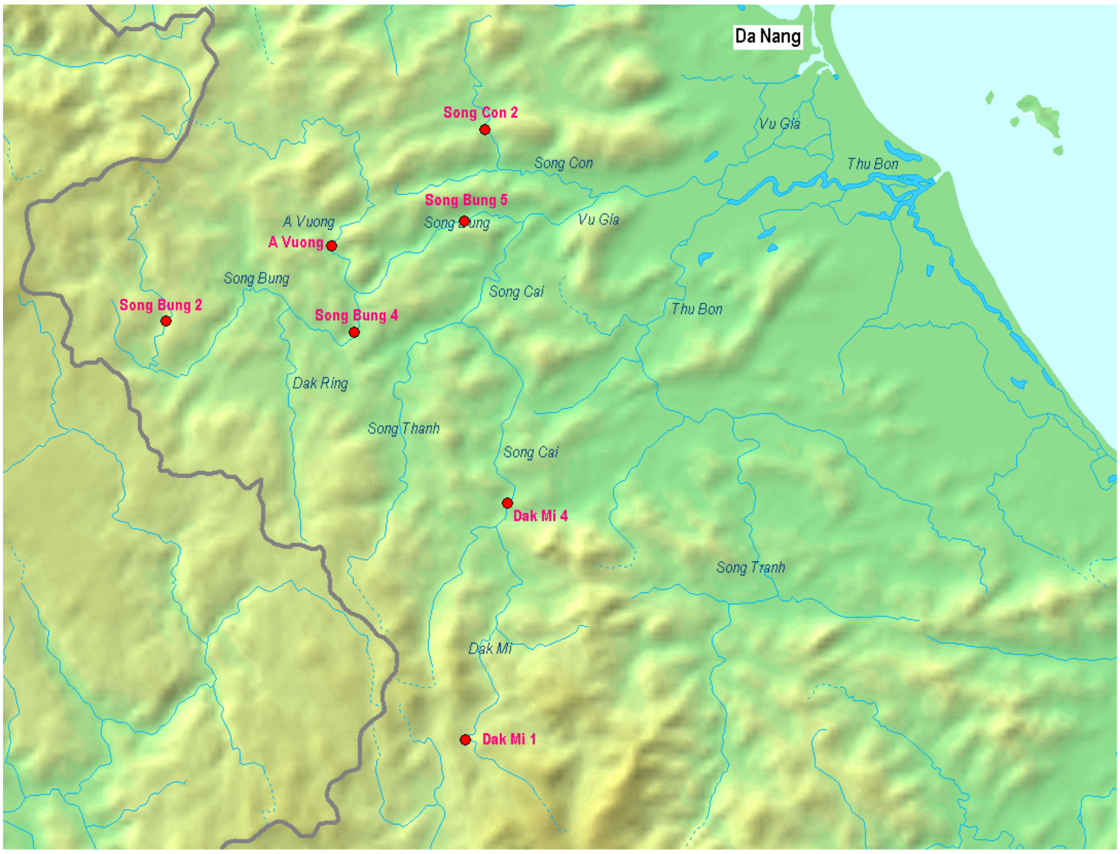


Figure 31. Vu Gia River system with planned hydropower regulations (red colour)

In the following river stretches, representative data on the aforementioned items should be collected:

1) Vu Gia from Da Nang up to the upper connecting canal to Thu Bon River
2) The upper connection canal to Thu Bon River and the surrounding flooded area (important spawning area)
3) Vu Gia from the connection canal up to the entrance of Song Bung
4) Song Con
5) Song Cai up to the entrance of Song Than
6) Song Than
7) Song Cai from the entrance of Song Than and up to where it changes name to Dak Mi (just downstream of Dak Mi 4 on the map in **Figure 31**)
8) Dak Mi
9) Song Bung from the junction with Vu Gia and up to the entrance of A Vuong
10) A Vuong
11) Song Bung from the junction with A Vuong and up to the entrance of Dak Ring
12) Dak Ring
13) Song Bung from the junction with Dak Ring and up to the Song Bung 2 dam.
14) Song Bung upstream Song Bung 2 dam

11.2.4 Sampling methods and sampling frequency

The Vu Gia River system has few natural migratory barriers for fish and other organisms. Therefore many species have a life cycle that includes migrations, e.g. for spawning, or for feeding, or for refuge seeking in dry season. Therefore it is necessary to perform the sampling over the annual cycle.

1) Sampling should be performed in every river section every month over one year

With respect to methodology it will be too laborious and expensive to conduct representative scientific test fishing in all these localities every month. This would have required purchase of a large electro-fishing devise of 11 kW which seems to be European Standard for test-fishing of rivers (see EU-project FAME on http://fame.boku.ac.at). The equipment is cumbersom and difficult to transport to remote areas with the poor road standard found in many places in this project area, see **Figure 32.**

Figure 32. Electro-fishing (11 kW, 4 anodes, 30 Hp gasoline el-generator) devise for test- fishing in large rivers. Likely to become EU-standard, and subsequent International-standard.

Therefore

2) Sampling should be done through organising catch report from local fishermen every month, combined with one night test-fishing with multi-mesh size nets in river junction areas in the

rainy season (Sept-Nov), dry season (March), and small rainy season (May-June). Shrimps, crabs, and mussels should be sampled by suitable hand net and bottom grab.

How this can be organised in practical terms should be up to the different bidders to describe.

11.2.5 Treatment of the data

In this section the list of “items to be studied” (see above) is explained in more detail.

11.2.5.1 Species composition

All organisms should be identified to species level, at least for the adult stages. Pre-adult stages of shrimps are sufficient to identify to genus level. The material should be organised according to species-genus-family-order and presented in tables.

11.2.5.2 Abundance

The Abundance should be given in numbers which allows for using the results as a basis for future monitoring, i.e. to see if it becomes more fish or less fish in the river.

As the collection methodology does not allow for biomass estimates, abundance should be given as catch per unit effort (CPUE). The material collected from the local fishermen has to be divided into what they have caught by the different gear types, and per unit time. The unit time used by gill-netting is often one night, but for other gear types e.g. handhold line with baited hook, the unit time is often hrs. The unit time should therefore be hrs to allow intercomparison of methods.

The bidders should figure out how they will organise this in practical terms.

11.2.5.3 Size structure of the different populations

If the livelihood becomes poorer for a certain fish type, it starts to grow slower. Growth rate is therefore a good measure of fish thriving or not. However, age determination is regarded to be too laborious for this study. Therefore, it will be sufficient to measure the length and weight of every fish in the catch of the 25 most important species. For small fish used to for example making “prohoc” (fermented fish), it is necessary to give the average size.

In the report, average size and maximum size of the different species should be used.

11.2.5.4 Living habitat of the different populations

The living habitat of the different species must be described, both the habitat where they live in each of the studied river sections, but also preferences given in the literature should be described. It is important to understand how this habitat will be altered due to future river regulations, and to what extent this will create problems for the species.

11.2.5.5 Food and feeding habits of the different populations

The food and feeding habits of the different species must be described, and how the food production will be impacted by the regulations, and how this can be mitigated.

11.2.5.6 Migration behaviour of the different populations

This should be described for the different fish populations. The catch data will reveal some of this information (where they catch the different species at different times), but most likely it must be supplemented by literature information. A distinction should be made between anadromous, catadromous, potamodromous, and stationary species, and it should be differed between spawning migrations and feeding migrations. Information on what triggers the migrations (time, water flow, water level, etc) is important, and also the description of other important conditions for successful migrations.

11.2.5.7 Spawning and nursery habitat of the different populations

In species rich tropical rivers the different species have developed many different ways of spawning and nursery behaviour. This is both to avoid competition from each other, as well as to reduce vulnerability to predators. Some spawn among the vegetation in flooded forest, some in wetlands and rice fields, some swim upstream and spawn floating eggs which will hatch when the eggs pass the living area for that species, some dig the eggs into the sediments in rapids, some keep the eggs in their mouth, etc.

This has to be described for the 25 most important species. It should be analysed how regulation encroachments will impact the spawning and nursery conditions for the different species, and how negative impacts can be mitigated.

11.2.5.8 Identify rare and endangered species (red-list status)

The sampling during SB4 project has revealed that there are several rare (some likely new to science) species in the river system. These should be identified, and verified. If some species are new to science they should be registered and given names. Their uniqueness and need of protecting should be evaluated. All rare species should be evaluated according to Vietnamese Red list and IUCN red list. Impacts of regulation should be described and proposals for protective/mitigation measures should be given.

11.2.5.9 Human use of the different populations

The human use of the different populations of aquatic organisms should be described. Data should be provided on the catch, how they catch the fish, how often they eat fish, if they sell the fish, if they have any alternative protein source if the fish disappears.

11.2.5.10 Identify natural or human made migratory barriers

Assess how far upstream the different species are found, and evaluate if there are some natural or man made barriers that are responsible for the restrictions in living area. This is for example falls, strong rapids, periodically dry-ups, etc., or dams created by man.

11.2.5.11 Identify ongoing human activity which can harm the different populations

Make a rapid assessment of the human activities in the catchment and evaluate if any of these activities can have negative impacts on the river life today, for example pollution discharges, irrigation dams, gold mining in the river bed, etc. Evaluate how these impacts will be altered (stronger or weaker) by the planned regulation scheme. Describe how the impacts can be mitigated.

11.2.6 Impact assessment of the overall planned regulation scheme in the Vu Gia River basin

Based on the data collection, and data from EVN on the most likely operation mode of the different hydropower stations in the basin, the consultant shall give an overview of the cumulative impacts on the biological resources in the Vu Gia River system. Even though it will be imprecise, an estimate of the change in fish production due to the regulation scheme should be given in percent of the to-day situation. Such estimates should be given without and with mitigation.

The impacts should relate to the items in the "item list", and the impacts should be ranked according to seriousness (read: important to mitigate).

11.2.7 Mitigation – protection – management plan

The consultant shall, based on the evaluation of the impacts (the ranking), as well as on the importance of the aquatic resources from a protection view point and from how important they are for the local people, propose the framework for

1. Mitigation measures
2. Protection of certain habitats
3. A management plan taking best care of the aquatic resources within the constraints of the hydropower development scheme

It should be a holistic approach for the whole Vu Gia River basin. No detailed mitigations for each of the Hydropower projects should be given, but general descriptions of realistic measures and regulations, proposal of protection of certain habitats, that can help to avoid severe environmental impacts from the planned hydropower development scheme in the river basin.

With respect to protection of certain habitats, one should particularly evaluate if certain whole tributaries should be protected, e.g. Song Than, Dak Ring, which are both without regulation plans. Song Than is heavily impacted by erosion material, while Dak Ring is more untouched. Several other tributaries are also important as refuges and nursery of main river biota.

Other areas that should get special attention are important spawning areas. The large annually flooded wetland around the junction canal to Thu Bon (see Figure 33) is such an area. Important spawning areas should be identified and given proposal for protective regulations.

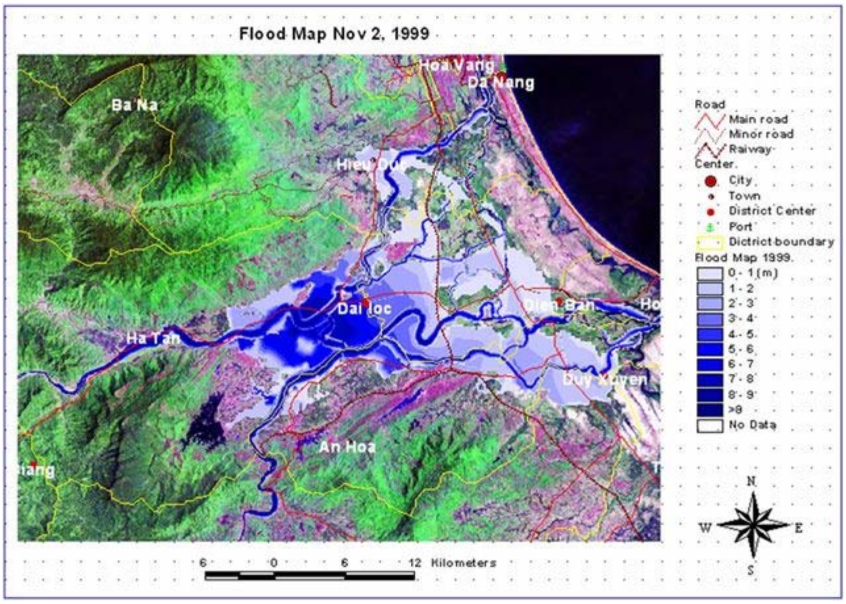


Figure 33. The lowland area of the Vu Gia – Thu Bon River System where there is flooded areas every rainy season is an important spawning area of many fish species, also down-migrating from Song Bung (simulated model picture from the high flood in Nov 1999, Basberg 2006).

In the framework of a water management plan, all human use interests (including the hydropower development plans) should be taken as a basis. The plan should also address the water environment's need for water flow, water quality, and water levels, as well as the local inhabitants need for ecological services from the river, and try to adjust river use requirements to the water environment requirements in a balanced way. The goal should be to take maximum benefits out of the river system with minimum loss of environmental values, and ecological services to the local people. The plan should include the recommended mitigations and protection proposals given in the previous paragraph. A monitoring programme for aquatic resources should be part of the management plan.

It should be noted that this is not a full and comprehensive water management plan as a political document to be treated and passed by the Vietnamese authorities. It should be given mainly for the purpose of overview, and example, on how human use interests and the requirements of a healthy water environment can be treated and adjusted in a balanced way (give and take to get an optimum result).

11.3 Time schedule

It is estimated that it will take one month to organise the field work of the study, to mobilise the local fishermen team, to teach them, give them necessary equipment, etc. The sampling should be carried out over one year. The analyses of the data plus report will take half a year. Altogether the study will take one year and seven months.

11.4 Staff

11.4.1 International team

Project leader (freshwater biologist/limnologist) (5 man months)
The project should be lead by an international consultant (freshwater biologist/limnologist) with broad experience from impact assessment and mitigations of hydropower regulations in tropical rivers, preferably in Vietnam. The project leader should also have some experience in integrated water resources management planning.

Hydrologist (modeller) (1.5 man months)
The hydrological modeller will be important for assessing the water flow and water level in the different sections of the river system given the operating mode of the different hydropower plants in the basin.

11.4.2 Domestic team

The project will need a Freshwater biologist (bottom animals-5 man months) as well as a fish biologist (5-man months) with good knowledge of the fish fauna in the region to be able to identify the correct species, as well as to organise the fishermen catch reporting programme, and to assist in the data treatment and reporting. In addition one domestic socio-expert (3 man-months) is needed with experience in collecting data and evaluating how local residents depend on aquatic resources.

11.4.3 Man months

Altogether this will require 6.5 man-months of international experts, and 13 man-months of domestic experts.

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13 Primay Data

Table 27. Observed zooplankton species of Vu Gia-Thu Bon river system

No.	Taxon	Section 1	Section 2	Section 3	Section 4	Section 5
	Phylum Arthropoda					
	Class Crustacea					
	Subclass Copepoda					
	Order Calanoida					
	1. Fam. Diaptomidae					
1	*Schmackeria curvilobata* Dang *					+
2	*Schmackeria bulbosa* Shen et Tai*					+
3	*Allodiaptomus rappeportae* (Brehm)				+	+
	2. Fam. Acartiidae					
4	*Acartia pacifica* Sreuer *					+
5	*A. clausi* Giesbrecht*					+
	Order Cyclopoida					
	3. Fam. Cyclopidae					
6	*Mesocyclops leuckarti* (Claus)	+	+	+	+	+
7	*Microcyclops varicans* (Sars)	+	+	+	+	+
8	*Thermocyclops hyalinus* (Rehberg)				+	+
9	*Thermocyclops taihokuensis* (Harada)		+	+	+	+
10	*Eucyclops serrulatus* (Fischer)	+	+	+	+	+
11	*Paracyclops fimbriatus* (Fischer)	+	+		+	
12	*Ectocyclops phaleratus* (Koch)				+	+
13	*Tropocyclops prasinus* (Fischer)			+		
	4. Fam. Oithonidae					
14	*Oithona rigida* Rosendorn*					+
	Order Harpacticoida					
	5. Fam. Canthocamptidae					

No.	Taxon	Section 1	Section 2	Section 3	Section 4	Section 5
33	*Elaphoidella sp*	+	+			
	Ostracoda					
	6. Fam. Cypridae					
15	*Physocypris crenulata* (Sars)	+	+	+		+
16	*Cypris subglobosa* Sowerby		+	+		
	Subclass Branchiopoda					
	Order Cladocera					
	7. Fam. Bosminidae					
17	*Bosmina longirostris* (O. F. Muller)			+	+	+
18	Bosminopsis deitersi *Richard*			+	+	+
	8. Fam. Sididae					
19	Diaphanosoma sarsi *Richard*			+	+	+
20	Diaphanosoma excisum *Sars*					+
	9. Fam. Macrothricidae					
21	*Macrothrix triserialis* Brady		+	+	+	+
22	*Ilyocryptus halyi* Brady		+	+	+	+
	10. Fam. Daphniidae					
23	Moina dubia de *Guerne et Richard*				+	+
24	Moinodaphnia macleayii *(King)*				+	+
25	*Ceriodaphnia rigaudi* Richard		+	+	+	+
26	*Simocephalus elizabethae* (King)					+
	11. Fam. Chydoridae					
27	*Alona rectangula* Sars	+	+		+	
28	*A. eximia* Kiser					+
29	*A. davidi* Richard			+		
30	*Pleuroxus similis* (Vavra)	+			+	
31	*P. hamatus hamatus* Birge	+	+		+	
32	Chydorus alexandrovi *Poggenpol*		+		+	

No.	Taxon	Section 1	Section 2	Section 3	Section 4	Section 5
33	Chydorus sphaericus sphaericus *(O.F. Muller)*	+	+	+	+	+
34	Disparalona rostrata *(Koch)*				+	
35	Biapertura karua *(King*)			+		
	Phylum Nemathelminthes					
	Class Rotatoria					
	Order Monogononta					
	12. Fam. Asplanchnidae					
36	*Asplanchna sieboldi* (Leydig)	+			+	+
	13. Fam. Brachionidae					
37	*Platyias quadricornis* Ehrenberg					+
38	*Brachionus plicatilis* (Muller)					+
	14. Fam. Euchlanidae					
39	*Diplois daviesiae* Gosse	+				+
	Diptera					
	15. Fam. Chaboridae					
40	*Chaoborus sp.*	+	+	+	+	
	Others					
41	*Ephemeroptera*	+	+		+	+
42	Fish egg & larvae	+				+
	Total	**15**	**17**	**17**	**25**	**32**

Note: * : brackish water species

Table 28. Observed phytoplankton species of Vu Gia-Thu Bon river system

No.	Taxon	Section 1	Section 2	Section 3	Section 4	Section 5
	Phylum Bacillariophyta					
	Order Discinales					
	1.Fam. Coscinodiscaceae					
1	Melosira gralunata (Ehr.) Ralfs	+	+	+		+
2	M. granulata var. angustissima	+	+	+	+	+
3	M. varians Ag	+	+	+	+	+
4	M. distans Kutzing		+		+	+
	Order Araphinales					
	2. Fam. Fragilariaceae					
5	Synedra acus Kutz	+	+	+	+	+
6	S. ulna (Nitzsch) Ehr.	+	+	+	+	+
7	S. ulna (Nitzsch) var. biceps Schonf	+	+			+
8	Fragillaria construens Grunow	+	+	+	+	+
9	F. virescens Ralfs.	+	+		+	+
	Order Raphinales					
	3.Fam. Tabelariaceae					
10	Diatoma elongatum Ehr	+	+	+	+	+
11	Tabeleria fenestrata Kutz	+	+	+	+	+
	4.Fam. Naviculaceae					
12	C. tumida (Breb.) V. H.	+	+	+	+	+
13	Cymbella turgida Clever	+	+		+	+
14	C. ventricosa Kutz.	+	+	+		+
15	Gomphonema sphaerophorum Ehr.	+	+	+	+	+
16	G. olivaceum Ehr	+	+	+	+	+
17	Navicula placentula Grun	+	+	+	+	+
18	N. gracilis Ehr.	+			+	+
19	Gyrosigma attenuatum		+		+	+
20	G. kutzingii	+	+	+	+	+
21	Amphora hendeyi n. sp.	+	+			+

22	Neidium affine var. longiceps (Greg.) Cl.	+	+	+		+
23	N. affine var. amphirhynchus (Ehr .) Clever	+	+	+		+
24	Pinularia gibba	+	+		+	+
25	P. nobilis Ehr		+			+
26	Amphiprora alata *					+
	5.Fam. Nitzschiaceae					
27	Nitzschia acicularis W. Sm.	+	+	+	+	+
28	N. recta	+	+	+	+	+
29	N. philippinarum Ehr	+	+	+	+	+
30	N. nyasssensis	+	+	+	+	+
31	N. paradoxa *					+
	6.Fam. Surirellaceae					
32	Surirella. robusta Ehr.	+	+	+	+	+
33	S. robusta var. splendida	+	+	+		+
	Phylum Chlorophyta					
	Order Volvocales					
	7.Fam. Characiaceae					
34	Schroederia spiralis (Printz). Korschk	+	+			+
	8.Fam. Hydrodictyaceae					
35	Tetraedron arthrodesmiforme.	+	+			+
36	T. lobulatum var. lobulatum					
37	Pediastrum biradiatum Meyen	+	+	+		+
38	Pediastrum. simplex var. duodenarium (Baylei)	+	+	+		+
39	P. dublex var dublex	+	+	+	+	+
	9.Fam. Oocystaceae					
40	Chlorella vulgaris Beij.	+	+		+	+
41	Ankistrodesmus bibraianus (Reinsch) Rors			+		
42	Tetraedron trigonum Naeg.	+	+		+	+
	10.Fam. Scenedesmaceae					
43	Actinastrum hantzschii Lagerh	+	+		+	+
44	Tetrastrum triacanthum	+	+		+	+

	Korsch					
45	Crucigenia fenestrata Sohmidle	+	+	+	+	+
46	Scenedesmus acuminatus Chodat	+	+	+	+	+
47	Sce. bernardii	+	+			+
48	Sc. bicaudatus (Pansg) chodat	+	+		+	+
	Order Zygnematales					
	11.Fam. Zygnemataceae					
49	Mougiotia viridis (Kutz.)	+	+	+	+	+
50	Spirogyra ionia	+	+	+	+	+
51	S. azygospora	+	+	+	+	+
52	S. prolifica	+	+	+	+	+
53	Zygnemopsis americana Transeau	+	+		+	+
	12.Fam. Desmidisceae					
54	Closterium moniliferum ((Bory) Ehr.	+	+	+		+
55	Cl. parvulum Naeg.				+	+
56	Cosmarium amplum Nordst.	+	+			+
57	Co. askenasyi Sebmidle	+	+		+	+
58	Hyalotheca dissiliens (J.E. Smith) Breb.	+	+			+
	Order Ulotrichales					
	13.Fam. Ulothriceae					
59	Ulothrix zonata (Schmide) Bohlin	+	+	+	+	+
	Order Oedogoniales					
	14. Fam. Oedogoniceae					
60	Oedogonium crassum Hass	+	+	+	+	+
	Order Cladophorales					
	15. Fam. Cladophoraceae					
61	Bacicladia chenonum (Collinis) Hoff. & Til.	+	+			+
62	Chaetomorpha fuciformis Ralfs.	+	+		+	+
	Order Schizogoniales					
	16. Fam. Schizogoniaceae					

63	Schizogonium murale Kutz	+	+	+	+	+
	Order Ulvales					
	17. Fam. Schizomeridaceae					
64	Schizomeris leibleinii Kutz.	+	+		+	+
	Phylum Cyanobacteria					
	Order Nostocales					
	18. Fam. Anabaennaceae					
65	Anabaena circinalis (Kutz) Rab.	+	+	+	+	+
	19. Fam. Nostocaceae					
66	Nostoc linckia (Roth) Born)	+	+	+		+
	Order Oscillatoriales					
	20. Fam. Pseudonostocaceae					
67	Pseudanabaena schmidlei Zaag.	+	+	+	+	+
	21. Fam. Oscillatoriaceae					
68	Lyngbya birgei G.M.S. Smith	+	+	+	+	+
69	Oscillatoria formosa Bory	+	+	+		+
70	Os. limosa Ag.	+	+	+	+	+
71	Os. princeps	+	+	+	+	+
72	Phormidium autumnale (Ag.) Grun.		+			
	Order stigonematales					
	22. Fam. Nostochopsidaceae					
73	Nostochopsis lobatus Wood em. Geitler		+		+	+
	23. Fam. Scytonemataceae					
74	Plectonema tomasiniana (Kutz) Born.	+	+		+	+
	Phylum Euglenophyta					
	Order Euglenophyceae					
	24. Fam. Euglenaceae					
75	Euglena caudata Hubner	+				+
76	E. acus Ehr.	+	+	+	+	+
	Phylum Xanthophyta					
	Order Heterotrichales					

	25. Fam. Tribonemetaceae					
77	Triboneme utrilucosum Hazen		+	+	+	+
	Phylum Pyrophyta					
	Order Dinophyceae					
	26. Fam. Ceratiaceae					
78	Ceratium hyrundinella	+	+	+	+	+
		67	71	46	53	75

Note: * : brackish water species

Table 29. Observed algae and moss species in periphyton of Bung river

No.	Taxon	Bung upstream	Reservoir.	Bung downstream
	Bacillariophyta			
	Order Araphinales			
	Fam. Fragilariaceae			
1	Synedra acus Kutz		+	+
2	S. ulna (Nitzsch) Ehr.		++	+
3	S. ulna (Nitzsch) var. biceps Schonf	++		
4	Fragillaria construens Grunow		+	+
5	F. virescens Ralfs.		+	
	Order Raphinales			
	Fam. Tabelariaceae			
6	Diatoma elongatum Ehr	+++	+++	+++
7	Tabeleria fenestrata Kutz	++	++	++
	Fam. Naviculaceae			
8	Cymbella turgida Clever		++	++
9	C. ventricosa Kutz.	++		
10	Gomphonema sphaerophorum Ehr.	+++	+++	++
11	G. olivaceum Ehr	+++	++	+
12	Navicula placentula Grun		+	+

13	N. gracilis Ehr.	+		
14	Gyrosigma attenuatum		+	
15	Gy. kutzingii			
16	Amphora hendeyi n. sp.		+	
	Fam. Nitzschiaceae			
17	Nitzschia acicularis W. Sm.	+		
18	N. recta		+	+
19	N. filiformis Hust.	+		
20	N. philippinarum Ehr		+	
	Fam. Surirellaceae			
21	Surirella. robusta Ehr.	+	+	
22	S. robusta var. splendida	+		
	Chlorophyta			
	Order Volvocales			
	Fam. Scenedesmaceae			
23	Crucigenia fenestrata Sohmidle		+	
24	Scenedesmus acuminatus Chodat	+		
25	Sce. bernardii			
	Order Zygnematales			
	Fam. Zygnemataceae			
26	Mougiotia viridis (Kutz.)	++	++	++
27	Spirogyra ionia	+++	+++	+++
28	S. azygospora	++	+++	+++
29	Sp. prolifica	++	+++	+++
30	Zygnemopsis americana Transeau		+	
	Fam. Desmidisceae			
31	Closterium moniliferum ((Bory) Ehr.		+	+
32	Cl. parvulum Naeg.	+		
33	Cosmarium amplum Nordst.		+	
34	Hyalotheca dissiliens (J.E. Smith) Breb.	+	+	

	Oder Ulotrichales			
	Fam. Ulothriceae			
35	Ulothrix zonata (Schmide) Bohlin	++	++	++
	Order Oedogoniales			
	Fam. Oedogoniceae			
36	Oedogonium crassum Hass	+	+	
	Order Schizogoniales			
	Fam. Schizogoniaceae			
37	Schizogonium murale Kutz	++	++	++
	Order Ulvales			
	Fam. Schizomeridaceae			
38	Schizomeris leibleinii Kutz.	+	+	
	Cyanobacteria			
	Order Nostocales			
	Fam. Anabaennaceae			
39	Anabaena circinalis (Kutz) Rab.		++	+
	Fam. Nostocaceae			
40	Nostoc linckia (Roth) Born)	++		
	Order Oscillatoriales			
	Fam. Oscillatoriaceae			
41	Lyngbya birgei G.M.S. Smith	+	++	++
42	Oscillatoria formosa Bory	+	+	
43	Os. limosa Ag.	+	+	
44	Os. princeps	+		
	Order Stigonematales			
	Fam. Nostochopsidaceae			
45	Nostochopsis lobatus Wood em. Geitler	+++	++	++
	Fam. Scytonemataceae			
46	Plectonema tomasiniana (Kutz) Born.	++	++	+
	Phylum Xanthophyta			

	Order Heterotrichales			
	Fam. Tribonemetaceae			
47	Triboneme utrilucosum Hazen	+	+	
	Bryophyta			
	Fam. Pottiaceae			
48	Hyophila involuta (Hook) Jaeg.	++	++	
49	Trichogtomum orthodontium C.M.	+	+	
	Fam. Bryoceae			
50	Bryum argenteum Hedv.	+	+	
	Fam. Bartramiaceae			
51	Philonotis turneriana (Schwaegr.) Mitt.	+	+	

Note:
+++: high frequence
++ : moderate frequence
+ : low

Table 30. Observed zoobenthic species of Vugia-Thubon river system

No.	Taxon	Section 1	Section 2	Section 3	Section 4	Section 5	Value
	Class Crustacea						
	Macrura						
	Fam. Palaemonidae						
1	Macrobrachium hainanense (Parisi)		+	+	+		Food
2	M. nipponense (de Haan)		+	+	+		Food
3	Macrobrachium sp1		+	+			Food
4	Macrobrachium sp2		+	+			Food
5	Macrobrachium sp3			+			Food
	Fam. Atyidae						
6	Carina acuticaudata Dang	+	+	+	+		Food
7	Atya moluccensis de Haan			+	+		
	Brachyura						

	Fam. Potamidae						
8	Potamon frustorferi (Balss)	+	+				T
9	Vietopotamon aluoiensis Dang et Ho	+	+				
	Fam. Parathelphusidae						
10	Somanniathelphusa sinensis sinensis (H.M. Edwards)				+		Food
	Gastropoda						
	Prosobranchia						
	Fam. Pachychilidae						
11	Brotia solenmiana (Brandt)	+	+	+			Food
12	Thiara scabra (Muller)	+	+	+	+	+	
13	Tarebia granifera (Lamarck)	+	+	+	+		
14	Melanoides tuberculatus (Muller)	+	+	+	+	+	
	3. Fam. Ampullariidae						
15	Pila polita (Deshayes)				+	+	Food
16	Pila conica (Gray)				+	+	Food
17	Pomacea canaliculata (Lamarck)				+	+	
	4. Fam. Viviparidae						
18	Angulyagra polyzonata (Frauenfeld)				+	+	Food
19	Sinotaia aeruginosa (Reeve)				+	+	Food
	Pulmonata						
	8. Fam. Lymnaeidae						
20	Lymnaea swinhoei Adams	+	+	+	+		
21	Lymnaea viridis Quoy.et.Gaimard	+	+	+	+		
	Bivalvia						
	Fam.Corbiculidae						
22	Corbicula lamarckiana Prime				+	+	Food
23	Corbicula bocourti Morlet				+	+	Food
24	Corbicula baudoni Morlet		+	+			Food

25	Corbicula moreletiana Prime		+	+	+	+	Food
26	Batissa sp.*					+	Food
	Fam. Unionidae						
27	Sinanodonta jourdyi (Morlet)				+		Food
28	Nodularia douglasiae crassidens Haas				+	+	
	Fam. Amblemidae						
29	Oxynaia micheloti (Morlet)				+		Food
	Insecta larvae						
	Order Ephemeroptera						
30	Fam. Baetidae	+	+	+			
31	Fam. Pothamanthidae	+	+	+			
32	Fam. Ephemrellidae	+	+	+			
33	Fam. Heptageniidae	+	+	+			
34	Fam. Leptophlebiidae	+	+	+			
	Order Plecoptera						
35	Fam. Perlidae	+	+				
	Order Odonata						
36	Fam. Aeshnidae		+	+	+	+	
37	Fam. Gomphidae	+	+	+	+	+	
38	Fam. Libellulidae	+	+	+	+	+	
	Order Lepidoptera						
39	Fam. Pyralidae		+	+			
	Order Coleoptera						
40	Fam. Dytiscidae	+	+	+			
41	Fam. Hydrophilidae	+	+				
	Order Hemiptera						
42	Fam. Corixidae	+	+	+			
43	Fam. Gerridae	+	+	+			

44	Fam. Naucoridae	+	+				
	Order Diptera						
45	Fam. Chironomidae		+	+	+	+	
46	Fam. Chaoboridae	+	+	+	+	+	
47	Fam. Culicidae	+	+	+	+	+	
48	Fam. Tipulidae		+	+	+		
		24	34	31	28	18	

Note: * : brackish water species

Table 31. Observed fish species in the Vu Gia-Thu Bon river system

	English name	Scientific Name	1	2	3	4	5	EconomicValue	Red Data book of Vietnam
	Herrings and Anchovies	**Clupeiformes**							
	Herrings and Shads	**Clupeidae**							
1	Small gizzard shad	*Clupanodon thrissa* (Linnaeus, 1758) *			+	+	+	+	V
	Bonytongues and Featherbacks	**Osteoglossiformes**							
	Featherbacks	**Notopteridae**							
2	Bronze featherback	*Notopterus notopterus* (Pallas, 1769)			+	+	+	+	
	Eels	**Anguilliformes**							
	Freshwater eels	**Anguillidae**							
3	Giant mottled eel	*Anguilla marmorata* Quoy & Gaimard, 1824	+	+	+	+	+	+	R
	Snake eels	**Ophichthidae**							
4	Rice-paddy eel	*Pisodonophis boro* (Hamilton, 1822) *					+		
	Minnows and Carps	**Cypriniformes**							
	Minnows and Carps	**Cyprinidae**							
5		*Acheilognathus kyphus* (Mai, 1978)				+			

6		*Acheilognathus tonkinensis* (Vaillant, 1892)				+			
7	Bighead carp	*Aristichthys nobilis* (Richardson, 1845)				+	+		
8		*Bangana lemassoni* (Pellegrin & Chevey, 1936)	+	+	+	+		+	V
9		*Barbodes altus* (Gunther, 1868)	+	+		+	+	+	
10		*Barbodes gonionotus* (Bleeker, 1850)	+	+		+	+	+	
11		*Barbodes schwanefeldi* (Bleeker, 1853)				+			
12		*Barbodes duraphani*							
13		*Carassioides acuminatus* (Richardson, 1846)				+	+		
14	Goldfish	*Carassius auratus* (Linnaeus, 1758)				+	+	+	
15		*Cirrhinus microlepis* Sauvage, 1884	+	+		+		+	
16	Mud carp	*Cirrhinus molitorella* Valenciennes, 1844	+	+		+		+	
17	Predatory carp	*Culter flavipinnis* Tirant, 1883			+	+			
18		*Cyclocheilichthys enoplos* (Bleeker, 1850)				+		+	
19		*Cyclocheilichthys furcatus* Sontirat, 1985		+		+			
20		*Cyclocheilichthys repasson* (Bleeker, 1853)				+		+	
21		*Elopichthys bambusa* (Richardson, 1844)	+	+		+		+	
22		*Esomus longimanus* (Lunel, 1881)				+	+		
23	Stripped flying barb	*Esomus metallicus* Ahl, 1924					+		
24		*Garra bourreti* Pellegrin, 1928	+	+	+	+			
25		*Hainania serrata* Koller, 1927			+	+			
26		*Hemiculter leucisculus* (Basilewsky, 1855)				+		+	
27		*Hypsibarbus malcolmi (*Smith, 1945)			+	+			
28		*Lissochilus clivosius* Lin, 1935				+			
29		*Megalobrama terminalis* (Richardson, 1846)				+		+	
30		*Metzia formosae* (Oshima, 1920)	+	+		+			
31		*Metzia lineata* (Pellegrin, 1907)				+	+		
32		*Onychostoma ovale* Pellegrin & Chevey, 1936	+	+	+	+		+	

33		*Onychostoma ovalis rhomboides* Tang, 1942				+			
34		*Opsariichthys bidens* Gunther, 1873	+	+	+	+	+		
35		*Osteochilus salsburyi* Nichols & Pope, 1927				+	+		
36		*Osteochilus schlegeli* (Bleeker, 1851)			+	+			
37		*Paraspinibarbus macracanthus* (Pellegrin & Chevey, 1936)	+	+	+	+			
38		*Poropuntius deauratus* (Valenciennes, 1842		+	+	+			
39		*Pseudohemiculter dispar* (Peters, 1931)			+	+			
40		*Puntius brevis* (Bleeker, 1850)	+		+	+	+		
41		*Puntius semifasciolatus* (Gunther, 1868)		+	+	+			
42		*Rasbora steineri* Nichols & Pope, 1927				+			
43		*Rasbora sumatrana* (Bleeker, 1852)	+	+	+	+			
44		*Rhodeus vietnamensis* Mai, 1978			+	+	+		
45		*Sinibrama affinis* (Vaillant, 1892)	+	+	+	+	+		
46		*Spinibarbichthys denticulatus* (Oshima, 1926)	+	+		+		+	
47		*Squalibarbus curriculus* (Richardson, 1846)				+	+		
48		*Squalidus argentatus* (Sauvage & Dabry, 1874)				+			
49		*Squalidus atromaculatus* Nichols & Pope, 1927				+			
50		*Toxabramis houdemeri* Pellegrin, 1932				+			
51		*Tor stracheyi* (Day, 1871)	+	+					
52		*Tor tambroides* Bleeker, 1854		+	+				V
	River Loaches	**Balitoridae**							
53		*Annamia normani* (Hora, 1930)	+	+	+				
54		*Schistura carbonaria*			+				
55		*Schistura caudofurca* (Mai, 1978)	+	+	+	+			
56		*Schistura finis* Kottelat, 2000	+	+	+	+			
57		*Schistura namboensis*	+	+	+	+			
58		*Sewellia lineolata* Valenciennes, 1842	+	+		+			

	Loaches	**Cobitidae**							
59		*Misgurnus anguillicaudatus* (Cantor, 1842)				+	+		
	Catfishes	**Siluriformes**							
	Bagrid catfishes	**Bagridae**							
60		*Mystus gulio* (Hamilton, 1822) *					+		
	Breathing catfishes	**Clariidae**							
61	Walking catfish	*Clarias batrachus* (Linnaeus, 1758)				+	+	+	
62		*Clarias fuscus* (Lacepede)	+	+		+	+	+	
63		*Clarias macrocephalus* Gunther, 1864				+	+	+	
	Cranoglanids	**Cranoglanididae**							
64		*Cranoglanis henrici* (Vaillant, 1893)	+	+	+	+	+		
65		*Cranoglanis bouderius* (Richardson, 1896)				+			
	Sheatfishes	**Siluridae**							
66		*Pterocryptis cochinchinensis* (Valenciennes, 1840)	+	+	+	+			
67		*Silurus asotus* Linnaeus, 1758			+	+	+		
68		*Wallago attu* (Schneider, 1801)		+	+	+	+		
	Sisorid catfishes	**Sisoridae**							
69		*Bagarius yarrelli* Sykes, 1838?	+	+	+	+	+	+	
70		*Glyptothorax interspinalum* Mai, 1978	+	+					
71		*Pseudecheneis sulcatus (*McClelland, 1842)	+	+	+	+			
	Swamp eels and Spiny eels	**Synbranchiformes**							
	Spiny eels	**Mastacembelidae**							
72		*Mastacembelus armatus* (Lacepede, 1800)	+	+	+	+		+	
73		*Mastacembelus taeniagaster* (Fowler, 1935)				+			
	Swamp eels	**Synbranchidae**							
74		*Monopterus albus* (Zuiew, 1793)	+	+	+	+	+	+	

	Needlefishes and Halfbeaks	**Beloniformes**							
	Ricefishes	**Adrianichthyidae**							
75		*Oryzias pectoralis* Roberts, 1998	+	+	+	+			
	Needlefishes	**Belonidae**							
76		*Strongylura strongylura* (van Hasselt) *					+		
	Spiny rayed fishes	**Perciformes**							
	Asiatic glassfishes	**Ambassidae (Chandidae)**							
77		*Chanda gymnocephala* (Lacepede, 1802) *		+	+	+	+		
78		*Chanda siamensis* Fowler, 1937				+			
	Climbing perches	**Anabantidae**							
79		*Anabas testudineus* (Bloch, 1792)	+	+	+	+	+	+	
	Snakeheads	**Channidae**							
80		*Channa gachua* (Hamilton, 1822)	+	+	+	+	+		
81		*Channa maculata* (Lacepede, 1802)				+			
82		*Channa marulius* (Hamilton, 1822)				+	+		
83		*Channa striata* (Bloch, 1793)	+	+	+	+	+		
	Sleepers	**Eleotridae**							
84		*Eleotris fusca* (Schneider, 1801)				+	+		
	Gerreidae	**Gerreidae**							
85		*Gerres filamentosus* Cuvier, 1829 *					+		
	Gobies	**Gobiidae**							
86		*Acentrogobius viridipunctatus* (Cuvier & Valenciennes, 1837)					+		
87		*Brachygobius sua* (Smith, 1931)		+					
88		*Glossogobius giuris* (Hamilton, 1822)				+	+		
89		*Papuligobius uniporus* Chen & Kottelat, 2001		+					
90		*Rhinogobius giurinus* (Rutter, 1897)				+			
91		*Rhinogobius honghensis* Chen, Yang & Chen, 1999				+			

92		*Rhinogobius sp.*				+			
	Mullets	**Mugilidae**							
93	Blue tailed mullet	*Liza seheli* (Forsskal, 1775) *					+		
	Odontobutids	**Odontobutididae**							
94		*Neodontobutis tonkinensis* (Mai, 1978)				+			
	Giant gouramies	**Osphronemidae**							
95		*Trichogaster. trichopterus* (Pallas, 1770)				+	+	+	
	Threadfins	**Polynemidae**							
96		Eleuthronema tetradactylum *(Shaw, 1804) **					+		
	Drums and Croakers	***Sciaenidae***							
97	Soldier croaker	Nibea soldado *(Lacepede, 1802) **					+		
	Smelt Whitings	***Sillaginidae***							
98	Silver sillago	Sillago sihama *(Forsskal) **					+		
		Total	34	41	38	79	41		

Note: * : brackish water species
1, 2,3,3,5: River sections
R: Rare; V: Vulnerable (Classification level in the Red Data Book of Vietnam, 2000)

Table 32. Observed Cultured fish species in the Vu Gia catchment

	Characins	**Characidae**
1	Pirapitinga	*Piaractus brachypomus* (Cuvier, 1818
		Cyprinidae
2	Mrigal	*Cirrhinus mrigala* (Hamilton, 1822)
3	Grass carp	*Ctenopharyngodon idella* (Valenciennes, 1842)
4	Common carp	*Cyprinus carpio* Linnaeus. 1758
5	Silver carp	*Hypophthalmichthys molitrix* (Valenciennes, 1844)
6	Rohu	*Labeo rohita* (Hamilton, 1822)

		Clariidae
7	North African catfish	*Clarias gariepinus (Burchell, 1815)*
		Pangasiidae
8		*Pangasius bocourti Sauvage, 1880*
	Tilapia	**Cichlidae**
9	Mozambique tilapia	*Oreochromis mossambicus (Peters, 1852)*
10	Nile tilapia	*Oreochromis niloticus (Linnaeus, 1757)*