ISSN: 1683-1489

Mekong River Commission

Biomonitoring of the lower Mekong River and selected tributaries

MRC Technical Paper
No. 13

December 2006

Meeting the Needs, Keeping the Balance

Mekong River Commission

Biomonitoring of the Lower Mekong River and selected tributaries

MRC Technical Paper

No. 13

December 2006

Published in Vientiane, Lao PDR in December 2006 by the Mekong River Commission

Cite this document as:

Supatra Parnrong DAVIDSON, Tatporn KUNPRADID, Yuwadee PEERAPORNISAL, NGUYEN Thi Mai Linh, Bounnam PATHOUMTHONG, Chanda VONGSAMBATH and Anh Duc PHAM (2006) Biomonitoring of the Lower Mekong and selected tributaries. MRC Technical Paper No.13, Mekong River Commission, Vientiane. 100 pp. ISSN: 1683–1489

Editors: Dr. Ian Campbell, Dr. Bruce Chessman, Prof. Vincent Resh and Dr. Tim Burnhill

Design and layout: Dr. Tim Burnhill

184 Fa Ngoum Road, Unit 18, Ban Sithane Neua, Sikhottabong District,
Vientiane 01000, Lao PDR
Telephone: (856-21) 263 263 Facsimile: (856-21) 263 264
E-mail: mrcs@mrcmekong.org
Website: www.mrcmekong.org

Table of Contents

Abstract

The ecological health of the Mekong River and its tributaries is vitally important to lives and livelihoods of the more than 60 million people who live in the Lower Mekong Basin (LMB). The Mekong River Commission (MRC) is developing systems that will help to manage the ecological health of the river. Biological assessment (biomonitoring) is one of the tools that will support this management.

The 2004 biomonitoring survey was part of a five-year MRC project aimed to develop a biomonitoring method designed specifically for the environmental conditions of the Mekong River and its tributaries. Accordingly, the principal objective of this survey was to test methodologies rather than to provide definitive information about the ecological health of the river and its tributaries.

The survey sampled 20 sites along the length of the Mekong system from northern Thailand, through Lao PDR and Cambodia, to southern Viet Nam. Data were collected on four groups of organisms, benthic diatoms, zooplankton, littoral macroinvertebrates and benthic macroinvertebrates, which are believed to be best suited for biomonitoring purposes. Physical and chemical data were also collected to assist in interpretation of the biological data. Analysis of these data aimed to:

1. Examine the diversity, abundance and composition of the aquatic communities at each site;

2. Identify those physical and chemical variables that most strongly associate with spatial variations in the biological communities;

3. Compare the within-site and among-site variability of community composition.

The analyses found that all four groups of organisms are diverse and abundant in the Mekong River system, with considerable variation in abundance and composition from site to site. Spatial variation among sites was related to environmental variables such as temperature, electrical conductivity (an indicator of salinity), pH, and dissolved oxygen concentration. Statistical analyses also showed that in the case of each group, replicate samples from the same site were almost always more similar to one another than to samples from other sites. This shows that the sampling methods are well able to assess biological differences among sites.

The results of the 2004 survey demonstrate that biomonitoring is potentially a valuable tool with which to assess the ecological health of the Lower Mekong river-system. Future surveys will build on the 2004 survey by including additional sites and providing more comprehensive, and representative, coverage of the Lower Mekong Basin. In future the project will also develop and test biological indices that are able to distinguish deleterious human impacts from the effects of natural variation in environmental variables.

KEY WORDS: Mekong; ecology; environmental health; bioassessment; water-quality; benthic diatoms; zooplankton; littoral macroinvertebrates; benthic macroinvertebrates.

1. Introduction

The Mekong River flows though the territory of six countries: China, Myanmar, Lao PDR, Thailand, Cambodia, and Viet Nam. The river and its tributaries are the main source of livelihoods for approximately 60 million people who live in the Lower Mekong Basin. Fish are one of the most important of these resources; fishing or fishing-related activities support the partial or entire livelihoods of some 40 million people. But the river provides the inhabitants with more than just fish; they also eat many types of invertebrates, frogs, snakes, turtles, algae, and higher plants. In addition, they use reeds and the products of many other river-dependent plants to build houses, cages, traps, and boats.

The Mekong River is also especially important for its diverse freshwater fauna and flora. Of the world's large rivers, only the Amazon and the Congo rivers contain more species of fish. The many endemic species of crabs, snails and other invertebrates add to the Mekong's unique biodiversity.

The perpetuation of these resources for the long-term benefit of the basin's inhabitants depends on the river remaining in an ecologically healthy condition. However, in order to know whether river health is being maintained, it must be monitored in appropriate ways that describe its condition accurately. Accordingly, the Mekong River Commission (MRC) is developing monitoring methods designed specifically for the Mekong.

The study described aimed to establish the suitability of a 'biological assessment' approach (biomonitoring) to monitor the health of the Lower Mekong River system. The advantages of monitoring biological indicators together with physical and chemical parameters are well known: (i) it reflects overall ecological integrity (biological, physical, and chemical), (ii) it provides a holistic measure of environmental conditions by integrating stresses over time, and (iii) the public understands that living organisms are good indicators of a 'healthy environment'.

Like human health, river health can be monitored with a suite of indicators. In 2003, the MRC conducted a preliminary study to evaluate a number of possible methods for assessing the health of the river and to investigate which groups of organisms are best suited for this purpose. The study identified four biological groups that could be used use as indicators: benthic diatoms, zooplankton, littoral macroinvertebrates and benthic macroinvertebrates. It also identified several physical and chemical parameters that would complement the data collected on the biological indicators.

This report documents a second field survey that was conducted during the dry season (March) of 2004. Applying the knowledge gained in the 2003 study, the 2004 survey sampled sites 20 sites located on both the mainstream of the Mekong and its tributaries. The sampling represents a full geographical coverage of the Lower Mekong River system from the Kok River in northern Thailand, through Lao PDR and Cambodia, to the Mekong Delta in southern Viet Nam.

The overall objectives of the 2004 survey were to:

1. Examine the number of species and the composition of aquatic communities at each site;
2. Investigate the 'with-in' and 'among-site' variability of these attributes;
3. Group sites according to composition of their aquatic fauna and flora;
4. Identify those physical and chemical factors that most strongly associate with variations in the biological communities.

As such, the 2004 survey is another step in the development of biomonitoring techniques that are tailored

for the particular environmental conditions of the Lower Mekong River system. Field surveys planned for 2005, 2006 and 2007 will refine these techniques and help establish a objective, robust and reliable system for monitoring the ecological health of the river.

2. Study sites

Twenty sites were sampled during the dry season (March) of 2004 (Table 1 and Figure 1—over page). The particular geomorphological and environmental features of the sites that may have influenced the results of the biomonitoring are listed below.

LNO – Nam Ou ~ 5 km from the river's confluence with the Mekong

Unlike the substratum at the other sites in this survey, extensive beds of gravel and cobble form the substratum at LNO. The high biological richness at this site is influenced by the nature of the substratum, making comparison with sites further downstream difficult. Here, the river water was also much less turbid than in the mainstream.

LPB – Mekong River above Luang Prabang (upstream of Pak Nam Karn)

At this site, the river bed is made of sand and silt. The location is also subject to a great deal of river traffic. High-speed tourist craft, in particular, may have caused scouring of the substratum, especially in littoral areas that were subjected to boat-wash.

LVT – Mekong River above Vientiane

Here the land is inundated during the wet season, when it is used to grow tomatoes. This may have increased deposition of silt in the sandy riverbed where the samples were taken.

LNG – Nam Ngum

The riverbed at this site, which is located below Nam Ngum Dam, is made of fine silt. Even so, the river water at this locality was much less turbid than in the mainstream.

LKD – Nam Ka Ding at Haad Sai Kam

This site is on a dammed tributary about 4 km above the confluence with the Mekong River. Hand-paddled canoes were used for sampling, which limited the area that could be sampled. The flow rate was extremely low.

LPS – Mekong River above Pakse, upstream of the mouth of the Se Done River

The river was extremely wide at this site, and had a bed of muddy clay.

TMU – Mun River at Ban Tha Phae, Ubon Ratchathani

The samples were taken from about 800 m above the confluence of the Mun and Mekong Rivers. The site is probably influenced by back-flow from the Mekong during the flood season. However, the Pak Mun Dam is located only a few hundred metres upstream, which limited the area available for sampling. The site is also influenced by its proximity to this dam, and the river's low turbidity was probably a result of the settling of suspended material in Pak Mun Reservoir.

TCH – Chi River at Wat Srithararam, Yasothon

To avoid impoundment effects, samples were taken about 5 km above a weir. Sand had been dredged from the main channel just downstream of the sampling site, and some cattle were grazing on the bank. The stream bed was mainly sand with areas of mud and silt.

Table 1. *Sites sampled during the March 2004 Survey*

Code	Location	Date
LNO	Nam Ou, ~ 5 km from river mouth	07/03/04
LPB	Mekong River, above Luang Prabang, upstream of Pak Nam Karn	07/03/04
LVT	Mekong River, upstream of Vientiane	08/03/04
LNG	Nam Ngum, below Nam Ngum Dam, just downstream of Nam Lik mouth	09/03/04
LKD	Nam Ka Ding, at Haad Sai Kam	10/03/04
LPS	Mekong River, at Pakse, upstream of Se Done River mouth	11/03/04
TMU	Mun River, at Ban Tha Phae, Ubon	12/03/04
TCH	Chi River, at Wat Srithararm, Yasothon	13/03/04
TSK	Songkhram River, ~ 8 km from river mouth	14/03/04
TKO	Kok River, ~ 15 km upstream of Chiang Rai Weir, Chiang Rai	15/03/04
CPP	Tonle Sap River, at Phnom Penh Port	17/03/04
CTU	Tonle Sap River, at Prek Kdam	17/03/04
CPS	Por Sat River, at Prek Thot Village	18/03/04
CSS	Se San River, at Veun Sai	20/03/04
CSP	Sre Pok River, at Kampong Saila Lumpat	21/03/04
CKT	Mekong River, at Kampi pool, ~ 15 km upstream of Kratie	23/03/04
VTC	Mekong River, at Tan Chau	25/03/04
VCD	Bassac River, at Chau Doc	26/03/04
VKT	Dak Bla River, tributary of Se San River, Kon Tum hydrographic station, ~20 km from river mouth	28/03/04
VSP	Sre Pok River, Ban Don hydrographic station	29/03/04

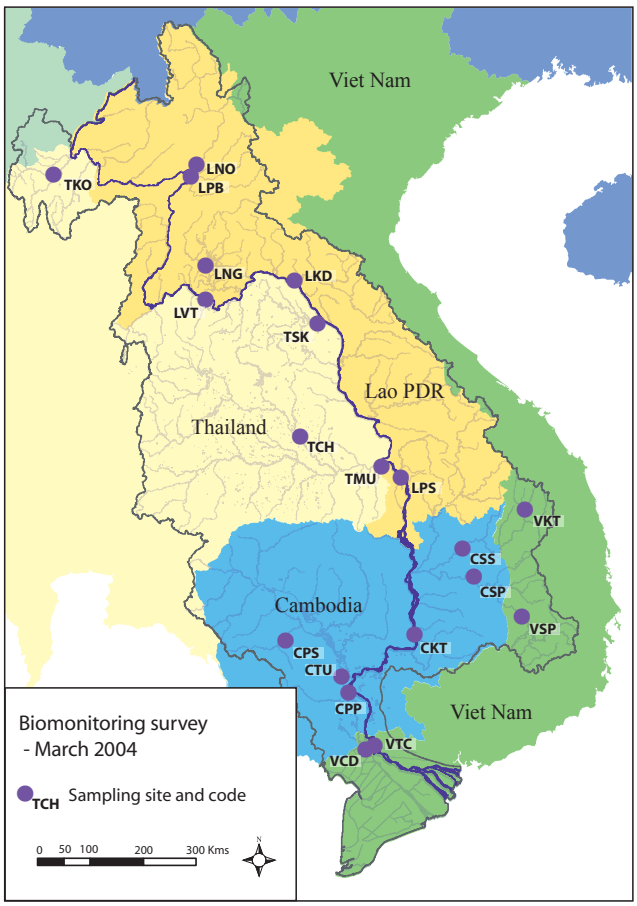

Figure 1. Location of sites sampled in March 2004

TSK – Songkhram River

The sampling site is about 7 km above the confluence with the Mekong River; this distance is presumed to be beyond back-flow from the Mekong. Fish farms (for *Tilapia* spp.) lined the entire length of river, and vegetable patches and grazing buffaloes were present on the banks. The water appeared very green from phytoplankton.

TKO – Kok River

This site, which is about 15 km above the weir at Chiang Rai, is disturbed by frequent tourist boat traffic. This, together with the narrowness of the channel, means both banks suffer significantly from boat-wash. The site is also downstream from the city of Chiang Rai.

CPP – Tonle Sap River at Phnom Penh port

At the time of sampling this site a lot of urban refuse was stranded on the shore of the river, and children collecting snails may have disturbed the substrata that were sampled for diatoms and littoral macroinvertebrates.

CTU – Tonle Sap River at Prek Kdam Ferry

Dead bivalves with erosion holes along the sides of the hinge were found in the middle of the channel, indicating the habitat was under high hydraulic stress. Heavy boat-traffic in the main channel may have caused impact from wash.

CPS – Pursat River, 4 km above Prek Thot

The site, a pool about 400 m long, was within Pursat town. Water buffalo were common and town residents used the pool for bathing and other domestic purposes.

CSS – Se San River at Veun Sai

Large fluctuations in water level caused by a dam upstream (residents indicated these were about 1 m per day) occurred at this site, and much detritus was present along the bank. The narrow riparian zone is used for strip cropping of coconuts, bananas, and sweet corn.

CSP – Sre Pok River at Kampong Saila Lumpat

The riparian zone at this site is lined with bamboo, and bars of large rocks, across the river. It was selected as a possible comparison with the Se San River, in order to evaluate the effects of damming and for baseline data in anticipation of the construction of dams on this river in the future.

CKT – Mekong River at Kampi pool

At this site, which is located about 15 km above Kratie, the river was almost 1.5 km wide. Rocky islands occurred within the braided, shallow side channels.

VTC – Mekong River at Tan Chau

The river was about 2.5 km wide at this site, with large islands of sand and reed beds. The substratum was heterogeneous: the left bank substrata comprised mud with some fine sand and a lot of detritus; at the centre of the river, the bed was formed mainly from fine sand with little detritus; and near the right bank, the bed was made from fine sand, mud, and clay, with some stones and rubble.

VCD – Bassac River upstream of Chau Doc

At this site the river was about 330 m wide and had a steep left bank of heavily eroded clay, modified with boat moorings. The substratum near the left bank was lumpy clay and mud, whereas the bed in mid-river comprised fine sand and mud. The right bank was gently sloping, with vegetable plots and a benthic substratum of mud and clay.

VKT – Tributary of Se San River at Kon Tum Hydrological Station

Here the river, which was 200-220 m wide, had a bed mainly composed of mobile sand.

VSP – Sre Pok River

At this site the river was 110 m wide and had a bed with sand and rocky outcrops with substantial areas of riparian rainforest.

3. Environmental variables

Introduction

Physical and chemical variables, such as conductivity, temperature, dissolved oxygen and pH, can provide essential information with which to characterise aquatic ecosystems, because these variables directly influence the composition and function of an ecosystem's biological components. They guide the interpretation of biological data and facilitate the assessment of water-quality. Physical and chemical variables are often good indicators of river health: for example, high concentrations of nutrients may be indicative of eutrophication. Some can be measured easily and quickly with simple electronic meters.

Physical and chemical variables are used widely to define water-quality criteria and measures and to set water-quality standards. For instance, the standards for inland water quality in Thailand, which are based almost entirely on physical and chemical variables, include just a single biological indicator—bacteria (Parnrong, 2002). Likewise, the water chemistry of the Mekong has been studied in detail, while data on biomonitoring are scarce. (The MRC has monitored chemical water-quality data in the Mekong River Basin since the 1980s.)

In this survey, physical and chemical data were collected to complement data on the biological community and to assist in their interpretation. The primary task for this part of the survey was to examine various physical and chemical characteristics of 20 sites along the Mekong River system. In addition, within-site variability of water quality was examined and the sites were grouped using multivariate statistical analysis. Physical and chemical information on each site was then related to data on the various biological assemblages examined.

Study sites and methods

Sites

Several physical and chemical variables were measured at the 20 sites on the Mekong River and its tributaries described in Chapter 2.

Field methods

The map coordinates and altitudes of the sampling sites were determined with a Garmin Geographical Positioning System (GPS), and stream width was measured with a Bushnell laser rangefinder. At each site, water-quality measurements were made in three sections of the river, on the left bank (L), the right bank (R), and in the centre (C). Centre measurements were taken only if the channel width was less than 100 m and the depth less than 5 m. Dissolved oxygen (DO), pH, and electrical conductivity (EC) were measured with Enviroquip TPS meters, calibrated according to the manufacturer's instructions. DO readings were taken at the surface and the bottom of the river, and the other measurements were taken at 0.1 m below the surface of the water, unless the difference in DO values between the surface and bottom was greater than 2 mg/l. In that case, measurements were taken at depth intervals of 1 m. A Secchi disc was used to indicate water transparency. Readings were taken by slowly lowering the disc into the water and recording the depth at which it could be seen no longer. The disc was lowered another metre, and then

slowly pulled up until it reappeared. If the depth at which the disk reappeared was not within 0.05 m of the depth of disappearance, the procedure was repeated.

Data analysis

Cluster analysis and ordination were performed on the environmental data. Variables were log-transformed prior to this analysis if their skewness was > 1, and all variables were relativised by subtracting the mean and dividing by the standard deviation. Euclidean distance was used as the distance measure with the transformed and relativised data. Cluster analysis was done with the flexible beta method of group linkage (beta = -0.25). Ordination was done with two-dimensional non-metric multidimensional scaling with varimax rotation. The correlations of the original variables with the ordinations were calculated and the strongest correlations were plotted as vectors on ordination diagrams. Analyses were also undertaken on nutrient data (nitrates and phosphate) collected in 2002 (14 sites).

Results

Physical and chemical variables

The study sites, whose locations were dispersed widely through the Mekong River system, had diverse characteristics. For example, the altitude of the sites varied from 565 masl (metres above sea level) at Se San in Viet Nam (VSS) to 3 masl at other sites in Viet Nam (VTC and VCD). Channel widths also varied greatly among sites, from as narrow as 50 m in the Pursat River (CPS) to as wide as 2600 m in the Tan Chau (VTC), Viet Nam. Secchi-disc depths ranged from 0.2 m to 3.4 m; the deepest was measured at the site below the Nam Ngum Dam in Lao PDR (LNG). The shallowest Secchi depth (0.2 m) was recorded in disturbed and shallow still water in the Pursat River in Cambodia (CPS) (Table 2).

Levels of DO were reasonably high, averaging 7.1 mg/l (± 1.6 mg/l). High DO values were recorded at most of the sites in Lao PDR and Thailand, and at the Se San sites in Cambodia and Viet Nam. Lower DO values were found at sites in populated areas, such as CPP, CTU, and CPS in Cambodia (4.0, 4.2, and 5.3 mg/l respectively) (Figure 2). Water temperature also varied greatly from site to site. The average was 27.3°C (± 2.8°C), with the highest temperature (30.6°C) recorded at CKT in Cambodia and the lowest (21.3°C) at Luang Prabang in Lao PDR (LPB) (Figure 2).

The river water was neutral to slightly alkaline at all sites and pH varied between 7.1 and 8.6, with an average of 7.9 (± 0.5). The conductivity varied from 38 to 771 µS/cm, with an average of 169 (± 164) µS/cm. The highest conductivity was found at the site in the Songkhram River (TSK), the upstream reaches of which pass through salty soil (Figure 3).

Within–site variability

A cluster analysis of physical and chemical data from individual sampling points at each site (left, right, and centre) showed that, in every case, samples from the same site clustered together. This indicated that variability within a site was low compared to variability among sites.

Among-site variability

Cluster analysis of averaged physical and chemical data for each of the 20 sites produced six groups at the 50% level of information remaining (Figure 4). Site TSK, which had the highest EC and DO values,

Table 2. *Altitude, river width and Secchi disc depth for the 20 survey sites*

Site	Altitude (masl)	River width (m)	Secchi depth (m)
LNO	280	214	2.80
LPB	276	295	0.90
LVT	159	480	0.98
LNG	161	196	3.40
LKD	160	173	2.00
LPS	100	1324	1.30
TMU	98	248	0.90
TCH	127	185	0.33
TSK	137	125	2.50
TKO	390	270	0.70
CPP	10	490	0.60
CTU	5	533	0.60
CPS	15	50	0.20
CSS	85	335	1.60
CSP	108	215	1.50
CKT	20	2000	0.62
VTC	3	2600	0.70
VCD	3	1000	0.50
VSS	565	207	0.60
VSP	178	110	1.25

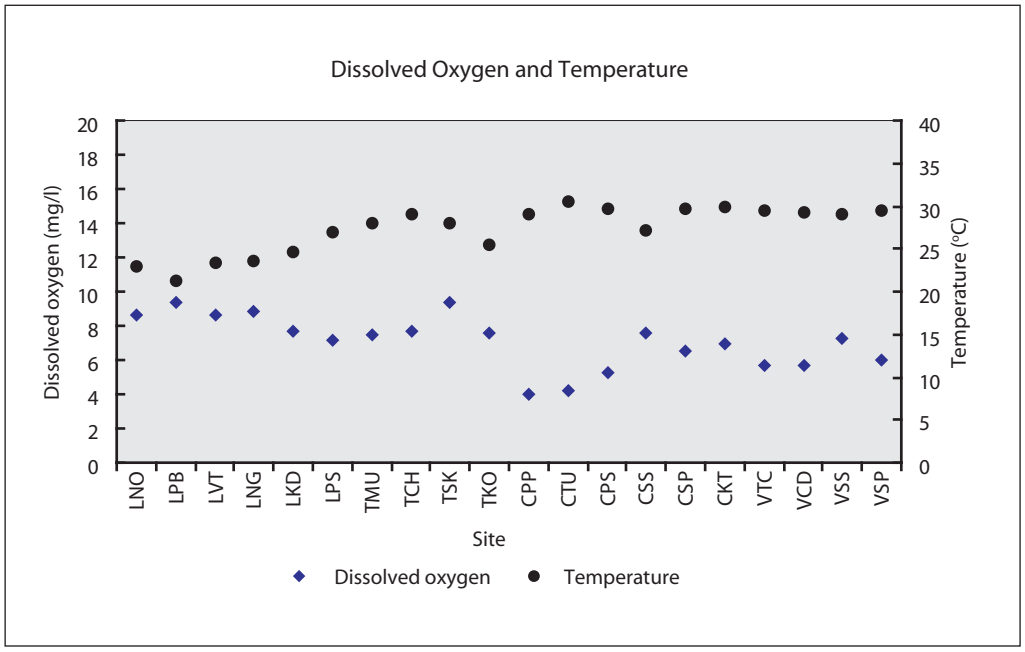

Figure 2. Average dissolved oxygen concentration (mg/l) and temperature (°C) at the water surface, based on measurements taken at the left bank, right bank and in the centre of the channel, sampled during March 2004

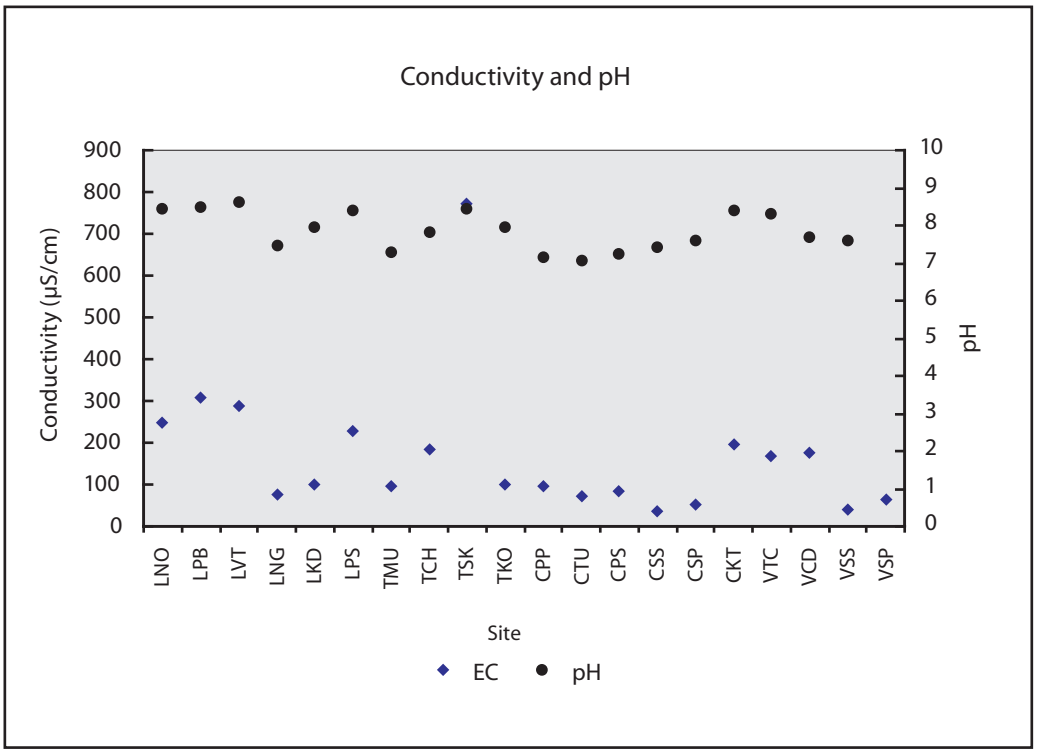

Figure 3. Average conductivity (µS/cm) and pH at the water surface, based on measurements taken at the left bank, right bank and centre of the channel, sampled during March 2004

was distinct from the other sites and formed its own cluster, as did CPS, a site where the river was narrow and where DO levels were low. Clustering of the sites LNO, LPB, and LVT was associated with high DO and low temperatures. The sites LPS, CKT, VTC, and VCD, which formed another cluster, were located on wide rivers, with moderate DO and high temperatures. Sites CTU and CPP formed a small group with high temperatures and low DO values. The sixth cluster consisted of sites with mid-range values for all the environmental variables.

An ordination of the same sites (Figure 5) agreed with the pattern of sites in the cluster analysis. Furthermore, the low stress value (2.8) indicated that the similarities among the sites were well represented in the ordination. DO and altitude were most strongly associated with Axis 1 of the ordination ($r = -0.99$), while temperature was negatively correlated with this axis ($r = -0.72$). Axis 2 was mainly associated with river width ($r = 0.83$) and EC ($r = -0.64$). Axis 1 tended to separate upstream sites in Lao PDR with high DO and low temperature from lowland sites in Cambodia with low DO and high temperature. Axis 2 tended to separate sites on wide rivers with high pH and EC from sites on narrow rivers with low pH and EC (Figure 5).

Discussion

The general physical and chemical variables at the sampling sites were mostly within the ranges expected for surface water quality in a natural system in this region. The pH, DO, and temperature were within the ranges defined for aquatic ecosystems by the standards for surface water quality set by Thailand, Viet Nam, and Cambodia (MRC, 2005; PCD, 2004: Annex 1). DO values were mostly on the high side, all the sites had DO levels of at least 4.0 mg/l, falling within Class 3 (medium clean) of Thailand's water quality

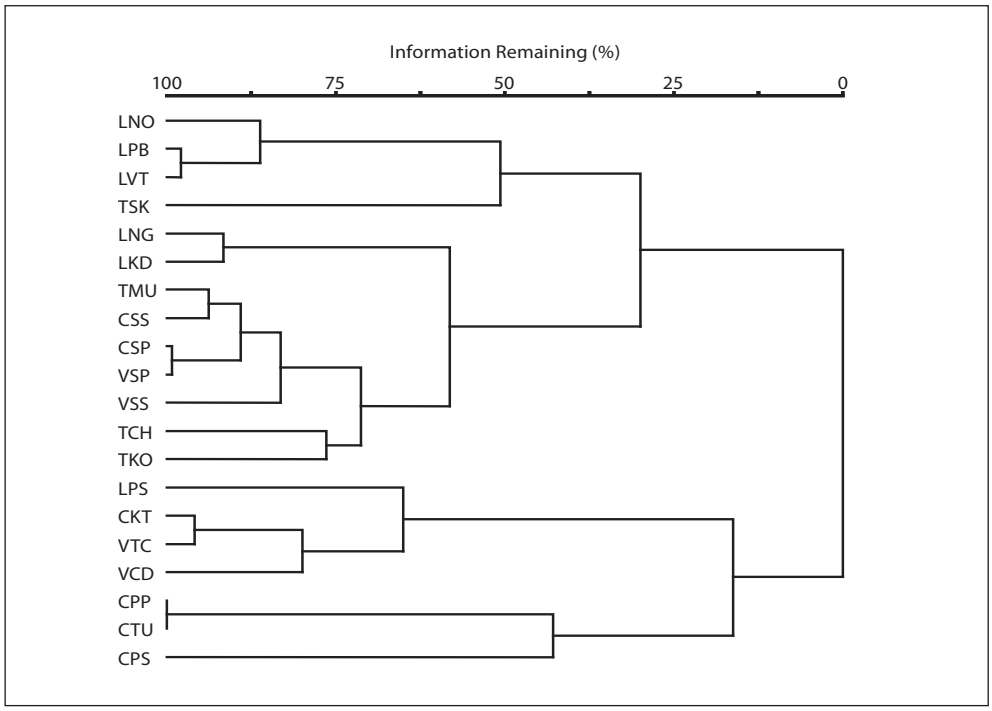

Figure 4. Dendrogram from cluster analysis of the average values of physical and chemical variables at all 20 of the March 2004 Survey sites

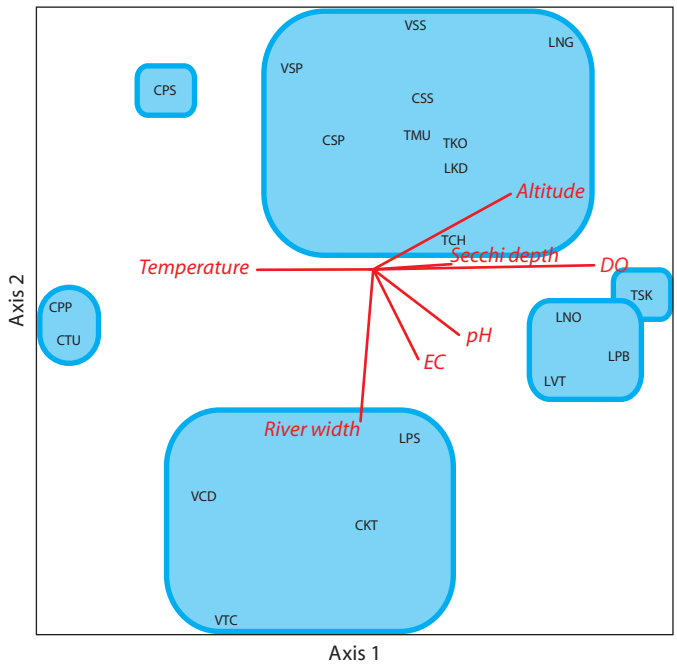

Figure 5. Ordination based on average values of physical and chemical variables at all 20 of the March 2004 Survey sites. The sites are group according to the cluster analysis results in Figure 4 (above). Lines indicate directions and relative magnitude of the correlation with environmental variables

standards (Annex 1) and within the range specified for biodiversity conservation for Cambodian rivers (RGCM, 1999). However, only daytime data were obtained and high daily DO and pH fluctuations can occur in systems with high plant photosynthesis rates.

Although conductivity is not included in the Thai standard, the site measurements were within the ranges for natural inland waters, except for those at site TSK. It is possible that its high conductivity was a result of contamination from saline land upstream.

Dissolved oxygen (DO), temperature, and sampling site altitude had consistently high correlations with Axis 1 of the ordination analyses, while Axis 2 was mostly associated with the width of the river section, conductivity and algal biomass. Nitrate and phosphate may not have exhibited strong correlations because the data were collected two years earlier, or because these variables behaved independently of the others. Its is recommended that concurrent collection of data on nutrient concentrations may improve future interpretation.

Overall, the physical and chemical variables at the 20 sites on the Mekong River and its tributaries indicated that most of the sites were relatively undisturbed. Although physical and chemical information was insufficient for determining the overall ecological health of the river, it did provide important supporting information that will be used in the interpretation of biological data in subsequent chapters.

4 Benthic diatoms

Introduction

Benthic diatoms are microscopic plants that lie on rock, stones, cobbles, gravel, mud, or other substrata. They are widely used for biological monitoring (Whitton *et al*., 1991; Wetzel, 2001). They have varying water-quality tolerances, depending on the species, and are generally considered excellent indicators of environmental quality in running-water environments. In aquatic ecosystems, some species grow well where nutrients are in low concentrations while other species are more abundant where nutrient levels are high. Some species respond strongly to high levels of inorganic matter or toxic materials. It is on this basis that these organisms are used to assess the environmental health of inland waters.

Diatoms were used as indicators in the 2004 survey on the basis of a preliminary evaluation of various methods for monitoring the Mekong River using biological indicators. The evaluation, which was undertaken during 2003, found that benthic diatoms were more useful than macroalgae as ecological health indicators, even though identifying them accurately requires more expertise.

The primary task was to obtain information on the richness and relative abundance of diatom species at the 20 sites examined. The variability of replicate samples collected within a site was assessed, and multivariate methods were used to see how sites grouped together according to their diatom assemblages. Finally, the relationships of diatom assemblages to the environmental characteristics of the sites were assessed.

Study sites and methods

Sites

Benthic diatom samples were collected from the 20 sampling sites along the Mekong River and its tributaries as listed in Chapter 2.

Field methods

Habitats sampled

The preferred sampling areas for diatoms are shorelines where the water depth is less than 1 m at 5 m from the river-bank, and where the length of suitable substratum (ideally cobbles or other stones) exceeds 100 m. At sites with predominantly muddy or sandy substrata and no stones, hard substratum materials such as bamboo sticks, aquatic plants, or artificial substrata were sampled. The specific habitats from which diatoms were collected at each site were as follows (these may differ slightly from the overall site descriptions given in Chapter 2):

LNO: from gravel and cobbles in the middle of the river.

LPB: from gravel and cobbles on the left bank of the island in the middle of the river.

LVT: from bamboo sticks and aquatic plants such as reeds. The samples were taken from the left bank of the sand dune island in the middle of the river.

LNG: from gravel and cobbles on the left bank of the island in the middle of the river.

LKD: from rock by breaking bedrock that was colonised by benthic diatoms.

LPS: from rock and artificial substrata on the right bank of the river.

TMU: from rock by breaking bedrock that was colonized by benthic diatoms.

TCH: from aquatic plants such as reeds and artificial substrata on the right bank of the river.

TSK: from rock by breaking bedrock that was colonized by benthic diatoms.

TKO: from gravel and cobbles on the left bank of the river.

CPP: from bamboo piers and artificial substrata on the right bank of the river.

CTU: from piers, bamboo sticks and artificial substrata on the right bank of the river.

CPS: from bamboo sticks and aquatic plants such as reeds.

CSS: from gravel and cobbles on the left bank of the river.

CSP: from bamboo sticks and aquatic plants such as reeds.

CKT: from bedrock and aquatic plants such as reeds and sedges on the middle island of the river.

VTC: from the left bank of the sand dune island in the middle of the river.

VCD: from sticks and artificial substrata on the right bank of the river.

VKT: from gravel and cobbles of the left bank of the river.

VSP: from gravel and cobbles of the left bank of the river.

Sampling method

Sampling points were chosen as follows. A random number table was used to select 10 one metre square plots from a sampling area of 100 x 5 m. At each plot, a single stone was chosen for examination (abundant benthic diatoms are seen as a thin brownish film covering the stone which may also be slippery to the touch). As each diatom sample was to be removed with a brush from 10 cm^2 of the upper surface of a stone, stones were required with a surface area greater than 10 cm^2, but not larger than the bowl (20–30 cm diameter) used to collect the diatom sample after brushing. In those plots without stones, any hard substratum in, or nearest to, the plot was sampled.

When sampling, a plastic sheet with a 10 cm^2 cutout (Figure 6) was placed on the upper surface of the stone or other substratum. Benthic diatoms on the substratum surface were brushed off and rinsed with water until the cutout area was completely clear. Each sample was collected in a plastic bowl and transferred to a plastic container.

Processing samples in the field

The plastic container with the sample was labelled with the site name, location code, date, and replicate number. The collector's name, sampling site, substratum type and replicate number were recorded on the field data sheet.

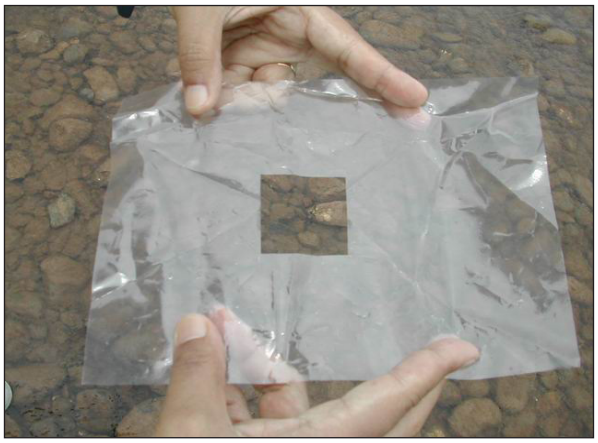

Figure 6. Plastic sampling sheet with a 10 cm^2 square cut out of the middle

Preservation and transport to the laboratory

Samples were preserved with Lugol's solution and kept in plastic boxes in an ice box that was kept at low temperature (5–10 ^oC).

Laboratory methods

In the laboratory, each sample was cleaned by a concentrated acid digestion method. The samples were centrifuged at 3500 rpm for 15 minutes. The diatom cells (brown layer between supernatant and solid particles) were placed in an 18 cm core tube. Strong acid (H_2SO_4, HCl or HNO_3) was added and the tube was heated in a boiler (70–80 ^oC) for 30–45 minutes. The samples were rinsed with de-ionized water 4–5 times, and 2–3 drops of each sample were placed on a microscope slide and dried. A mounting agent solution such as Naphrax or Durax was used to make a permanent diatom slide for counting and identification under a compound microscope, and 300 individual cells were counted per slide.

The identification of diatoms was based on the type of frustule, size, special characteristics, and structure. Relevant textbooks, publications, and monographs on temperate and tropical diatoms were used, e.g. Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b), Hustedt (1937), Foged (1971, 1975, 1976), and Pfister (1992). In most cases, specimens were identified to species. The permanent slides are kept in the Applied Algal Research Laboratory Collection at Chiang Mai University.

Data analysis

The four most abundant diatom species at each site were recorded and those believed to indicate differing levels of ecological health were identified from relevant literature including Del Giorgio *et al*. (1991), Silva-Benavides (1994), Conforti *et al*. (1995), and Loez and Topalian (1997) for polluted quality, Hempattarasuwon (2001) for moderate-polluted quality, and Pektong (2002) and Supan and Peerapornpisal (2002) for moderate quality.

Cluster analysis and ordination were performed on diatom count data transformed as log (count + 1). The Sorenson (Bray-Curtis) distance measure was used. Cluster analysis was done with the flexible

beta method of group linkage (beta = -0.25). Ordination was done with two-dimensional non-metric multidimensional scaling with varimax rotation. The correlations of the environmental variables with the ordinations were calculated and the strongest correlations were plotted as vectors on the ordination diagrams.

Results

General characteristics of the diatom flora

In total, 206 species of benthic diatoms were collected from the 20 sites examined. Of these, 197 species were in the Order Pennales and nine in the Order Centrales (Annex 2). The number of species at a site ranged from 17 to 60 (Table 3). The highest number of species (60) was collected at site TKO (Kok River, Thailand) and the lowest at site CPS (Pursat River, Cambodia). *Achnanthes minutissima* and *Cocconeis placentula* were the most widely distributed species, and *Nitzschia clausii* and *Synedra ulna* var. *aequalis* were also widespread (Table 4).

Pollution-tolerant diatoms were the most abundant species at two sites (CPP and CTU). At two other sites (TCH and TKO), pollution-tolerant species were among the four most abundant species, but these diatoms were not present in significantly large numbers. At two further sites (VCD and VTC), moderately-tolerant to pollution-tolerant species were the most abundant or the second most abundant diatoms species recorded.

Table 3. *The number of benthic diatoms recorded at all 20 of the March 2004 Survey sites*

Site	Number of species
TKO	60
LPB	47
TSK	44
LNO	43
VTC	39
LNG	36
CKT	36
TCH	35
LKD	35
VSP	34
TMU	30
VKT	29
LVT	28
CSP	26
VCD	25
LPS	24
CTU	24
CSS	20
CPP	19
CPS	17

Table 4. *The four most abundant species of benthic diatoms at each site (including pollution tolerance—where known)*

Site	Species	% of total cells	Tolerance to pollution
LNO	*Cocconeis placentula*	56.6	-
	Epithemia adnata	18.0	-
	Achnanthes lanceolata	7.3	Moderate
	Navicula viridula var. *germainii*	5.5	-
LPB	*Achnanthes minutissima*	30.6	-
	Gomphonema sp. 1	14.5	-
	Achnanthes lanceolata	13.9	Moderate
	Amphora sp.1	11.5	-
LVT	*Navicula* sp. 1	74.1	-
	Cymbella turgidula	5.5	Moderate
	Navicula sp. 2	3.8	-
	Luticola sp. 1	3.6	-
LNG	*Achnanthes minutissima*	23.8	-
	Encyonopsis sp.1	22.8	-
	Navicula sp.26	16.0	-
	Encyonema sp.7	11.5	-
LKD	*Achnanthes minutissima*	63.4	-
	Fragilaria ulna var. *acus*	9.0	-
	Encyonema sp.7	5.2	-
	Fragilaria capucina	2.5	-
LPS	*Synedra ulna* var. *aequalis*	33.1	Moderate
	Cymbella turgidula	23.1	Moderate
	Navicula sp.31	15.4	-
	Synedra ulna	7.3	-
TMU	*Cymbella* sp.1	56.2	-
	Achnanthes minutissima	15.4	-
	Gomphonema sp.1	7.9	-
	Gomphonema sp.2	5.5	-
TCH	*Achnanthes minutissima*	54.6	-
	Nitzschia clausii	10.4	Tolerant
	Gomphonema parvulum	7.3	Tolerant
	Navicula symmetrica	6.6	-
TSK	*Achnanthes* sp.1	33.7	-
	Achnanthes minutissima	17.4	-
	Gomphonema sp.1	11.1	-
	Nitzschia sp. 6	8.4	-
TKO	*Navicula* sp.14	30.2	-
	Cocconeis placentula	10.5	-
	Achnanthes minutissima	9.7	-
	Navicula viridula var. *rostellata*	5.8	Tolerant
CPP	*Nitzschia clausii*	49.0	Tolerant
	Navicula sp.36	17.0	-
	Navicula sp.35	14.8	-
	Gomphonema parvulum	2.6	Tolerant
CTU	*Gomphonema parvulum*	17.6	Tolerant
	Cymbella sp.17	17.1	-
	Nitzschia palea	9.8	Tolerant
	Nitzschia sp.16	7.9	-
CSS	*Achnanthes minutissima*	50.0	-
	Encyonema sp.12	13.8	-
	Navicula sp. 39	9.7	-
	Cocconeis placentula	5.7	-
CPS	*Synedra ulna* var. *aequalis*	27.1	Tolerant
	Navicula sp.35	22.6	-
	Cocconeis placentula	11.6	-
	Gomphonema sp.12	10.7	-
CKT	*Cymbella* sp.6	20.3	-
	Achnanthes minutissima	13.3	-
	Cocconeis placentula	8.3	-
	Rhopalodia gibberula	7.4	-
VTC	*Aulacoseira granulata*	24.8	Moderate
	Rhopalodia sp.2	13.4	-
	Gomphonema sp.10	9.5	-
	Aulacoseira muzzanensis	8.9	-
VCD	*Aulacoseira granulata*	20.6	Moderate
	Nitzschia sp.17	21.9	-
	Navicula sp.32	12.7	-
	Melosira varians	6.5	-
VKT	*Navicula* sp.39	38.3	-
	Cymbella japonica	13.8	-
	Achnanthes minutissima	13.0	-
	Encyonema sp.11	7.7	-
VSP	*Cymbella turgidula*	26.8	Moderate
	Encyonema sp.9	26.7	-
	Navicula sp.30	15.5	-
	Nitzschia palea	2.2	-

Within-site variability

The ten replicates from each site, when plotted as a cluster dendrogram, were more similar to one another than to samples collected from other sites. For example, only one sample from each of two sites clustered with the 'incorrect' site. Therefore it seemed reasonable to use averaged data from each site in further analyses.

Among-site variability

When averaged data from each site were clustered, the sites split into two major groups (Figure 7), one including mostly Vietnamese and Cambodian sites and the other including mostly Thai and Lao sites. The Vietnamese–Cambodian group also included two Lao sites, but one of these, LVT, was an outlier with a low level of similarity to the rest of the group, while the other was the Pakse site (LPS), the furthest downstream site in Lao PDR. The Thai–Lao group of sites included one Cambodian site, at Kratie (CKT). Essentially these two clusters seemed to represent the upstream sites (Thai–Lao PDR) and the downstream sites (Cambodia–Viet Nam).

The ordination plot (Figure 8) also shows the similarity of sites according to the distribution and abundance of diatoms. Vectors for chemical and physical variables, including substratum types, were superimposed on the ordination. A low stress value of 12.4 showed that the ordination was a good representation of the similarities among the sites. The grouping of sites in the ordination was similar to the grouping in the cluster analysis. The factors most strongly related to the distribution of diatoms were physical and chemical properties of the water (DO, EC and temperature) and the amount of cobble grade substratum. Axis 1 of the ordination separated sites such as TCH, with muddy and sandy substrata, from sites like LNG and CSP that had gravel and stony substrata. On Axis 2, sites associated with higher conductivity grouped separately from sites with higher dissolved oxygen (Figure 8).

Discussion

Benthic diatoms provide five types of information that can be used to help assess of the ecological health of the river: (1) information from indicator species, (2) information from multivariate analyses, (3) *a priori* knowledge of likely impacts and impacted sites, (4) environmental data, and (5) information from other biological indicators. Information from these five sources needs to be compared and reconciled when making judgments about the health of the river and assessing the validity of benthic diatoms as indicators of this health.

The indicator species analysis was limited in scope because the tolerance of most species is not yet known. The results from the multivariate analyses provided limited support for the results based on indicator species. For example, the sites that indicator species suggested were most stressed (CPP and CTU) grouped together, but also grouped with sites dominated by species that are indicative of moderate water-quality. The cluster analysis and ordination reflect both natural and human-generated variations in the diatom flora, and are therefore not simply a reflection of the impact of water-quality. In addition, sites that suffer similar levels of pollution may support different types of pollution-tolerant species, and as a result these sites may not group together under multivariate analysis.

The ordination separated four sites, LVT, CSP, LNG, and TMU, as relatively distinctive from one another and from all other sites. Of these, CSP was a tributary site in a relatively undisturbed catchment, where sampling was conducted on a rock bar. Sites LNG and TMU were both downstream of dams. Dams may influence the diatom community although possibly not in consistent ways, because the two sites were

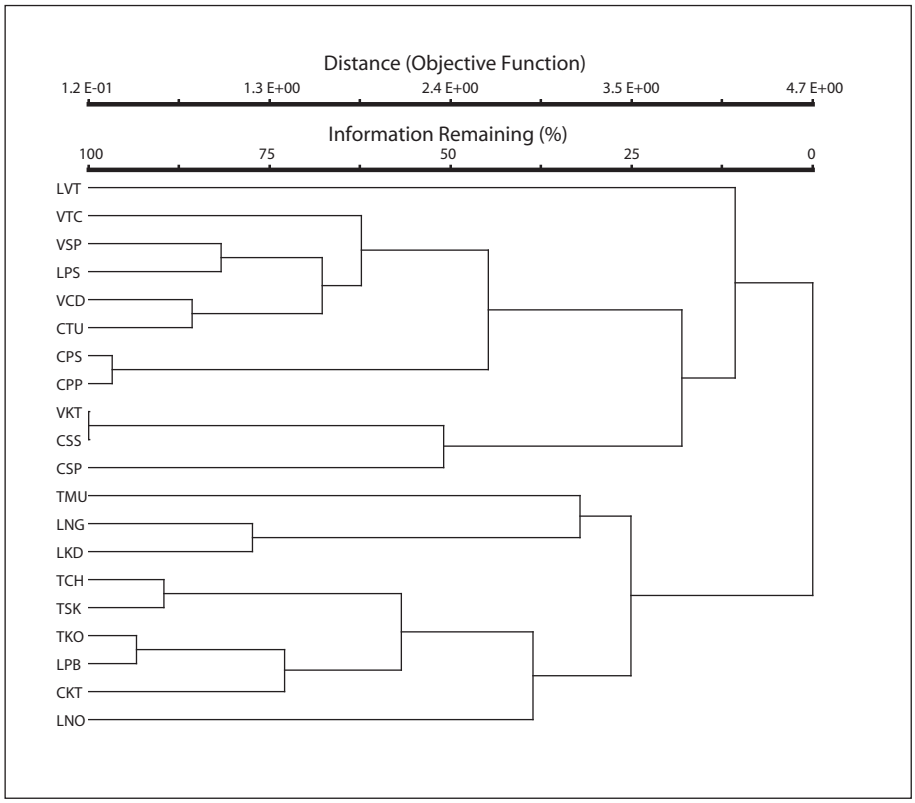

Figure 7. Dendrogram from cluster analysis of average diatom data at the March 2004 Survey sites

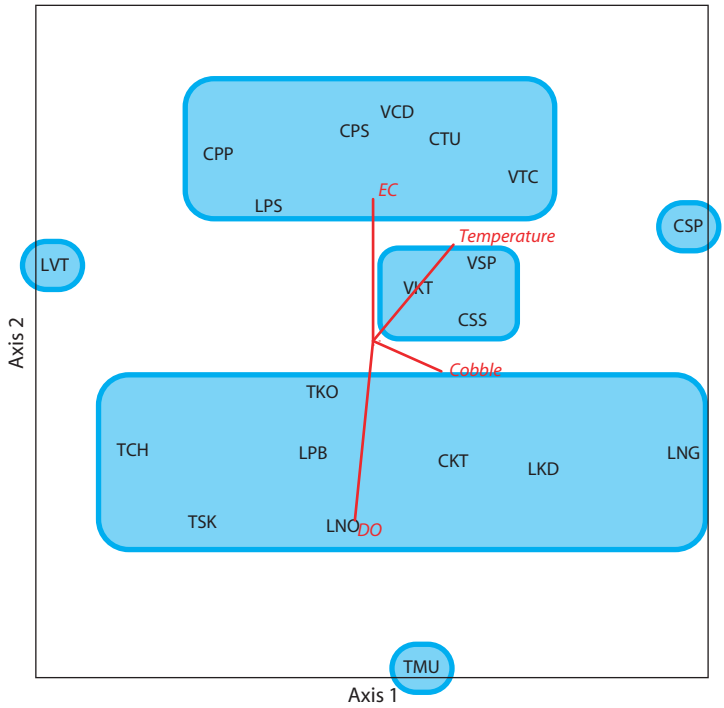

Figure 8. Ordination based on average diatom data in Figure 7 (above). Lines indicate directions and relative magnitude of correlations with environmental variables

not similar. The impact of dams may vary depending on the nature of the river that is dammed, because the Nam Ngum and Nam Mun rivers are different in their physical characteristics. The distinctive nature of site LVT, near Vientiane, is more difficult to explain. The diatom assemblage was dominated by a single species, which made up almost 75% of the cells counted. This would seem to indicate a stressed assemblage, though possibly by a natural factor.

Several sites included in this survey are localities where human impacts are possible. In Lao PDR these included LVT, where there could be impacts from Vientiane city, and LNG, where there could be influences from river regulation. In Thailand, possibly affected sites included TMU, downstream of Pak Mun Dam, and TKO, in the Kok River where water-quality monitoring has found elevated suspended solids and nutrients (MRC, 2005). In Cambodia, CPP and CTU are both close to Phnom Penh and could be affected by urban runoff, CSS may have been affected by river regulation and CPS may have been affected by urban runoff from Pursat, upstream diversion of water for irrigation and intense domestic use. In Viet Nam the most likely sites to be impacted are those in the delta, VCT and VCD, where agriculture is most intense, in-stream aquaculture is common and there are relatively dense human settlements along the banks.

There are also several sites where it would be expected that conditions are likely to be exceptionally good. These include Nam Ou in Lao PDR (LNO), the Songkhram River in Thailand (TSK) and the Sre Pok River in Cambodia (CSP). All of these sites are in catchments with no industrial development, with agricultural development of low intensity and without large dams.

The ordination separated some of the probable disturbed sites (LVT, LNG and TMU) as individually distinctive and grouped several others together (CPP, CPS, VCD, CTU, VTC) along with one other site (LPS). Indicator species suggested that LPS had moderate water quality. Chemical water-quality data indicate some human impact on water quality at CPP, CTU, VCD and VTC (MRC 2005) but not at LPS. Because the assemblage similarities in the diatom data reflect the full range of factors, natural and anthropogenic, that influence the assemblages, anthropogenic influences will become evident only where they are relatively strong compared with natural factors.

The ordination did not group the presumed high-quality sites, and the indicators identified one as being of moderate water quality. The sites are different river types: Nam Ou shallow with cobbles, Songkhram deep and slow flowing, and Sre Pok with deep pools and bedrock bars. Therefore it was expected that their diatom assemblages would differ. The presence of a moderate water-quality indicator in the Nam Ou was unexpected since the water quality at this site appeared good. However, the indicator species made up only 7% of the sample.

5 Zooplankton

Introduction

Zooplankton includes both free-floating and swimming organisms that readily move with water currents. Species of zooplankton play an important ecological role in lakes and large rivers, feeding on non-living organic matter, phytoplankton and bacteria, and in turn being eaten by secondary consumers such as fish. Their reproductive cycles, development, and survival rates may directly influence other components of the ecosystem, such as the abundance of the organisms on which they feed. Zooplankton also play a significant role in fish and crustacean production because they make energy produced by algae through photosynthesis available to higher levels in the food chain. Finally, the community characteristics of zooplankton can be key elements in assessing the recovery of an ecosystem following stress caused by natural or human factors.

The use of zooplankton in biological monitoring is more common in lakes than in rivers. However, these organisms offer several advantages as indicators of environmental quality in both environments: (1) as a group, they have worldwide distribution, (2) techniques for sampling them are well developed, simple, and inexpensive, (3) the species composition and community structure of zooplankton are sensitive to changes in environmental conditions and/or nutrients, and (4) some species and groups of zooplankton are indicative of water-quality conditions.

In southeast Asia, zooplankton have been studied for many purposes but primarily in lake environments. There have been no comprehensive studies of zooplankton in the Mekong River system. In the Mekong Delta, there have been some small unpublished studies on zooplankton in the Tien and Hau Rivers, the two main branches of the Mekong River**.** These were mainly in relation to aquaculture or for small-scale environmental assessments.

In May 2003, the Mekong River Commission started a biomonitoring programme to assess river health in the Mekong River system within the countries of Cambodia, Lao PDR, Thailand and Viet Nam. Sampling of zooplankton at 13 sites in the main river and selected tributaries yielded information on species richness, and composition and community structure, which enabled the development of appropriate methods for future monitoring of zooplankton in the Mekong.

In the current study, the distribution and abundance of zooplankton were used again to evaluate the ecological health of the Mekong River and its system of tributaries. This chapter: (i) describes the richness and abundance of zooplankton at 20 sites in the Mekong River and selected tributaries, (ii) examines within-site variability of zooplankton samples, (iii) examines how sites group according to their taxonomic composition, (iv) examines the association of environmental characteristics with zooplankton assemblages at the sites sampled, and (v) describes the ecological conditions of the study area inferred from the results of the analyses.

Study sites and methods

Sites

Zooplankton samples were collected at 20 sites in the lower Mekong River basin in Lao PDR, Thailand, Cambodia, and Viet Nam. The sites have been described previously in detail in Chapter 2.

Field methods

At each site, three samples were collected as follows: a sample at the left side of the river (at a distance about 4–5 m from the water's edge where the stream margin was gently sloping), a similar sample at the right, and another in the middle. The samples were taken at least 1 m from potentially contaminating substances such as debris and aquatic plants and at least 2 m from vertical banks. Samples were collected with a 10 l plastic bucket, filtered through a plankton net (20 µm mesh, 20 mm × 60 mm), stored in plastic jars (250 ml) and fixed with formaldehyde (4%). Samples were processed in the field according to the following procedures:

1. The net, bucket, and plastic jar were washed with water at the sampling site to remove animals or material from the previous site.
2. Ten litres of surface water (from 0–0.5 m depth) were collected using the bucket and filtered through the net. The water was filtered slowly to avoid the water overflowing from the net, until the remaining water volume in the net was about 150 ml.
3. At those sites where the current was too fast to permit sampling exactly in the mid-stream, samples were collected slightly closer to the left or the right bank, but not as close as where the side-samples were taken.
4. The sample jar was labelled with the site name, site code, sampling date, and sample number.

Laboratory methods

The samples were analysed in the Laboratory of Aquatic Science, Institute of Tropical Biology, Ho Chi Minh City, Viet Nam. All the zooplankton were collected identified and counted. The identification was made to the lowest taxonomic level possible; this was generally species level. Identification was based on morphology, using Vietnamese and international references. Large species of zooplankton (> 50 µm in diameter) were observed under a microscope at 40 x magnification. The smaller species or details of larger species were examined at 100–400 x magnification. Samples were processed as follows:

1. Large particles of organic and inorganic matter were removed with forceps. The samples were rinsed with distilled water and filtered through a net with a mesh size of 10 µm and then allowed to settle in a graduated cylinder. Excess water was discarded, leaving about 50 ml of water and residue; this was transferred to a petri dish for examination.
2. The residue was examined under a microscope and every specimen identified and counted.
3. After analysis, samples were transferred back into the bottles and preserved. All specimens are stored at the Institute of Tropical Biology, Ho Chi Minh City, Viet Nam.

Data analysis

Cluster analysis and ordination were performed with the PC-ORD statistical software (version 4: MjM Software Design, Geleneden Beach, Oregon, USA) on zooplankton count data transformed as log (count + 1). The Sorenson (Bray–Curtis) distance measure was used. Cluster analysis was done with the flexible beta method of group linkage (beta = -0.25). Ordination was done with two-dimensional non-metric multidimensional scaling with varimax rotation. The correlations of the environmental variables with the ordinations were calculated and the strongest correlations were plotted as vectors on the ordination diagrams.

Results

General characteristics of the zooplankton

In total, 138 taxa were collected at the 20 sites (Annex 3). The taxa belonged to four main groups: Crustacea, Eurotatorea, Protozoa, and larval forms (Table 5). Taxon richness at a site ranged from 13 at LKD to 61 at TMU. Distribution in the Mekong system varied greatly among taxa. *Arcella vulgaris* (Protozoa: Arcellidae) and nauplius larvae of Copepoda (Crustacea) had the widest distributions, occurring at 19 sites. Several other taxa were also widely distributed, occurring at 13–14 sites: *Keratella cochlearis cochlearis* and *Keratella valga tropica* (Eurotatorea: Brachionidae), *Polyarthra vulgaris* (Eurotatorea: Synchaetidae), *Difflugia elegans* (Protozoa: Difflugiidae), and bivalvia larvae (Mollusca: Bivalvia). In all, 17,681 individuals were collected. The mean abundance recorded at the sites ranged from 22 individuals (CSP) to 1327 individuals (TMU) (Table 5).

Within-site variability

In general, there was little difference among the samples collected within a site (left and right banks, and middle of river). In 98% of cases the cluster analysis grouped samples from the same site together, the exception being one sample collected at Tan Chau (VTC). The consistency of these results is expected at sites in turbulent rivers where the water body is well mixed.

Table 5. *Zooplankton species richness, composition and abundance (total number of specimens collected) at the 20 March 2004 Survey sites*

Site code	No. taxa	Crustacea (% taxa)	Eurotatorea (%taxa)	Protozoa (% taxa)	Larvae (% taxa)	Mean abundance	Abundance range
LNO	16	0	44	31	25	57	51–69
LPB	18	6	44	33	17	182	155–218
LVT	17	18	29	35	18	24	17–31
LNG	28	29	39	29	4	398	347–452
LKD	13	8	38	46	8	18	7–38
LPS	31	10	48	35	7	227	193–257
TMU	61	31	56	12	2	1327	1269–1398
TCH	28	25	50	18	7	751	498–1237
TSK	18	6	67	22	6	580	404–787
TKO	22	14	55	18	14	53	52–55
CPP	34	21	53	21	7	318	309–335
CTU	30	17	57	20	7	744	374–1144
CPS	30	17	50	27	7	192	156–219
CSS	26	12	54	27	8	50	48–52
CSP	20	10	55	20	15	22	14–31
CKT	24	21	38	29	13	35	29–44
VTC	35	23	57	14	6	459	299–775
VCD	25	16	60	16	8	363	133–536
VSS	19	16	36	42	5	65	43–88
VSP	21	5	43	33	19	27	19–32

Among-site variability

The cluster analysis of average data for each of the 20 sites produced seven groups at the 50% level of information remaining (Figure 9). The sites LPB and LVT had similar taxonomic composition of Protozoa and larvae, and the dominant taxon was *Ceratium* spp. Sites TKO, CSS, CKT, VSS, VSP, and CSP were characterized by the dominant species being filter feeders that ingest non-living organic matter and bacteria. They included species of Brachionidae (Eurotatorea), Centropyxidae, and Arcellidae (Protozoa). All of these sites were tributary sites, but some (such as TKO and VSS) were located in quite developed catchments while others (such as CSP) were in relatively undisturbed catchments. Sites LNG and TMU had a species composition characteristic of both flowing and still water, and the highest proportion of Branchiopoda (Crustacea) in terms of the number of taxa present. Both were located only a short distance below reservoirs. Sites TSK, CPP, VTC, VCD, CTU, and CPS had similar species composition, similar representation of Copepoda, and the highest proportion of Eurotatorea (Crustacea). All were located close to nutrient sources such as fish cages or townships.

Ordination analysis of the same data produced a pattern with a stress value of 16.5, indicating that the ordination was a good representation of the similarities among the sites (Figure 10). The arrangement of sites in the ordination generally agreed with the grouping of sites in the cluster analysis. For example, sites VTC, VCD, CPP, and TSK were aligned in both analyses, as were sites CTU and CPS, sites VSS and VSP, and sites LPB and LVT. With the exception of sites in the Nam Ngum River (LNG) and at Pakse (LPS), the sites in Lao PDR (LNO, LPB, LVT, and LKD) tended to be separated from the sites in Thailand, Cambodia, and Viet Nam in the ordination plot. No Crustacea were collected in four of the Lao sites (LNO, LPB, LVT, and LKD). The cluster analysis also indicated that the similarity between these Lao sites and other sites was low.

The environmental factors that were correlated most strongly with the ordination of all 20 sites were temperature, altitude, pH, DO, and conductivity (EC) (Figure 10). When the 2002 water-quality data for nitrates, phosphates, and suspended solids were included, the environmental factors that correlated most strongly with an ordination of the 14 sites for which these data were available were temperature, DO, altitude, pH, NO_3, and EC (Figure 11).

Discussion

The Eurotatorea, a mainly freshwater group, was dominant in the Mekong River in terms of the numbers of families (49% of total), genera (48%), and species (57%) collected. This was not surprising because rotifers commonly dominate the zooplankton in large rivers (e.g. Hynes 1970). The four main zooplankton groups (Crustacea, Eurotatorea, Protozoa, and larvae) were present at all of the sites except for LNO. Among these groups, the Eurotatorea were most dominant at the sites TSK, VCD, VTC, and TMU. These sites also had the highest prevalence of species that feed on non-living suspended organic matter (e.g. species of Trichocercidae and Brachionidae), which are typically abundant in lakes having high nutrient levels, as for example from fish-cages.

The Branchiopoda (Crustacea), which include filter feeders of the genera *Bosmina, Diaphanosoma*, *Daphnia*, and *Ceriodaphnia* are characteristic of lentic waters and made up the highest proportion of taxa at sites LNG (21% of total) and TMU (18%). Both sites are downstream of impoundments. In contrast, the Copepoda (Crustacea), which included species of Cyclopidae, and the Bosminidae (Branchiopoda) are characteristic of low current and nutrient-rich waters and contributed the bulk of the species at TMU (13% of total) and CKT (13%). The highest proportion of zooplankton larvae occurred at sites LPB (25% of total) and VSP (19%), which were high altitude sites, having strong current, turbulence, and a rocky bed.

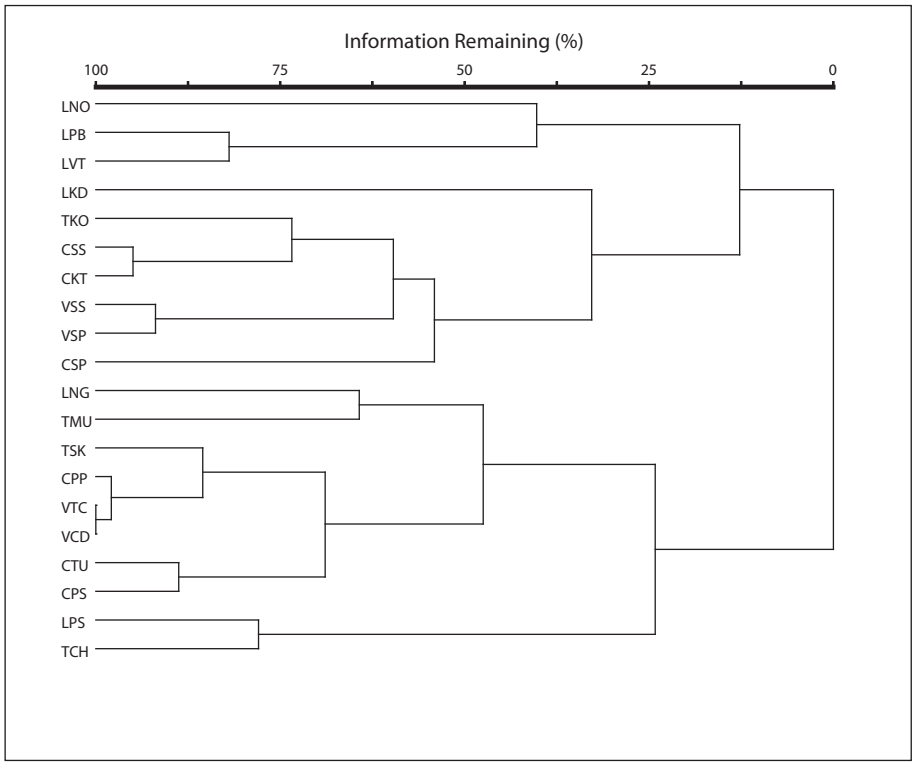

Figure 9. Dendrogram from cluster analysis of zooplankton diatom at all 20 of the March 2004 Survey sites

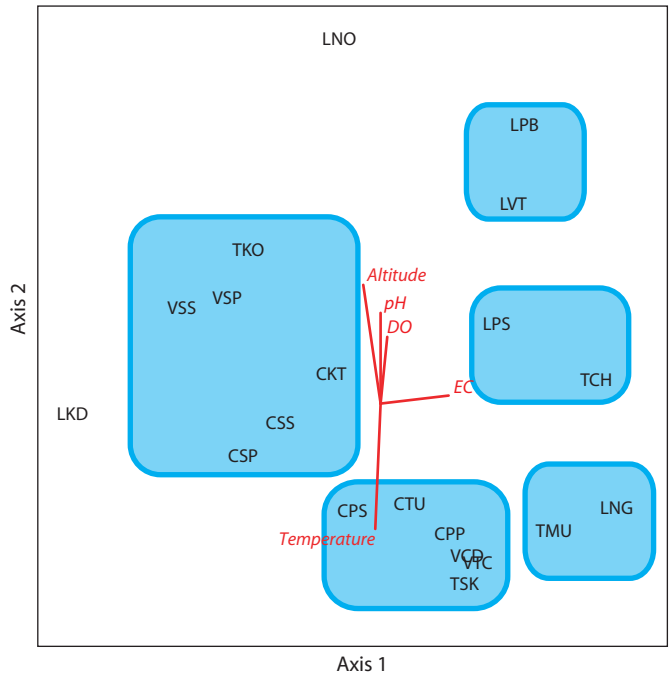

Figure 10. Ordination based on average zooplankton data in Figure 9 (above). Lines indicate directions and relative magnitudes of correlations with environmental variables

Site TMU, the richest site, was characterized by taxa that occur in both rivers and lakes. These taxa were predominantly species of Eurotatorea (56% of total) and Crustacea (31%). The site was located only a few hundred metres below Pak Mun Dam and so the presence of lacustrine species from the reservoir was not surprising.

Site LKD had the poorest species richness; species of Copepoda and Ostracopoda (Crustacea) were absent. This low richness partly reflected the environmental characteristics of low current and nutrient-poor waters. The main taxa present (Lobosea, Protozoa: Lecanidae, Eurotatorea) are characteristic of environments with decomposing organic matter with abundant bacteria, fungi, and other protozoa.

Species of Eurotatoria and Protozoa were numerically dominant at most sites. Protozoa feed on bacteria and develop well in habitats where flow is slow. The mixture of sand and rock substrata, and the large amount of decomposed organic matter, provided excellent conditions for species such as *Pseudodifflugia gracilis, Difflugia elegans, Ceratium* spp.*,* and *Centropyxis aculeata,* which are numerically dominant at sites LNO, LPB, LVT, LPS, VSS, VSP. *Polyarthra vulgaris*, which characteristically occurs in areas with high suspended organic matter, was numerically dominant at sites CPS, CTU, VTC, and CSP. At VTC, CPS, and CTU, there were high suspended solids levels and waste water, and at VTC there were also fish cages. However conditions were quite different at CSP, which was a more pristine site.

The site with the highest abundance of zooplankton was TMU, where there were high densities of larvae of Copepoda and *Ceratium* spp. (Protozoa). In contrast, at LKD, the nutrient-poor environment was reflected in the lowest abundance found at all of the sites, with the exception of *Keratella cochlearis* (Eurotatorea) and *Arcella vulgaris* (Protozoa).

The ordination analysis for zooplankton samples for 20 sites indicated that the arrangement of sites was most strongly associated with two variables, temperature and altitude. Temperature was inversely correlated with both altitude and DO. Because higher-altitude locations are cooler and the solubility of oxygen is higher at lower temperatures, it was expected that most sites with high temperatures would have been at low altitude in the downstream part of the Mekong River and would have had low DO concentrations (CPS, CTU, CPP, VTC, and VCD). In the upland sites (LNO, LPB, and LVT) temperatures were low and DO had the highest values. Altitude can be used to divide the sites into two well-defined areas: (1) an upland area with sites LNO, LPB, LVT, TKO, VSP, and VSS, where there were many filter-feeding species such as Testudinella, Cephalodella, and Mytilina that are well adapted to fast currents, and (2) a lowland area with sites CKT, CSS, CSP, CPS, CTU, CPP, VTC, and VCD located in the downstream part of the Mekong River Basin.

For the ordination analysis of 14 sites (Figure 11), sites in Lao PDR tended to separate from the sites in Thailand, Cambodia, and Viet Nam, except for the site in Nam Ngum River (LNG). The arrangement of the 14 sites was most strongly associated with temperature, altitude, and DO. Almost all these sites were located at high altitude with high DO concentrations and low temperature. Nitrate had the strongest relationship with the zooplankton in the downstream sites such as CTU, CPP, VTC, and VCD, possibly because of the influence of nitrates on phytoplankton growth.

The ordinations produced several groupings of sites subject to similar human influences, for example sites downstream of dams (TMU and LNG), Cambodian tributaries (CSS and CSP), Vietnamese highland sites (VSS and VSP) and several sites corresponding to a downstream series (LPB, LVT, LPS). Finally, two sites, LNO and LKD, appeared to be unlike any others with respect to zooplankton. LNO was a shallow, stony section of a tributary, which is a less than ideal habitat for potamoplankton, while the upper reaches of Nam Kandinh were influenced by a dam and flows had been altered.

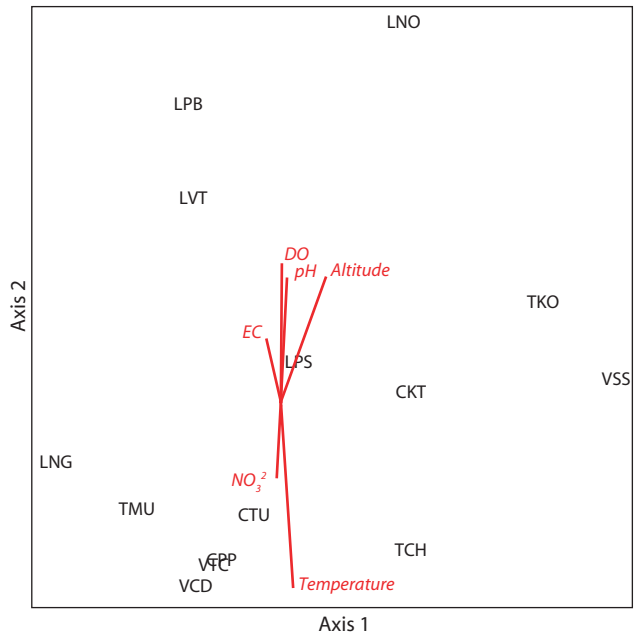

Figure 11. Ordination of 14 of the March 2004 Survey siues based on average zooplankton data in Figure 9 (over page). Lines indicate directions and relative magnitudes of correlations with environmental variables

6 Littoral macroinvertebrates

Introduction

Worldwide, benthic macroinvertebrates (including littoral taxa) are the biological assemblage most widely used for biomonitoring. They have several characteristics that make them particularly useful for this purpose (Barbour *et al*., 1999): (i) macroinvertebrates occur in almost all types of freshwater habitats, (ii) among the many taxa of macroinvertebrates there is a wide range of sensitivity to pollution and environmental stress, (iii) macroinvertebrates have mostly sedentary habits and so they are likely to be exposed to pollution or environmental stress, (iv) their life cycles are sufficiently long that they are likely to be exposed to pollution and environmental stress, and the community will not recover so quickly that the impact will go undetected, (v) sampling the benthic macroinvertebrate assemblage is relatively simple and does not require complicated devices or great effort, and (vi) taxonomic identification is almost always easy to the family level and usually relatively easy to the genus level.

Bioassessment approaches using benthic macroinvertebrates have been used previously in tropical areas. For example Thorne and Williams (1997) applied a variety of rapid assessment methods using macroinvertebrates in Brazil, Ghana, and Thailand. They tested 20 analytical methods that had been used in temperate regions, including representatives of the five major types of analytical tools identified by Resh and Jackson (1993): richness indices, enumerations, diversity and similarity measures, biotic indices, and functional-feeding group measures. Of this number, seven specific measures behaved as expected in response to pollution gradients, but these measures did not include any of the enumeration or functional-feeding-group indicators. The two diversity indices also failed to respond to a pollution gradient in the predicted manner, although the three 'similarity/loss indices' all met the test criteria. Both the BMWP score and BMWP (ASPT) performed satisfactorily.

In northern Thailand, Mustow (1997) studied the macroinvertebrate community at 23 sites on the Mae Ping River and also suggested some modifications to the BMWP score to suit local conditions. According to Mustow (1997), 71 of the 85 families in the original index are known to occur in Thailand and 65 of these, together with an additional 33 that do not occur in the U.K., were found in the Mae Ping system. He incorporated 10 of these additional families in a modified BMWP scoring system, which he called the $BMWP^{THAI}$ score.

In 2003, a littoral macroinvertebrate study in the Mekong River system was conducted under the ecological health monitoring activity of the Mekong River Commission. The study included 13 sites in the Mekong River system in the four lower Mekong countries: Cambodia, Lao PDR, Thailand, and Viet Nam. The study applied 'kick' and 'sweep' sampling techniques, both of which are useful and applicable for evaluating the diversity of macroinvertebrates. However, for site comparisons, the sweep sampling technique was more appropriate because it can be applied to all sites in the Mekong River system. The littoral macroinvertebrate data were then summarised in term of diversity and abundance, and with a biotic index (SIGNAL value). The sites were also analysed with cluster analysis.

In 2004, littoral macroinvertebrates were collected by sweep sampling from 20 sites in the lower Mekong River and selected tributaries. The tasks for this component of the survey were to describe the ecological condition of the study sites by using sample data to (i) describe the taxonomic richness and composition and the relative abundance of littoral macroinvertebrates at the sites, (ii) examine within-site variability of replicate samples, (iii) compare the sites in terms of how they group in multivariate analyses, and (iv) relate these results to the physical and chemical characteristics of the sites.

Study sites and methods

Sites

At the 20 sites described in Chapter 2, littoral macroinvertebrate samples were taken in March 2004 on one side of the river.

Field methods

We attempted to select as similar habitats as possible at each site and used a standard sweep method for sampling. This was important because the study area was large, covering a wide range of habitats with many different physical and chemical environments. Standardisation was critical in order to be able to compare sites. The detailed sampling protocol used is described below.

1. As a result of experience in 2003, only a sweep-net method (D-frame net with 30 cm x 20 cm opening, mesh size 475 μm) was used for sampling littoral macroinvertebrates in this study.

2. At each site, one side of the river was selected as a sampling area, usually the depositional side where samples easily could be taken and more aquatic vegetation occurred. Eight sites were sampled on the left side of the river: LNO, LPB, LKD, TMU, TKO, CPP, VCD, and VSP. Eleven sites were sampled on the right side: LVT, LNG, LPS, TCH, TSK, CTU, CPS, CSS, CSP, CKT, and VSS. One site was on an island in the middle of the river, VTC. The length of the sampling was 100 m divided into ten plots of 10 m. Six of the ten plots were chosen for sampling with a random number table, and a single sample was taken in each.

3. The collector stood in the river about 1.5 m from the water's edge. Working in an upstream direction, the net was swept 10 times near the substratum surface (for one sample) while moving forward. Each sweep was about 1 m at right angles to the bank and in water between 1 and 1.5 m deep. All substrata, including cobbles, gravel, sand, silt, mud, and aquatic plants, were sampled.

In order to reduce the amount of material returned to the laboratory, and laboratory sorting time, field sorting was done following the procedures described below.

1. The net contents were washed to the bottom of the net, the net was inverted, and the contents were emptied into a bucket, rinsing off any material remaining on the net. A lid was placed on the bucket to prevent mobile macroinvertebrates from jumping or flying away.

2. After the lid was lifted, a handful of material was removed from the bucket and placed quickly on a 0.5 mm mesh sieve. The material on the sieve was washed thoroughly by half submerging the sieve in the river or a bucket of clean water and shaking it. Mobile macroinvertebrates were prevented from jumping or flying out of the sieve.

3. The contents of the sieve were placed in a white sorting tray, adhering material was rinsed off with clean water, and the sample was dispersed in the water. Any animals clinging to the net were picked off and added to the tray.

4. While picking, the tray was shaken from time to time to redistribute the contents and tilted occasionally to look for animals adhering to it.

5. All animals were removed from the sorting tray in the field using forceps and pipettes, and placed into plastic jars containing 70% alcohol.

6. Species present in large numbers were washed off in bulk. A second person then checked the tray to be sure no animals were present. Steps 2–6 were repeated until the entire sample had been processed.
7. The sample jars were labelled with site name, location code, date, and replicate number.
8. The collector's name, the sampling site, and replicate characteristics (including substrata sampled) were recorded in a field notebook.

Small samples were kept in 30 ml jars, and large samples in 150 ml jars, stored at room temperature (25–30 ^{o}C). When large numbers of macroinvertebrates were to be kept in a jar or dilution with water occurred, some 95% ethanol was added in order to keep the preservative medium (ethanol) at 70%.

Laboratory methods

The collected samples were sorted and identified as follows:

1. In the laboratory, the samples were divided into taxonomic orders, kept in separate jars and labeled as in step 7 of the field procedure.
2. Identification was done to the lowest taxonomic level that could be applied accurately, usually to genus.
3. The identification was made with the aid of a stereo-microscope with 20–40x magnification.
4. All specimens were kept in the Department of Biology at the National University of Laos.

Data analysis

Cluster analysis and ordination were performed with the PC-ORD statistical software (version 4: MjM Software Design, Geleneden Beach, Oregon, USA) on littoral macroinvertebrate count data transformed as log (count + 1). The Sorenson (Bray-Curtis) distance measure was used. Cluster analysis was done with the flexible beta method of group linkage (beta = -0.25). Ordination was done with two-dimensional non-metric multidimensional scaling with varimax rotation. The correlations of the environmental variables with the ordinations were calculated and the strongest correlations were plotted as vectors on the ordination diagrams.

Results

General characteristics of the littoral macroinvertebrates

In total, 128 taxa and 23,365 individuals were collected at the 20 sites examined in March, 2004 (Table 6 and Annex 4). Taxon richness at a site ranged from 7 to 53 (Figure 12). The highest richness occurred at sites CSP and VSP and the lowest richness at site CPP. Species of Decapoda, Hemiptera, and Diptera had the widest distribution and occurred at 19 sites. Ephemeroptera and Mesogastropoda were also widely distributed and occurred at 18 sites. The number of individuals at a site ranged from 36 to 9,759 (Figure 13). The highest abundance occurred at site VTC and the lowest at site CPP.

The samples collected contained some macroinvertebrate taxa that are eaten by humans: the groups Decapoda, Bivalvia, and Mesogastropoda, and individual species such as the three economically important species of Decapoda (*Macrobrachium pilimanus, M. lanchesteri*, and an atyid species), two

species of Bivalvia (*Scabies* sp. and *Corbicula* sp.), and two species of Mesogastropoda (*Melanodes tuberculata* and *Taribia granifera*).

Table 6. *Abundance of littoral macroinvertebrate taxa*

Taxon	Number of individuals	Percentage of individuals	Percentage of sites at which taxon occurred
Bivalvia	597	2.56	85
Mesogastropoda	3790	16.22	90
Decapoda	1634	6.99	95
Amphipoda	22	0.09	10
Isopoda	26	0.11	35
Coleoptera	39	0.17	50
Lepidoptera	11	0.05	15
Odonata	502	2.15	80
Hemiptera	11391	48.75	95
Ephemeroptera	3778	16.17	90
Diptera	1399	5.99	95
Plecoptera	27	0.12	50
Trichoptera	49	0.21	60
Oligochaeta	90	0.39	60
Polychaeta	10	0.04	15
Total	**23365**		

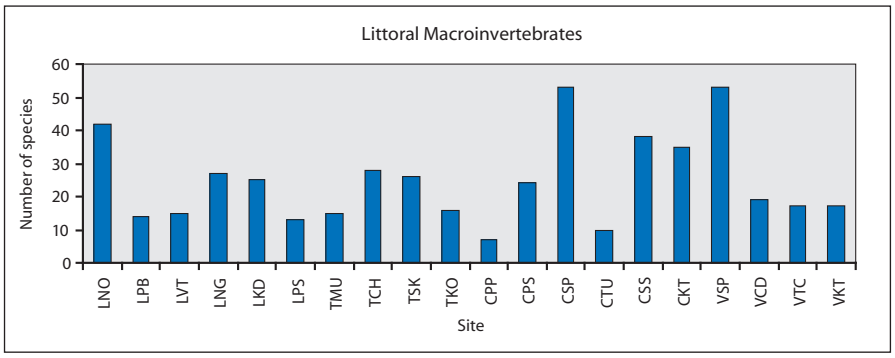

Figure 12. Species richness of littoral macroinvertebrate taxa

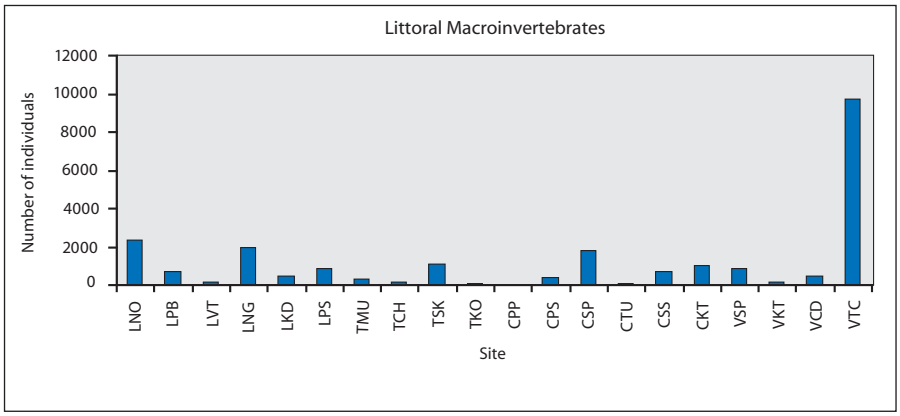

Figure 13. Abundance of littoral macroinvertebrate taxa

Within-site variability

A cluster analysis was conducted on all samples collected to assess within-site variability. For the most part, samples from within a site clustered together, indicating that within-site variability was less than the variability among sites. The six samples within a site clustered together for each of LNO, LNG, LPB, TSK, LPS, and CPS, but not for the other sites. However, at all sites at least three of the samples formed a single cluster.

Among-site variability

The cluster analysis of averaged data for each of the 20 sites produced seven groups at the 50% level of information remaining (Figure 14). Group I included two Lao sites (LNO, LKD), two Cambodian sites (CSS, CSP), and one Vietnamese site (VSP). These sites were located on Mekong River tributaries and had similar abundances of Hemiptera and Ephemeroptera species. Group II included two Lao sites (LPB and LVT) and one Thai site (TKO), which had the highest abundance of Ephemeroptera species. Group III included only two Lao sites (LNG and LPS), which were distinguished by the highest number of Hemiptera species. Group IV incorporated two Vietnamese sites (VCD and VTC) and one Thai site (TMU), this grouping resulting from the abundance of Mesogastropoda and Decapoda species. Group V clustered two Thai sites (TCH and TSK) and two Cambodian sites (CPS and CKT), which had high numbers of Mesogastropoda, Decapoda, Diptera, and Ephemeroptera species. Group VI included only one Cambodian site (CPP), which was lowest in both richness and abundance. Group VII included one Cambodian site (CTU) and one Vietnamese site (VSS), which had similar abundances of Decapoda and Diptera species.

The ordination analysis for the averages of each of the 20 sites produced a pattern with a stress value of 16.4, indicating that the ordination was a good representation of the similarities among the sites. The grouping of sites in the ordination was similar to the grouping in the cluster analysis, except that TSK and CKT were grouped with TCH and CPS in the cluster analysis but were not close together in the ordination (Figure 15). Vectors for chemical and physical variables, overlaid on the ordination space, indicated that the factors most strongly associated with the distribution of littoral macroinvertebrates were DO, pH, Secchi disc depth, and temperature (Figure 15). Axis 1 was strongly and positively correlated with temperature (Figure 15), and tended to separate the more downstream sites in Cambodia and Viet Nam from the more upstream sites. The correlations on Axis 1 with other factors (DO, pH, and Secchi depth) were weak and negative. Axis 2 was positively and moderately correlated with secchi depth, pH, and DO. The site groups 1, 2 and, 3 were associated with clearer water and higher dissolved oxygen and tended to have higher scores on this axis. Only temperature showed a negative correlation on this axis, and it was low.

The environmental factors that were most strongly correlated with the ordination of all 20 sites were temperature, secchi depth, pH, and DO (Figure 15). However, when the 2002 water-quality data for the 14 sites where levels of nitrates, phosphates, and suspended solids were measured, phosphorous was the environmental factor that correlated most strongly (Figure 16). Correlations with the remaining variables were weak ($r < 0.5$ with both axes).

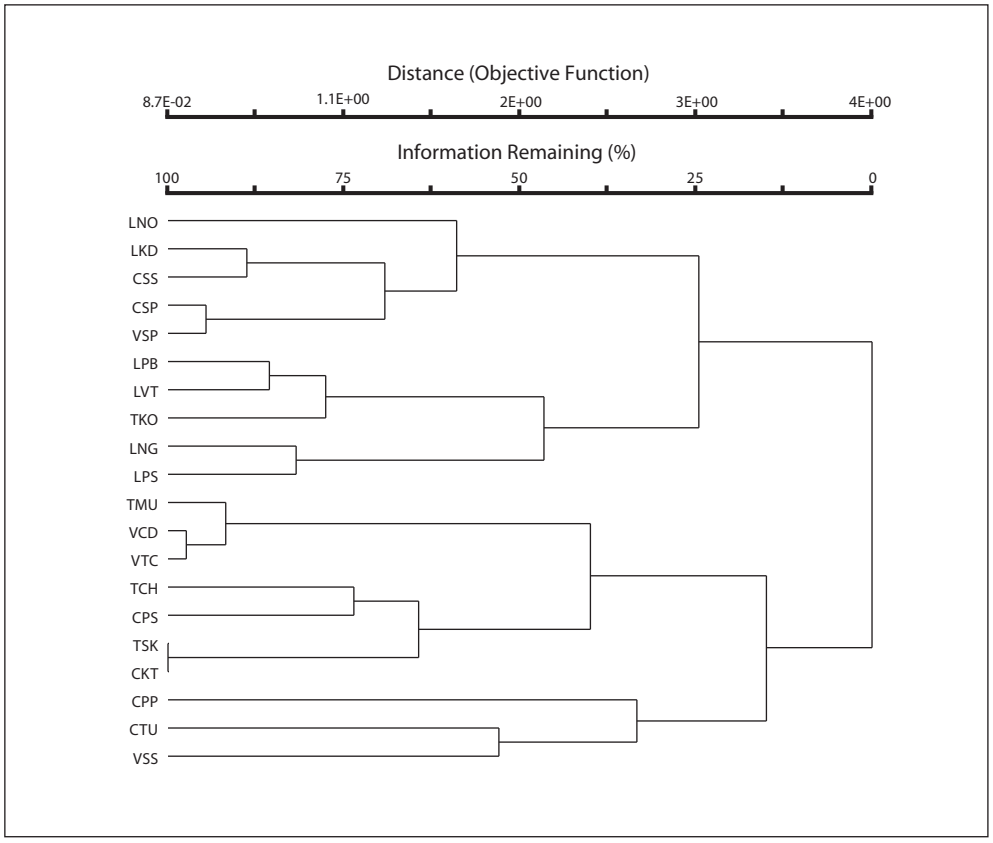

Figure 14. Dendrogram from cluster analysis of average data for littoral macroinvertebrates at all 20 of the March 2004 survey sites

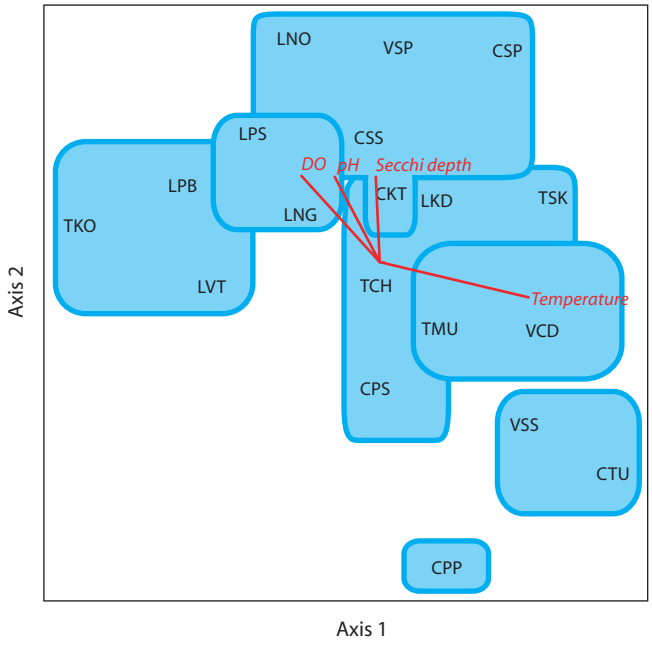

Figure 15. Ordination based on average littoral macroinvertebrates from in Figure 14 (above). Lines indicate directions and relative magnitudes of correlations with environmental variables

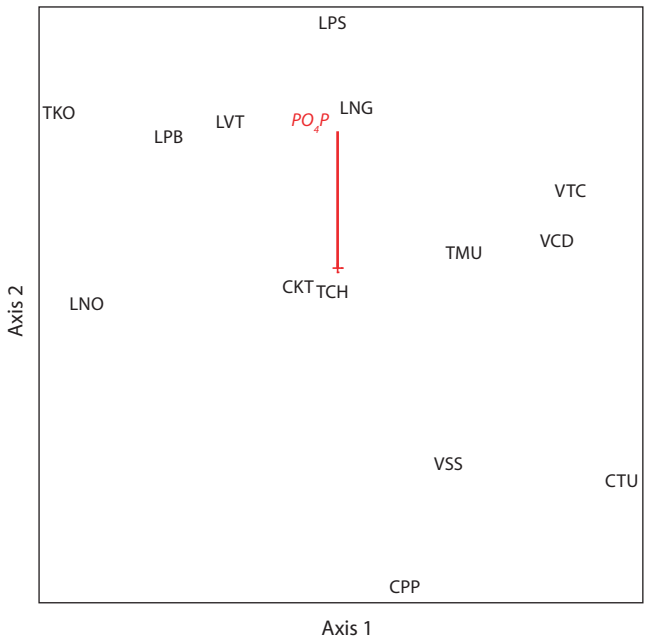

Figure 16. Ordination based on average littoral macroinvertebrates at 14 of the March 2004 Survey sites. Lines indicate directions and relative magnitudes of correlations with environmental variables

Discussion

The greatest species richness was found in two sites on the Sre Pok (CSP and VSP) and in the Nam Ou (LNO) and was likely associated with the habitat type (rocky beds and aquatic vegetation) at these sites. Cobble and boulder substrata, such as those at these sites, are well known to be the richest stream invertebrate habitats (e.g. see Hynes 1970). The sites that had a high diversity of species also displayed high DO, pH, and Secchi depth readings. In contrast, at CPP where there was low richness, DO, pH and Secchi disc readings were also low. In essence, the species richness of littoral macroinvertebrates depends on habitat type and the environmental factors present (e.g. rocky, vegetative habitat, and clean water).

The highest abundance throughout the catchment was in the order Hemiptera, which includes species that are considered to be relatively pollution tolerant. Pollution-sensitive species such as Ephemeroptera were also abundant at the sites studied, but were mostly found in the upper sites (e.g. LNO). The highest abundance of tolerant orders (Hemiptera, Mesogastropoda and Diptera) was found in the lower sites where environmental measurements such as DO and Secchi depth were also lower. The abundance of tolerant species tended to increase at sites with poorer water quality, whereas the sensitive species were more abundant at cleaner sites.

Both the cluster analysis and the dendrograms show distinct patterns and groupings of sites. One of the most obvious groups was a cluster of three left-bank tributaries: CSP, VSP and LNO. While differing in altitude, all three sites showed little evidence of physical disturbance, and all had cobble-boulder substrata that invertebrates often favour. Three sites associated with potentially poor water-quality did not form a cluster. CPP and CTU are sites close to Phnom Penh, and TKO is located in the Kok River downstream of Chiang Rai. Even though the physical characteristics of CPP and CTU were similar, these two sites likewise did not form a group.

By contrast, LNG and TMU, two sites that were potentially affected by upstream dams, did not form a group, but four Lao sites, LNG, LPB, LPS, and LVT, formed a relatively loose cluster. Three are located on the mainstream and one on a large tributary. The Vientiane (LVT) and Pakse (LPS) sites could be influenced to some extent by their proximity to cities. The Luang Prabang site (LPB) was upstream of the town, but possibly influenced by wash from fast tourist boats. Interestingly, the Kok River site (TKO), which also suffered from boat wash, ordinated fairly closely to this group.

Physical factors apparently influenced the groupings as well. For example, three sites, TSK, VTC, and VCD, grouped together at the low-DO and high-temperature region of the ordination. VTC and VCD are delta sites located near intense agriculture and high human population densities, and the delta waters have very high phosphorus concentrations. The Songkhram River (TSK) does not have elevated phosphorus levels but does have high levels of nitrate (MRC, 2005), and it is possible that this group of sites has elevated levels of nutrients in common.

7 Benthic macroinvertebrates

Introduction

Benthic macroinvertebrates living on the bottom of channels are one of the most promising of the potential indicators of river health for the lower Mekong River. They are (i) ubiquitous and abundant throughout the river systems, (ii) relatively easy to collect, (iii) relatively easy to identify, (iv) confined for the most part to one locality on the river bed and therefore indicative of the past as well as present water quality conditions, (iv) long lived and thus responsive to antecedent conditions over a long period, and (v) a heterogeneous collection of evolutionarily diverse taxa, so that it is likely that at least some will react to specific changes in water and habitat quality.

The objective of this component of the study was to describe the ecological status of the lower Mekong River and its tributaries in 2004 by (i) surveying the benthic macroinvertebrates of the study sites, (ii) investigating the taxonomic richness and composition and the assemblage structure of the benthic macroinvertebrates, (iii) determining how the sites sampled group together according to the fauna collected, and (iv) relating these grouping results to the environmental characteristics of the sites.

Study sites and methods

Sites

The zoobenthos was sampled at 20 sites in the Mekong River and selected tributaries. A description of the sampling sites and their environmental characteristics is presented in Chapter 2.

Field methods

Consistent field methods were used at all sites, following the steps listed below.

1. To select sample locations at a site, random numbers between 1 and 100 were chosen from a table of random numbers. These numbers were used to select five points within 100 m transects at each of the right, middle, and left portions of the river.
2. At each sampling site, five sample units (each a composite of 4 grabs) were taken on the right (R), five on the left (L), and five at the middle (M) (when possible; see point 5) of the river at these points. A Petersen grab sampler, which samples 250 cm^2, was used.
3. Prior the sampling, the grab, sieve, and other equipment used were thoroughly cleaned to remove any material left from the previous sample.
4. At each random point selected, the Petersen grab was used to sample a total area of 0.1 m^2. This was done by combining four individual grabs into a single sample unit. The material collected was washed in the sieve with care taken to be sure that macroinvertebrates did not escape.
5. A sample was not collected in the middle of the river at sites where there were rocky or hard beds in which the grab was ineffective, fast currents prevented the grab from taking a sample, or the water was less than 30 m wide.

6. Samples were discarded if the grab did not close properly, as for example when material such as wood, bamboo, large water plants, or stones jammed the grab's jaws.

7. After the sample was collected, the contents of the sieve were placed in a white sorting tray. Adhering material was rinsed from the sampler with clean water, and the sample was dispersed in the water. Any animals clinging to the sieve were picked or washed off and placed into the tray.

8. All animals in the tray were picked out with forceps and pipettes, and put in jars containing a solution of 95% alcohol. Samples picked by a less experienced sorter were checked by an experienced sorter.

9. Sometimes, samples could not be sorted on site, as for example if the boat was poorly balanced, too many animals were collected, or there was too little time at a site. In these cases, samples were preserved whole in the field and sorted in the laboratory.

10. The sample jar was labeled with site name, position, location code, date, and replicate number.

11. The sampling location conditions, collector's name, and sorter's name were recorded on the field sheet.

Laboratory methods

All individuals collected were identified and counted. The results were recorded on data sheets and specimens are kept at the Institute of Tropical Biology, Viet Nam.

Data analysis

The number of individuals collected in the four grab samples (each 0.1 m^2) was multiplied by 10 to calculate the number per square metre. Diversity and dominance indices were calculated for individual samples and then averaged for each site. Species diversity was calculated with the Shannon–Wiener diversity index:

$$H' = - \sum p_i \ln p_i$$

where p_i is the proportion of species i in the total sample (formula from Stiling, 1998).

Species dominance was calculated with the Berger–Parker dominance index:

$$D = 1 - \frac{N\max}{N}$$

where *N*max is the total number of individuals of the most common species and *N* is the total number of individuals in the sample (formula from Stiling, 1998).

Diversity indices have higher values when samples have larger numbers of species, i.e. when species richness is higher, and when individuals are more evenly distributed among species. Dominance indices assess species evenness, giving higher values when individuals are more evenly distributed among species. It has been suggested that stressed ecosystems tend to have reduced species diversity and evenness values.

Cluster analysis and ordination were performed with the PC-ORD statistical software (version 4: MjM Software Design, Geleneden Beach, Oregon, USA) on benthic macroinvertebrate count data transformed as log (count + 1). The Sorenson (Bray–Curtis) distance measure was used. Cluster analysis was done with the flexible beta method of group linkage (beta = -0.25). Ordination was done with two-dimensional

non-metric multidimensional scaling with varimax rotation. The correlations of the environmental variables with the ordinations were calculated and the strongest correlations were plotted as vectors on the ordination diagrams.

Results

General characteristics of the benthic macroinvertebrates

In total, 100 taxa of channel-bottom macroinvertebrates were collected at the 20 sites (Table 7). Most of these taxa were insects.

Table 7. *Total number of taxa in each phylum or class of benthic macroinvertebrates*

Phylum or class	Number of taxa
Polychaeta	3
Oligochaeta	5
Mollusca	38
Crustacea	7
Insecta (including larvae)	47
Total species	**100**

Taxon richness at a site ranged widely, from 2 to 30 taxa (Table 11 — over page). The highest richness occurred at the sites LNO (30 species) and VCD (30 species). Species of insect, including larval forms, were predominant at site LNO whereas species of Mollusca were dominant at site VCD. The lowest richness occurred at sites of VSS (2 taxa) and LVT (4 taxa), where species of insects were predominant.

In total, 9,331 individuals were collected at the 20 sites. The mean number of individuals at a site was highly variable, ranging from 2 to 2,190 individuals/m^2. As with numbers of taxa, the highest abundances occurred at sites with muddy substrates with abundant organic matter such as VTC (2,190 individuals/m^2), while the lowest abundances occurred at sites with sandy and clay substrata, such as sites LVT and VSS (2–3 individuals/m^2) (Table 12).

Insects were found at all 20 sites, and Oligochaeta and Mollusca were also widely distributed, being found at 18 of the 20 sites. Of the Oligochaeta, species of Naididae were usually found at sites with faster-flowing water, whereas species of Tubificidae commonly occurred at the lowland sites with slower currents. Crustacea were absent from uppermost sites, but increased in abundance in the downstream direction.

The chironomid midge larva *Polypedilum* sp. had the widest distribution, occurring at 16 sites. Several other taxa (*Limnodrilus hoffmeisteri, Branchiura sowerbyi, Corbicula tenuis, Corbicula blandiana, Dromogomphus* sp., Psychomyiidae., *Culicoides* sp., and *Ablabesmyia* sp.) were also widely distributed (Appendix 7.1).

Estuarine and marine species of polychaetes, isopods and amphipods occurred at 4 sites: CPP, CTU, VTC, and VCD. These sites were all in the lower reaches of the river and presumably within the area of salt water intrusion for at least part of the year, which most likely occurred in the dry season when this sampling was conducted. The channel-bottom macroinvertebrate fauna consisted entirely of freshwater species at the rest of the sites.

Table 8. *Number of taxa of benthic macroinvertebrates*

Site	Polychaeta	Oligochaeta	Mollusca	Crustacea	Insecta	Total
LNO	-	2	3	-	25	30
LPB	-	1	2	-	10	13
LVT	-	-	-	-	4	4
LNG	-	3	7	1	11	22
LKD	-	1	4	-	9	14
LPS	-	2	11	-	11	24
TMU	-	2	1	-	5	8
TCH	-	1	7	-	10	18
TSK	-	2	11	-	7	20
TKO	-	2	3	-	14	19
CPP	2	2	8	3	4	19
CTU	1	2	12	2	5	22
CPS	-	1	4	-	5	10
CSS	-	2	3	1	8	14
CSP	-	2	2	-	9	13
CKT	-	1	3	-	6	10
VTC	2	2	13	5	5	27
VCD	2	2	15	5	6	30
VKT (=VSS)	-	-	-	-	2	2
VSP	-	2	5	-	12	19

Table 9. *Abundance of benthic macroinvertebrates in various portions of the river*

Site	Density (individuals/m^2)			
	Left	Middle	Right	Average
LNO	300–1040	-	-	550
LPB	120–450	-	-	250
LVT	-	-	0–20	3
LNG	190–1480	-	90–450	420
LKD	50–990	-	220–360	370
LPS	250–1380	-	190–640	580
TMU	30–100	-	60–170	80
TCH	50–720	90– 200	80–190	200
TSK	1130–3520	-	60–830	1220
TKO	50–490	-	260–540	310
CPP	270–930	-	280–720	510
CTU	160–960	180–1080	130–430	460
CPS	10–90	-	20–320	80
CSS	0–30	0–10	10–150	30
CSP	20–180	10–90	60–170	80
CKT	110–200	0–10	10–90	70
VTC	690–4480	560–1940	60–6990	2190
VCD	140–900	310–760	270–540	430
VSS	0–10	0–10	0	2
VSP	400–1370		250–890	770

Oligochaeta and Mollusca were widely distributed, occurring at 18 sites. In terms of number of species, molluscs were most abundant at CTU (12 species, 55% of species at this site), VTC (13 species, 48%) and VCD (15 species, 50%). Of the Oligochaeta, species of Naididae were found mostly in the sites with riffles, while species of Tubificidae occurred commonly in the sites in the lowland with slower currents.

Relatively few crustacean species were encountered, while insects were more speciose and occurred at all sites. Crustaceans were apparently absent from most upstream sites and tended to increase in richness at downstream locations while the number of species of insects varied erratically.

Of the 100 taxa identified in this work, 45 were found at only a single site (Annex 5). In most cases these taxa occurred in low abundance. In some cases, these low-abundance taxa belong to groups that are not normally associated with the sort of soft sediments sampled in this component of the study. For example Heptageniidae and Leptophlebiidae (Insecta, Ephemeroptera) normally occur on rocks and stones, while Gerridae and Corixidae (Insecta, Hemiptera) are neustonic or pelagic. Many of these species could be considered 'vagrants' in the soft-sediment habitats.

Within-site variability

A cluster analysis of the samples collected within sites (left and right banks, middle of river) indicated that samples from the same site generally clustered together. For example, for four of the nine sites in which all three areas (left, right, and middle locations) could be sampled, all within-site samples clustered together. In another four of these nine sites, samples from two locations clustered together.

Among-site variability

The patterns of values for the diversity and dominance indices at the 20 sites were similar (Figures 17 and 18). The diversity index values ranged from 0 to 2.0 (Figure 17) while values of the dominance index ranged from 0 to 0.67 (Figure 18). Both indices ranked site LNO highest and site VSS as lowest. While there were differences in relative rankings, both indices ranked sites LVT, CKT, and CSS as having low values and LPB, LPS, CTU, VCD, CPP, and VTC as having high values

From the cluster analysis (Figure 19), the macroinvertebrate fauna could be divided into six groups: (i) LNO, and LPB (upstream sites); (ii) LPS and CKT (mid-region with fast currents); LNG, LKD, TKO, CPS (tributary sites); CPP (downstream sites with fast currents and tide effects); (iii) TMU, TCH, TSK, CSS, CSP, and VSP (tributary sites); (iv) CTU, VTC, and VCD (downstream sites with soft sediment); (v) LVT (middle of main Mekong River with low richness); and (vi) VSS (tributary site with low richness).

When ordination analysis was performed, the high stress value (27.6) indicated that the relationships were somewhat distorted in a two-dimensional plot and should be interpreted cautiously. Temperature and altitude were the environmental variables most strongly associated with the spatial patterns of the channel-bottom macroinvertebrates (Figure 20).

The ordination analysis results for channel-bottom macroinvertebrates at 14 sites, including water quality data collected in 2002, had a stress value of 15.8, which indicates that the ordination is a good representation of the similarities among the sites. Altitude and amount of mud were the environmental variables most strongly associated with the spatial patterns of the macroinvertebrates (Figure 21).

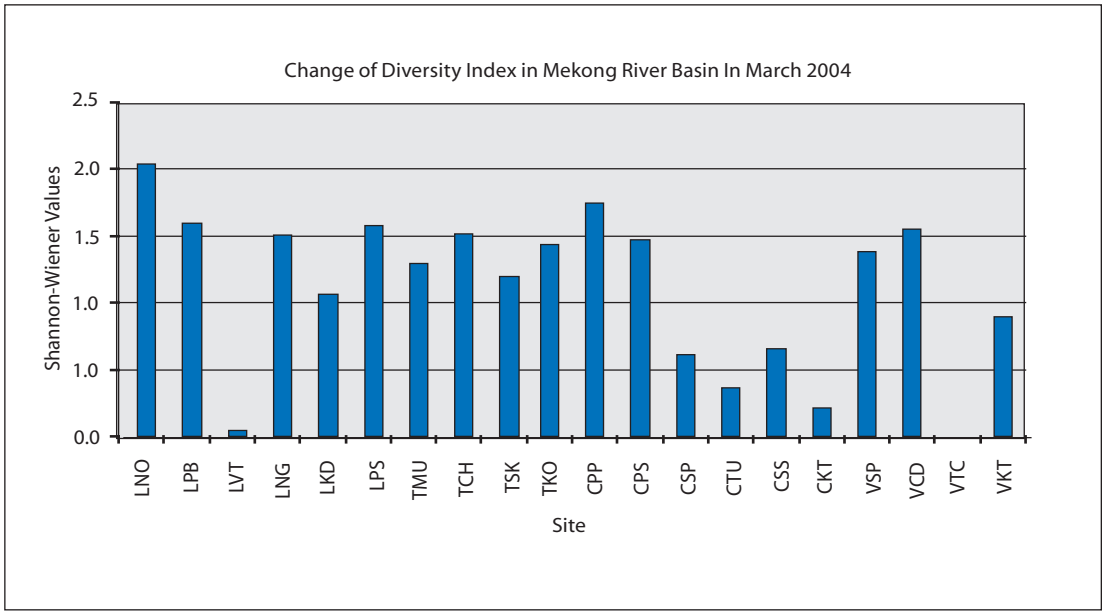

Figure 17. Values of the Shannon - Wiener index of benthic macroinvertebrates at the March 2004 Survey sites

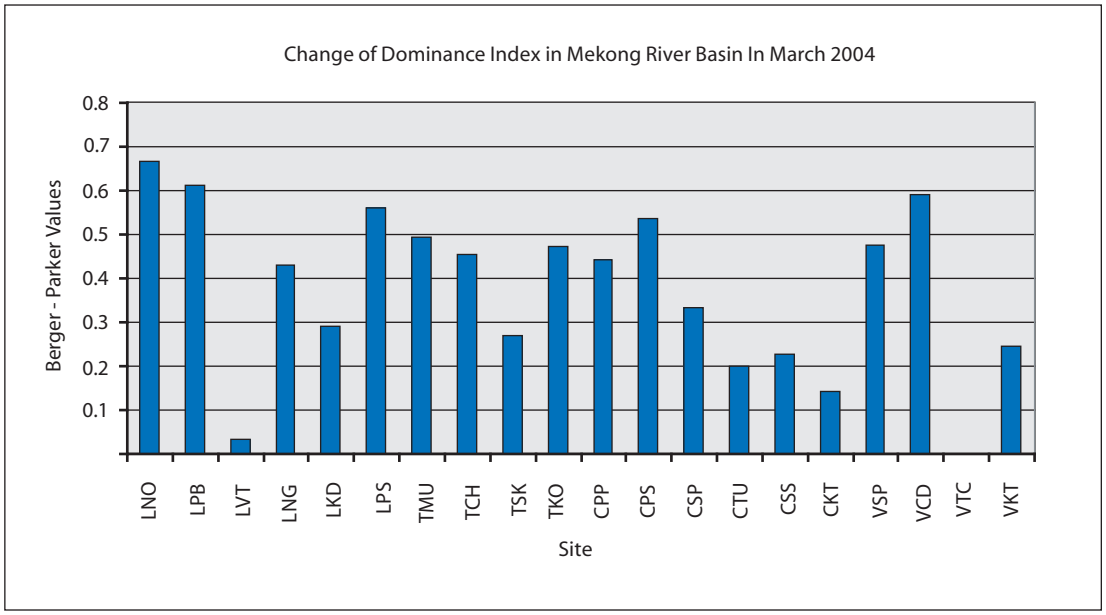

Figure 18. Values of the dominance index of benthic macroinvertebrates at the March 2004 Survey sites

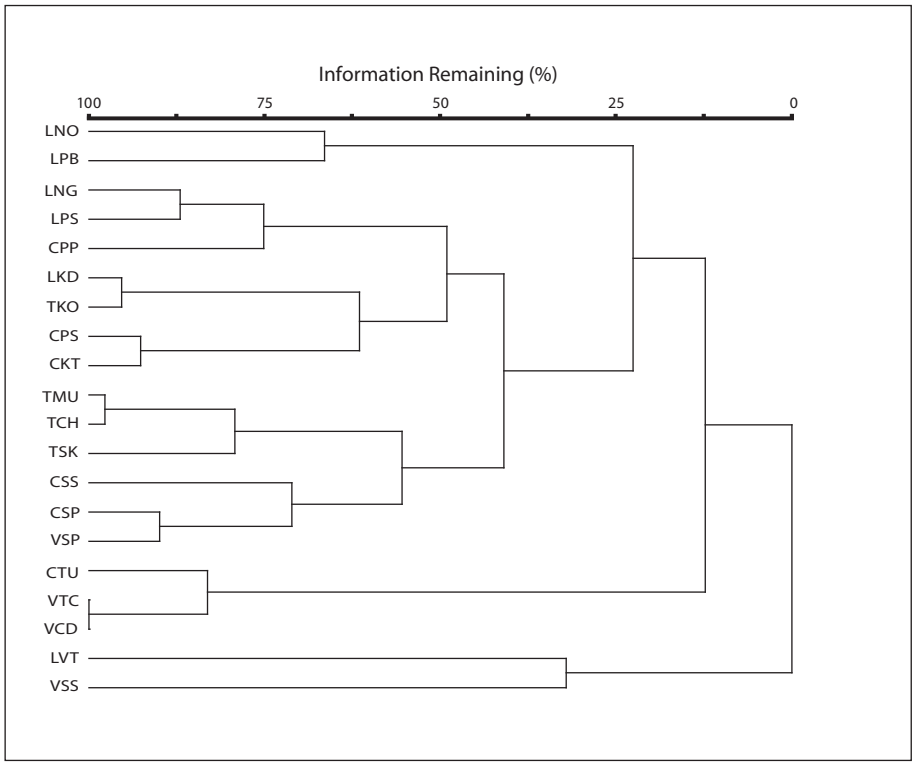

Figure 19. Dendrogram from cluster analysis of average data for benthic macroinvertebrates at the March 2004 Survey sites

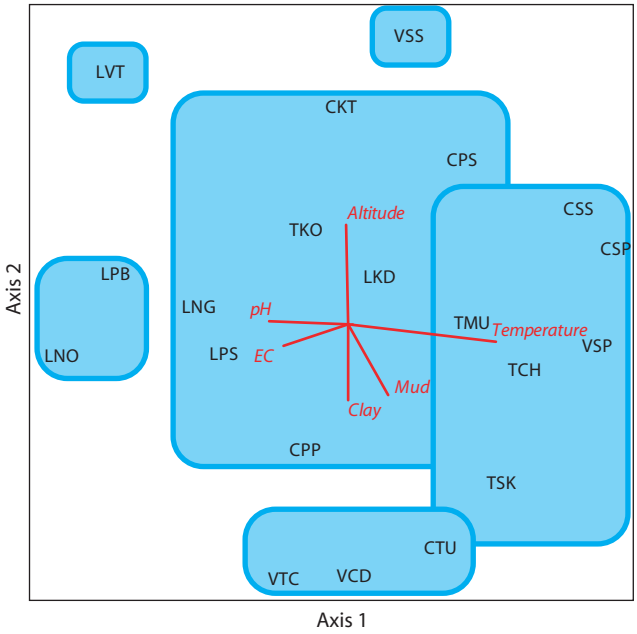

Figure 20. Ordination based on average data benthic macroinvertebrates. Lines indicate directions and relative magnitudes of correlations with environmental variables

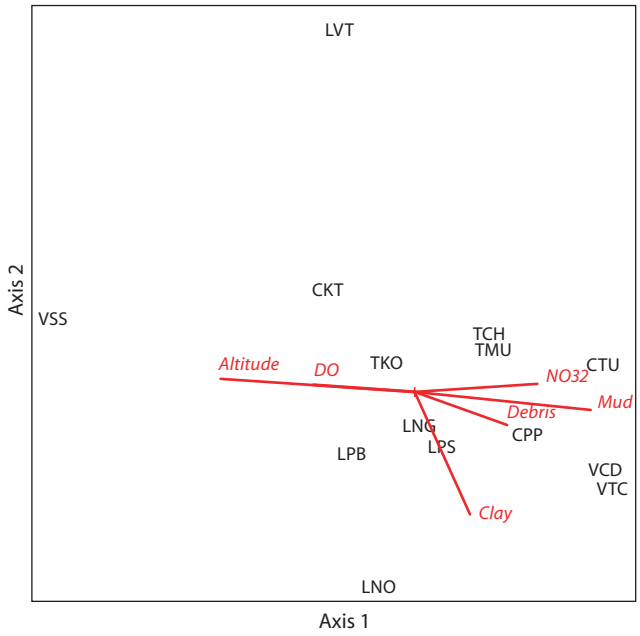

Figure 21. Ordination based on average data benthic macroinvertebrates at 14 of the March 2004 Survey sites. Lines indicate directions and relative magnitudes of correlations with environmental variables

Discussion

Taxon richness was highly variable among the sites, probably because of substrate and other habitat differences. The high richness at the sites LNO (30 species), LNG (22), LPS (22), VTC (27), and VCD (30) probably resulted from the soft sediment of mud, sand, and abundant organic debris that made these habitats conducive to channel-bottom macroinvertebrates. In contrast, the coarse sandy substrate at sites LVT (4 species) and VSS (2) was an obvious limiting factor for channel-bottom macroinvertebrates. Several of the species that were widespread are characteristic of nutrient-rich conditions. These included *Limnodrilus hoffmeisteri, Branchiura sowerbyi, Corbicula tenuis, Corbicula blandiana, Dromogomphus* sp., Psychomyiidae spp., *Culicoides* sp., *Ablabesmyia* sp., and *Polypedilum* sp. Furthermore, species of the family Tubificidae, which occurred in most sites in the lower reaches of the river, are also characteristic of nutrient-enriched waters. Estuarine and marine species (including species of Polychaeta) occurred in four sites (CPP, CTU, VTC, and VCD), which may indicate the upstream extent of estuarine salt intrusion. In other sites, the channel-bottom macroinvertebrates comprised entirely freshwater species.

As with richness, the mean numbers of individuals were probably highly variable among the sites surveyed because of the variety of different substrates and other features of the habitat. The more sandy substrate that occurred at the sites LVT and VSS limited the development of channel-bottom macroinvertebrates in terms both of richness and abundance. Abundances were higher at sites with more muddy substrates and abundant organic material.

The values of the diversity and dominance indices for channel-bottom macroinvertebrates did not reflect the patterns that would be expected from *a priori* knowledge about likely human impacts on the sites. We expected that sites such as CPP, CTU, VCD, VTC, LNG, TMU, and CSS would have low diversity and low dominance index values. We would also have expected sites such as VSP, CSP, and LNO would have

high index values. However, only one of the sites (LNO) where high index values were expected had high values and only one site where low values were expected (CSS) had low values. In fact, the values of the index at many of the potentially impacted sites, such as CPP, CTU, VCD, and VTC, were amongst the highest encountered. This possibly indicates the enrichment effect of small amounts of nutrients, and the absence of any toxicity.

Results obtained also indicate that water-quality impacts and other human influences were not sufficiently large at any of the sites, with the possible exception of CSS, to have a major impact on the diversity of channel-bottom macroinvertebrates. Had the impacts been more intense, it would be expected that both diversity and species richness would have been low at these sites. In the case of CSS, diversity and dominance were relatively low, but results from other indicators such as the diatoms and littoral invertebrates did not indicate severe environmental stress, suggesting that there is not a major problem at the site. It is likely that the low index values at some sites reflect habitat unsuitability for macroinvertebrates rather than human-induced stress. For example, sand and clay are both known to be poor habitats for freshwater invertebrates (Hynes, 1970), and sand was a major feature of the habitat at sites VSS, CSS, LVT and CKT which had the lowest index values.

In the ordination analysis, Axis 1 was mainly associated with temperature and tended to separate the cooler upland sites from the warmer lowland sites. This suggests that a strong natural gradient influenced the zoobenthos. Sometimes, temperature may have been affected by the times of day when the measurements were taken. For example, some sites in the uplands had high temperatures (TCH, VSS, and VSP). Axis 2 was mainly associated with altitude, clay, and mud. It tended to separate the upland sites with rocky, gravel, and sand substrates from the lowland sites with clay and mud. Thus, substratum type is another important natural factor influencing the fauna.

8 Conclusions

The 2004 biomonitoring survey was part of a five-year programme of surveys that aims to provide information on the ecological health of the Lower Mekong River system. Further field campaigns are being run in 2005, 2006, and 2007. By the end of the programme, sufficient knowledge will have been acquired to allow the MRC to develop a biomonitoring method that is designed for the particular environmental conditions of the Mekong and its tributaries.

The major objectives of the 2004 survey were (1) the collection of information on the taxonomic composition and abundance of four biological communities, (2) identification of the physical and chemical factors that most strongly associate with spatial variation in these biological communities, and (3) investigation of within-site and among-site site variability of the biological communities.

All four communities were shown to be taxonomically diverse, with 206 taxa of benthic diatoms, 138 taxa of zooplankton, 128 taxa of littoral macroinvertebrates, and 100 taxa of benthic macroinvertebrates recorded. Taxonomic richness, composition and abundance varied widely among the sites sampled. This is likely to be due to a combination of both human influences and natural variation in habitat characteristics.

The ordination analyses identified somewhat different variables as being most strongly associated with spatial variation among the survey sites for each group of organisms (Table 10). However, temperature was an important variable for all groups of organisms and electrical conductivity, pH, and dissolved oxygen were important for most. These environmental variables reflect natural physical and chemical gradients from cooler, dilute upland rivers to warmer and more enriched lowland rivers, but can also be affected by human activities such as waste disposal, the removal of riparian vegetation and the construction and operation of dams. A major task in the further development of biomonitoring for the Mekong will be to develop assessment measures that can distinguish human impacts from natural variation.

Table 10. *Environmental variables that were most strongly associated with each group of organisms according to ordination analysis. Variables are listed in decreasing order of correlation strength for each group.*

Correlation	Diatoms	Zooplankton	Littoral invertebrates	Benthic invertebrates
1st	Dissolved oxygen	Temperature	Temperature	Temperature
2nd	Electrical conductivity	Altitude	Dissolved oxygen	Altitude
3rd	Temperature	pH	pH	Mud
4th	Cobbles	Dissolved oxygen	Secchi depth	pH
5th		Electrical conductivity		Clay
6th				Electrical conductivity

The cluster analysis showed that in the case of each of the four biological indicator groups, replicate samples from the same site were generally more similar to one another than to samples from other sites. This demonstrates that with the sampling methods used, differences among sites can readily be distinguished from variability within each site. This is a significant finding because differences among sites are of most interest in a broad-scale monitoring programme, and it is important the survey methods

used do not allow among-site differences to be masked by natural variability within sites.

The results of the 2004 survey demonstrate that biomonitoring is potentially a valuable tool with which to asses the ongoing environmental health of the Lower Mekong river-system. It represents the first step in a long-term programme. Future surveys will include additional sites and provide more comprehensive, and representative, coverage of the Lower Mekong Basin. At the same time, the continued development of more objective bio-assessment metrics will provide a more accurate, biologically based, assessment of the condition of aquatic ecosystems.

The protection of the environment and the ecological balance of the Mekong River Basin is one of the goals of the 1995 Agreement on Cooperation for the Sustainable Development of the Mekong River Basin. The agreement was signed by the four countries in the Lower Mekong Basin: Cambodia, Lao PDR, Thailand and Viet Nam. Protection of the environment can only be effective if there are efficient monitoring tools in place to inform decision-makers about the condition of the environment and environmental trends. This report constitutes the first step towards the development and implementation of such monitoring for aquatic ecosystems.

9 References

Barbour, M.T., Gerritsen, J., Snyder, B.D., and J.B. Stribling (1999) Rapid bioassessment protocols for use in streams and wadable rivers: periphyton, benthic macroinvertebrates and fish. US Environmental Protection Agency, Washington D.C. 202 pp.

Conforti V., Alberghina J., and E.González Urda (1995) Structure Changes and Dynamics of the Phytoplankton Along a Highly Polluted Lowland River of Argentina. *J. Aquatic Ecosys. Health* **4**: 59–75.

Del Giorgio P.A., Vinocur A.L. Lombardo R.J., and H.G. Tell (1991) Progressive Changes in the Structure and Dynamics of the Phytoplankton Community Along a Pollution Gradient in a Lowland River – a Multivariate Approach. *Hydrobiologia* **224**: 129–154.

Foged N. (1971) *Freshwater Diatoms in Thailand.* Odense Publisher. Lehre.

Foged N. (1975) *Some Littoral Diatoms from the Coast of Tanzania.* Odense Publisher. Lehre.

Foged N. (1976) *Freshwater Diatoms in Srilanka (Ceylon).* Odense Publisher. Lehre.

Hempattarasuwon N. (2001) *Ecology of Diatoms in the Pasak River: Relationships between Diatoms and Stream Runoff.* M.Sc. thesis, Faculty of Science and Technology, Thammasart University, Bangkok.

Hustedt F. (1937) Systematische und Ökologische untersuchungen Über die diatomeen-flora von Java , Bali und Sumatra. Sonder–Abdruck aus dem arch. für Hydrobiologie. suppl. Bd. XV, 131–177.

Hynes, H.B.N. (1970) *The Ecology of Running Waters.* Liverpool University Press, Liverpool, UK.

Krammer K. and H. Lange-Bertalot (1986) Bacillariophyceae. Teil 1. Naviculaceae. Süβwasseflora von Mitteleuropa, Bd. 2, berg. Von A. Pascher. Gustav Fisher Verlag, Stuttgart.

Krammer K. and H. Lange-Bertalot H. (1988) Bacillariophyceae. Teil 2. Epithemiaceae, Surirellaceae. Süβwasserflora von Mitteleuropa, Bd. 2, berg. Von A. Pascher. Gustav Fisher Verlag, Stuttgart.

Krammer K. and H. Lange-Bertalot (1991a) Bacillariophyceae. Teil 3. Centrales, Fragilariaceae, Eunotiaceae. Süβwasseflora von Mitteleuropa, Bd. 2, berg. Von A. Pascher. Gustav Fisher Verlag, Stuttgart.

Krammer K. and H. Lange-Bertalot (1991b) Bacillariophyceae. Teil 4. Achnanthaceae.Kritische Ergünzungen zu Navicula. Süβwasseflora von Mitteleuropa, Bd. 2, berg. Von A. Pascher. Gustav Fisher Verlag, Stuttgart.

Loez C.R. and M.L. Topalián M.L. (1997) Use of Algae for Monitoring Rivers in Argentina with a Special Emphasis for the Reconquista River (Region of Buenos Aires). In Use of Algae for Monitoring River III. In Prygiel J., Whitton B.A. and Bukowska J. Proceedings of an International Symposium Held at the Agence de l' Eau Artois-Picardie, Douai Douai, France, 29 September–1 October 1997. 72–83.

MRC. (2005) Integrated Water Quality Management Report No. 1. draft: 10 June 2005. Mekong River Commission, Vientiane.

Mustow, S. E. (2002) Biological monitoring of rivers in Thailand: use and adaptation of the BMWP score. Hydrobiologia **479**:191–229.

OECD. (1982) *Eutrophication of Waters, Monitoring, Assessment and Control.* Organisation for Economic Cooperation and Development, Paris.

Parnrong, S. (2002) A Review of Biological Assessment of Freshwater Ecosystems in Thailand. Report submitted to Mekong River Commission.

PCD (2004) Standard Surface Water Quality for Thailand. Pollution Control Department, Ministry of Natural Resources and Environment, Thailand, Bangkok. (available at http://www.pcd.go.th/info_serv/en_reg_std_water05.html#s3).

Pekthong, T. (2002) *Biodiversity of Benthic Diatoms and their Application in Monitoring Water Quality of Mae Sa Stream, Doi Suthep-Pui National Park Chiang Mai*. Ph.D. thesis, Biology Department, Faculty of Science, Chiang Mai University, Chiang Mai.

Pfister, V. P. (1992) Phytobenthos Communities from 2 Tyrolean Mountain Streams. Arbeitsgemeinschaft Limnologie, Telfs, Österreich.

Prescott, G.W. (1970) *How to Know the Fresh Water Algae.* W.M.C. Brown Company. Iowa.

RGCM (1999) Sub-decree of Water Pollution Control. Royal Government Council of Ministers, Kingdom of Cambodia, Phnom Penh. (Unofficial translation.)

Resh, V.H. and J.K. Jackson (1993). Rapid assessment approaches to biomonitoring using benthic macroinvertebrates. In: *Freshwater biomonitoring and benthic macroinvertebrates,* (eds. D.M. Rosenberg and V.H. Resh), Chapman and Hall, New York, pp. 195–233.

Silva-Benavides, A.M. (1994) Algal Periphyton in Two Rivers in Costa Rica with Special Reference to Diatoms Organic Pollution and Altitudinal Differentiation. Ph.D. thesis. Institute of Botany, Innsbruck University, Austria.

Stiling, P.D. (1996) *Ecological Theories and Applications.* Prentice Hall International, New Jersey.

Supan, S. and Y. Peerapornpisal (2002) Diversity of Macroalgae and Benthic Diatoms in Huay Khayang Watershed, Thailand. Abstract on Algae 2002, Tsukuba, Japan, 19–24 July 2002.

Thorne, R/St.J., Williams, W.P. (1997) The response of benthic macroinvertebrates to pollution in developing countries: a multimetric system of bioassessment. *Freshwater Biology* **37**:671–686.

Waiyaka, P. (1998) *Diversity of Phytoplankton and Benthic Algae in Mae Sa Stream, Doi Suthep-Pui National Park, Altitude 550–1050 Metres.* M.Sc thesis, Biology Department, Faculty of Science, Chiang Mai University, Chiang Mai.

Wetzel, R.E. (2001) *Limnology.* Saunders College Publishing. Philadelphia.

Whitton, B. A., Rott, E. and G. Friedrich (1991) *Use of Algae for Monitoring Rivers.* Institut für Botanik AG HyDrobotanik Universität Innsbruck, Austria.

Annex 1 Classification of waters

Classification of surface waters in Thailand based on water quality and beneficial uses (PCD, 2004)

Classification	Objectives/condition and beneficial usage
Class 1	**Extra clean** fresh surface water resources used for (1) consumption, which may pass through water treatment requiring only ordinary processes for pathogenic destruction; (2) ecosystem conservation, where basic organisms can breed naturally.
Class 2	**Very clean** fresh surface water resources used for (1) consumption, which requires ordinary water treatment before use; (2) aquatic organism conservation; (3) fisheries; (4) recreation
Class 3	**Medium clean** fresh surface water resources used for (1) consumption, but passing through ordinary treatment before use; (2) agriculture.
Class 4	**Fairly clean** fresh surface water resources used for (1) consumption, but requiring special water treatment before use; (2) industry.
Class 5	Sources **not in classes 1–4**, and used for navigation.

Classification of the main rivers in north-eastern Thailand based on (PCD, 2004)

River and location	**Class**
Songkram River from Ta-uten, Nakhonpanom Province (km.0) to Sohpisai , Nongkai Province (km.189).	3
Phong River from Kosoompisai, Mahasarakarm Province (km.0) to Ubonrat Dam, Khonkhean Province (km.140)	3
Chi River from Warinchamrab, Ubonratchatani Province (km.0) to Bankwao, Chaiyaphum Province (km.429)	3
Mun River from Kongjuim, Ubonratchatani Province (km.0) to Chokchai, Nakhonratchasima Province (km.787)	3
Lamtakong Water from the conjunction with Moon River in Amphur Muang, Nakhonratcharatsima Province (km. 0) to Khonchum Dyke in Amphur Muang, Nakhonratchasima Province (km. 24) from Khonchum Dyke in Amphur Muang, Nakhonratchasima Province (km. 24) to Pakchong, Nakhonratchasima Province (km. 180)	4

Note: As notified by the Pollution Control Department, published in the *Royal Government Gazette*, Vol. 116, Part 53, July 6, B.E.2542 (1999).

Table 4. *Water-quality criteria appropriate for aquatic organisms (PCD 2004)*

Variable	Range	Remarks
Temperature (°C)	23–32	Changing naturally, with no rapid changes
pH	5–9	Daily change should not exceed 2 units
DO (mg/l)	Minimum 3	
Secchi disc depth (cm)	30–60	

Table 5. *Thailand's standard surface water quality classification according to temperature, pH, DO and NO_3-N*

Variable	Class 1	Class 2	Class 3	Class 4	Class 5
Temperature (C°)	n	n*	n*	n*	nd
pH	n	5–9	5–9	5–9	nd
DO (mg/l)	n	> 6.0	> 4.0	> 2.0	nd
NO_3-N (mg/l)	n	< 5.0	< 5.0	< 5.0	nd

Note: These classes are based on those proposed by the American Water Works Association (AWWA) and the Water Pollution Control Federation (WPCF). n = natural; n^* = not more than 3°C from natural; nd = not defined

Annex 2 Diatom species counts

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Division Bacillariophyta																				
Order Centrales																				
Aulacoseira granulata Ehrenberg	3	0	0	23	0	0	7	0	0	0	0	0	0	12	50	3	601	671	0	0
Aulacoseira muzzanensis (Meister) Krammer	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	215	0	0	1
Cyclotella meneghiniana Kützing	0	10	2	0	0	0	0	8	37	2	0	0	0	0	0	0	0	0	0	0
Cyclotella stelligera Cleve	1	0	0	66	0	3	6	29	12	0	0	0	0	54	50	3	0	0	0	0
Cyclotella sp. 1	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Meloseira varians Agardh	0	2	7	2	0	0	0	3	1	13	0	34	10	0	9	2	0	212	0	9
Pleurosira laevis (Ehrenberg) Compère	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thalassiosira sp. 1	0	0	0	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Order Pennales																				
*Achnanthes biasolettiana*Grunow	0	137	0	0	68	0	0	0	36	153	0	0	0	0	0	107	0	0	0	0
*Achnanthes crenulata G*runow	0	0	1	0	0	0	0	1	1	1	0	0	0	0	16	0	0	0	3	2
Achnanthes lanceolata (Brébisson) Grunow	259	497	6	0	0	96	0	6	263	216	10	0	0	0	0	175	65	0	16	54
Achnanthes lanceolata ssp. rostrala (Oestrup) Hustedt	0	0	0	1	79	0	0	0	31	6	0	39	0	0	25	6	21	0	7	4
Achnanthes minutissima Kützing	38	1093	0	784	2124	0	528	1659	554	360	0	0	0	1061	1061	423	0	0	414	70
Achnanthes oblongella østrup	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	5
Achnanthes sp. 1	16	0	0	0	0	0	0	0	1070	0	0	0	0	0	0	213	0	0	0	0
Achnanthes sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Achnanthes sp.3	0	0	0	0	0	259	0	0	0	0	0	0	40	0	0	0	0	0	0	0
Achnanthes sp.4	0	0	0	0	0	73	0	0	0	0	50	0	0	0	0	0	0	0	0	0
Achnanthes sp.5	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Achnanthes sp.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	81	0	0
Amphora sp.1	0	411	74	0	123	0	3	0	0	23	0	0	0	0	39	5	0	0	0	0
Amphora sp.2	0	3	0	0	0	0	0	34	3	20	0	0	0	0	39	3	0	0	0	0
Amphora sp.3	0	0	0	0	0	0	0	6	6	0	0	0	0	0	0	0	0	0	0	0
Amphora sp.4	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0
Amphora sp.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
Amphora sp.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Amphora sp.7	0	0	0	0	0	0	0	0	0	0	0	39	0	0	0	0	0	0	0	0
Bacillaria paradoxa Gmelin	0	0	2	0	0	6	2	0	0	3	0	0	0	0	0	1	0	0	0	5
Brachysira cf. neoexilis Lange-Bertalot	0	0	0	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caloneis sp.1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Caloneis sp.2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Caloneis sp.3	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Caloneis sp.4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Caloneis sp.5	0	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caloneis sp.6	0	3	0	0	2	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caloneis sp.7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caloneis sp.8	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caloneis sp.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Cocconeis placentula Ehrenberg	2002	138	36	8	29	28	1	0	3	389	49	48	268	122	277	264	87	59	80	31
Cocconeis sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Cocconeis sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Cocconeis sp.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
Cocconeis sp.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Cocconeis sp.5	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0
Cymatopleura elliptica (Brebisson) W. Smith	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella japonica **Reichelt**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	440	0
Cymbella sp. 1	109	18	0	0	17	0	1921	75	62	40	0	0	0	0	0	0	0	0	0	0
Cymbella sp.2	0	0	0	0	0	0	77	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella sp.3	0	0	0	0	0	0	0	33	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella sp.4	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Cymbella sp.5	0	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0
Cymbella sp.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	645	0	0	0	0
Cymbella sp.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	244	0	0	0	0
Cymbella sp.8	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella sp.9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella sp. 10	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella sp. 11	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella sp. 12	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella sp. 13	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella sp. 14	0	0	0	149	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella sp. 15	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella sp. 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Cymbella sp. 17	0	0	0	0	0	0	0	0	0	0	0	396	0	0	0	0	0	0	0	58
Cymbella sp. 18	0	0	0	0	0	0	0	0	0	0	0	0	0	103	103	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Cymbella tumida (Brébisson) Van Heurck	10	5	24	0	0	2	0	17	1	24	2	38	22	12	79	0	37	81	48	43
Cymbella turgidula Grunow	11	43	198	3	12	757	0	7	2	19	1	0	30	90	81	0	55	192	33	965
Diatoma vulgaris Bory	0	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diploneis subovalis Cleve	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Encyonema sp. 1	0	8	0	0	0	0	90	41	15	0	0	0	0	0	0	0	0	0	0	0
Encyonema sp.2	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Encyonema sp.3	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0
Encyonema sp.4	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Encyonema sp.5	0	3	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0	0	0	0
Encyonema sp.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0
Encyonema sp.7	0	0	0	380	173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Encyonema sp.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0
Encyonema sp.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	960
Encyonema sp. 10	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0
Encyonema sp. 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	246	0
Encyonema sp. 12	0	0	0	0	0	0	0	0	0	0	0	0	0	296	296	0	0	0	0	0
Encyonopsis sp. 1	0	0	0	753	0	0	0	0	0	0	0	0	0	0	0	130	0	0	0	55
Encyonopsis sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
Epithemia adnata (Kützing) Brébisson	638	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epithemia sp. 1	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Epithemia sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	0
Eunotia minor (Kützing) Grunow	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Fragilaria biceps (Kützing) Lange-Bertalot	0	162	0	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Fragilaria bidens Heiberg	0	1	0	7	0	0	0	21	0	9	0	0	0	0	0	4	0	0	0	0
Fragilaria capucina Desmazières	0	6	0	44	85	0	171	91	2	1	9	8	26	12	12	7	23	0	17	72
Fragilaria sp.1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Fragilaria sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
Fragilaria sp.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	54
Fragilaria sp.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
Fragilaria sp.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34
Fragilaria sp.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Fragilaria sp.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44
Fragilaria ulna var. acus (Kützing) Lange-Bertalot	0	0	0	0	301	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Frustulia sp.1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Frustulia sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Geissleria decussis (Østrup) Lange-Bertalot & Metzeltin	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Geissleria sp.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Gomphonema gracile Ehrenberg	4	0	0	47	0	14	0	2	1	0	0	233	0	0	0	4	15	0	0	6
Gomphonema parvulum (Kützing) Grunow	0	4	5	0	5	147	2	221	248	17	54	407	0	16	16	6	24	27	91	76
Gomphonema sp.1	24	516	0	0	0	0	270	75	352	1	0	0	0	0	0	112	0	0	0	0
Gomphonema sp.2	0	0	0	0	0	0	187	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema sp.3	0	0	0	0	0	0	6	63	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema sp.4	0	0	0	0	0	0	0	7	1	0	0	0	0	0	0	0	0	0	0	0
Gomphonema sp.5	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0
Gomphonema sp.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	183	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Gomphonema sp.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Gomphonema sp.8	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema sp.9	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema sp.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	230	0	0	0
Gomphonema sp.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	128	0	0	0
Gomphonema sp.12	0	0	0	0	0	0	0	0	0	0	11	0	247	0	0	0	0	169	0	0
Gomphonema sp.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	0
Gomphonema truncatum Ehrenberg	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyrosigma scalproides (Rabenhorst) Cleve	0	0	2	1	1	2	0	0	2	3	0	0	0	1	1	0	2	1	0	3
Gyrosigma spencerii (Quekett) Griffith & Herfrey	1	0	0	1	0	0	0	0	1	7	0	1	0	0	0	0	0	0	3	5
Hantzschia sp.1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hantzschia sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Hantzschia sp.3	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Luticula sp. 1	1	0	128	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luticula sp.2	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luticula sp.3	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luticula sp.4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Luticula sp.5	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
Luticula sp.6	0	0	0	0	0	0	0	0	0	76	0	0	0	0	0	0	0	0	0	0
Luticula sp.7	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Luticula sp.8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Luticula sp.9	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Luticula sp.10	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Luticula sp. 11	0	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Luticula sp.12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luticula sp.13	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luticula sp.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Luticula sp.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	99	0	0
Navicula constans Hustedt	1	1	0	0	1	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0
Navicula exigua (Grefory) Grunow	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula gastrum (Ehrenberg) Kützing	0	0	0	0	1	0	1	0	0	2	0	0	0	0	0	1	0	0	0	0
Navicula radiosa Kützing	0	0	0	167	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Navicula sp.1	0	0	2652	0	0	0	0	10	3	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.2	0	0	136	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.3	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.4	0	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.5	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.6	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.7	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.8	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.9	0	0	0	0	0	0	0	45	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.10	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.11	0	0	0	0	0	0	0	0	69	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.12	0	0	0	0	0	0	0	0	7	0	0	0	0	0	147	0	0	0	0	0
Navicula sp.13	0	0	0	0	0	0	0	0	0	261	0	0	0	0	0	0	0	0	0	0
Navicula sp.14	0	0	0	0	0	0	0	0	0	1124	0	0	0	0	0	0	0	0	0	0
Navicula sp.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0
Navicula sp.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Navicula sp.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0	0	0	0
Navicula sp.18	0	78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.19	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.21	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.22	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.23	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.24	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.25	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.26	0	0	0	528	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.27	0	0	0	0	176	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0
Navicula sp.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	0	0
Navicula sp.30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	558
Navicula sp.31	0	0	0	0	0	504	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp.32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	412	0	0
Navicula sp.33	0	0	0	0	0	0	0	0	0	0	0	26	0	0	0	0	0	0	0	0
Navicula sp.34	0	0	0	0	0	0	0	0	0	0	0	33	0	0	0	0	0	0	0	0
Navicula sp.35	0	0	0	0	0	0	0	0	0	0	307	0	520	0	0	0	0	0	0	0
Navicula sp.36	0	0	0	0	0	0	0	0	0	0	353	0	190	0	0	0	0	0	0	0
Navicula sp.37	0	0	0	0	0	0	0	0	0	0	76	0	0	0	0	0	0	0	0	0
Navicula sp.38	0	0	0	0	0	0	0	0	0	0	43	0	0	0	0	0	0	0	0	0
Navicula sp.39	0	0	0	0	0	0	0	0	0	0	0	0	0	208	208	0	0	0	1218	0
Navicula symmetrica Patrick	0	1	1	8	1	0	0	199	0	68	44	138	0	0	0	0	0	58	0	37
Navicula viridula (Kützing) Ehrenberg *var. viridula*	0	2	0	1	8	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Navicula viridula var. germainii (Wallace) Lange-Bertalot	193	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula viridula var. germainii Lange-Bertalot	0	0	0	2	8	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0
Navicula viridula var. linearis Hustedt	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula viridula var. rostellata (Kützing) Cleve	0	76	0	22	0	3	15	19	11	217	7	182	13	0	0	0	2	8	72	11
Neidium sp.1	2	0	0	0	0	0	0	0	1	11	0	0	0	0	0	0	0	0	0	0
Neidium sp.2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neidium sp.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Neidium sp.4	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Neidium sp.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Nitzschia calida Grunow	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Nitzschia clausii Hantzsch	1	0	65	2	0	0	0	316	47	0	1019	0	0	0	0	0	0	0	0	0
Nitzschia coarctata Grunow	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Nitzschia dissipata (Kützing) Grunow	2	1	1	0	5	5	3	0	12	33	0	0	0	1	1	1	0	0	0	41
Nitzschia levidensis (W.Smith) Grunow	0	0	0	0	1	0	0	0	1	2	0	0	0	0	0	0	0	0	0	2
Nitzschia levidensis var. salinarum Grunow	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Nitzschia palea (Kützing) W. Smith	28	3	1	4	38	23	2	0	1	103	29	226	7	28	28	99	57	9	33	79
Nitzschia sp.1	0	9	64	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia sp.2	0	0	109	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia sp.3	2	0	18	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0
Nitzschia sp.4	0	0	0	0	0	0	60	0	0	313	0	0	0	0	0	0	0	0	0	0
Nitzschia sp.5	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0
Nitzschia sp.6	0	3	0	0	0	0	0	0	268	11	0	0	0	0	0	65	0	0	0	0
Nitzschia sp.7	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Nitzschia sp.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Nitzschia sp.9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia sp.10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia sp.11	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia sp.12	0	0	0	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia sp.13	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia sp.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	179	0	0	0
Nitzschia sp.15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Nitzschia sp.16	0	0	0	0	0	0	0	0	0	0	0	183	0	0	0	0	0	199	0	0
Nitzschia sp.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	713	0	0
Nitzschia sp.18	0	0	0	0	0	0	0	0	0	0	0	23	0	36	36	0	0	2	0	0
Nitzschia subacicularis Hustedt	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia acrospharia W.Smith	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Pinnularia graciloides Hustedt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Pinnularia sp.1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Pinnularia sp.2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Pinnularia sp.3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Pinnularia sp.4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Pinnularia sp.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Pinnularia sp.6	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Pinnularia sp.7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Pleurosigma salinarum Grunow	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleurosira laevis (Ehrenberg) Compère	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	16	0	1
Reimeria sinuate (Gregory) Kociolck & Stcermer	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhopalodia gibba (Ehrenberg) O. Müller *var. gibba*	0	1	0	0	1	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Rhopalodia gibberula Ehrenberg O. Müller	51	0	0	0	7	0	0	0	0	0	0	0	0	0	0	236	0	0	0	0
Rhopalodia sp.1	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Rhopalodia sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	324	0	0	0
Rhopalodia sp.3	0	0	0	0	0	0	0	0	0	0	0	0	0	49	49	0	0	0	0	0
Sellaphora gibbula Lange-Bertalot	10	2	0	3	1	0	3	0	0	5	0	13	1	0	0	6	1	1	0	12
Sellaphora popula (Kützing) Mereschkowsky	0	0	0	0	1	0	0	0	2	0	0	27	6	1	1	0	2	0	1	2
Sellaphora sp.1	0	0	0	0	0	0	0	0	0	0	0	0	81	0	0	0	129	0	0	0
Sellaphora sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Stauroneis anceps Ehrenberg	8	0	0	0	0	4	0	0	0	4	0	0	0	0	0	0	0	0	0	4
Surirella angusta Kützing	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0
Surirella roba Leclercq	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0
Surirella sp.1	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Surirella sp.2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surirella sp.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Surirella sp.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Surirella tenera Grunow	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Synedra lanceolata (Kützing) Reichardt	0	1	0	0	0	0	0	0	0	29	0	0	0	6	6	0	0	0	239	0

Annex 3 Zooplankton counts

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
PHYLUM ARTHROPODA																				
Class Crustacea																				
Subclass Copepoda																				
Order Clanoida																				
Family Pseudodiaptomidae																				
Pseudodiaptomus beieri Brehm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Family Diaptomidae																				
Allodiaptomus calcarus Shenet Tai	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Allodiaptomus raoi Kiefer	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Eodiaptomus draconisignivomi Brehm	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Neodiaptomus visnu (Brehm)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	4	0	0	0
Neodiaptomus botulifer (Kiefer)	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0
Order Cyclopoida																				
Family Cyclopidae																				
Microcyclops varicans (Sars)	0	0	0	0	0	0	5	0	0	0	1	0	5	0	0	2	0	1	0	0
Microcyclops sp.	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0
Mesocyclops leuckarti (Claus)	0	0	0	0	0	1	34	0	0	0	0	0	0	0	0	0	4	1	0	0
Thermocyclops hyalinus (Rehberg)	0	0	0	42	0	0	0	0	0	0	5	1	1	0	0	2	2	0	0	0
Thermocyclops taihokuensis (Harada)	0	1	1	11	0	5	32	4	2	0	0	0	0	1	2	0	0	0	0	0
Thermocyclops sp.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Order Harpacticoida																				
Family Canthocamptidae																				
Elaphoidella sp.	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	1	0	0	0	0
Epactophanes sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Family Parastenocaridae																				
Parastenocaris sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Subclass Ostracoda																				
Order Podocopida																				
Family Cypridae																				
Heterocypris anomala Klie	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Heterocypris sp.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Subclass Branchiopoda																				
Order Cladocera																				
Family Bosminidae																				
Bosmina longirostris (O. F. Muller)	0	0	2	40	0	0	3	0	0	0	0	0	0	0	0	2	62	4	0	0
Bosmina coregoni Baird	0	0	1	1	1	0	4	10	0	0	0	0	0	0	0	0	0	0	0	0
Bosminopsis deitersi Richard	0	0	0	0	0	0	13	90	0	0	4	0	4	0	4	0	31	434	0	2
Family Sididae																				
Diaphanosoma sarsi Richard	0	0	0	1	0	0	2	0	0	0	1	0	0	0	0	0	3	0	0	0
Diaphanosoma paucispinosum Brehm	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Daphniidae																				
Moina sp.	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Daphnia lumholtzi Sars	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceriodaphnia rigaudi Richard	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceriodaphnia laticaudata O. F. Muller	0	0	0	14	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Ceriodaphnia cornuta Sars	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Chydoridae																				
Chydorus sphaericus sphaericus (O. F. Muller)	0	0	0	0	0	1	11	0	0	0	0	0	0	0	0	0	0	0	0	0
Alonella excisa (Fischer)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Disparalona rostrata (Koch)	0	0	0	0	0	0	0	0	0	4	0	0	0	1	0	0	0	0	2	0
Leydigia acanthocercoides (Fischer)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Alona rectangula Sars	0	0	0	0	0	0	2	0	0	7	0	1	0	1	0	0	0	0	0	0
Biapertura karua (King)	0	0	0	0	0	0	5	0	0	0	0	2	1	0	0	0	0	0	0	0
Biapertura intermedia (Sars)	0	0	0	0	0	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0
PHYLUM ASCHELMINTHES																				
Class Eurotatorea																				
Family Philodinidae																				
Trichotria tetractis (Ehrenberg)	0	0	0	0	0	3	3	0	0	2	0	0	0	1	0	0	0	0	8	1
Rotaria rotaria (Pallas)	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Philodina roseola (Ehrenberg)	0	0	0	0	0	0	0	0	0	0	0	10	10	2	0	4	2	1	5	0
Philodina sp.	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	2
Family Notommatidae																				
Monomata sp.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Notommata aurita (O.F.Muller)	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notommata sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Cephalodella compacta Wiszniewski	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cephalodella auriculata (O.F.Muler)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Cephalodella catellina (O.F.Muller)	4	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Scaridium longicaudum (Muller)	0	1	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Family Trichocercidae																				
Diurella similis (Wierzejski)	0	0	0	1	0	0	2	0	2	0	1	5	0	2	0	0	0	4	0	0
Diurella tigris (Muller)	0	0	0	0	0	0	8	0	0	0	0	2	0	0	0	0	1	0	0	0
Trichocerca gracilis (Tessin)	0	0	0	3	0	0	2	0	1	0	2	8	1	0	0	0	1	0	0	0
Trichocerca cylindrica (Imhof)	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichocerca capucina (Wiersejski et Zacharias)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	2	0	1
Trichocerca longiseta (Schrank)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0
Trichocerca rattus minor Fad	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichocerca rattus rattus Muller	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Trichocerca pusilla Jennigns	1	0	0	0	0	0	0	0	4	0	2	6	9	0	0	0	3	1	0	0
Trichocerca bicristata (Gosse)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diurella brachyura (Gosse)	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	1	0	0	0	0
Family Synchaetidae																				
Polyarthra vulgaris Carlin	0	0	0	0	0	1	152	1	37	0	75	1122	351	16	15	4	368	153	0	4
Ploesoma hudsoni (Imhof)	0	0	0	0	0	3	4	0	0	0	8	0	0	0	2	0	1	0	0	0
Family Testudinellidae																				
Testudinella patina (Hermann)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Testudinella sp.	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pompholyx complanata Gosse	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Pompholyx sulcata Hudson	0	0	0	0	0	0	2	69	0	0	0	0	0	0	0	0	0	0	0	0
Family Asplanchnidae																				
Asplanchna sieboldi (Leydig)	0	0	0	1	0	0	0	3	1	0	0	0	4	0	2	1	4	1	2	4
Asplanchna girodi de Guerne	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asplanchnopus multiceps (Schrank)	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Family Gastropodidae																				
Ascomorpha ecaudis Perty	0	0	0	0	0	0	2	0	3	0	0	0	47	2	3	0	0	0	0	0
Ascomorpha agilis Zach	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ascomorpha sp.	1	1	0	7	0	0	0	192	0	2	0	0	0	0	0	0	0	0	0	0
Family Lecanidae																				
Lecane leontina (Turner)	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0
Lecane luna (Muller)	0	0	0	1	1	3	33	3	1	0	0	3	1	0	1	0	3	0	6	4
Lecane curvicornis (Murray)	0	0	0	0	0	1	10	1	0	0	0	0	0	0	0	0	0	0	1	1
Lecane hastata (Murray)	0	0	0	0	0	0	0	0	0	1	0	0	4	0	0	0	0	0	0	0
Lecane pusilla Harring	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Lecane ludwigii (Eckstein)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecane hornemanni (Ehrenberg)	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecane sp.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Monostyla bulla (Gosse)	0	0	0	1	0	1	11	0	0	2	0	4	0	0	0	3	0	1	0	4
Monostyla lunaris Ehrenberg	0	0	0	0	2	1	0	0	0	0	0	0	0	2	2	0	0	0	7	0
Family Proalidae																				
Proales decipiens (Ehrenberg)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Family Mytilinidae																				
Mytilina ventralis (Ehrenberg)	0	0	0	0	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mytilina compressa (Gosse)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Family Colurellidae																				
Lepadella patella (Muller)	0	0	0	0	0	0	0	9	0	0	3	0	0	0	0	0	0	0	0	0
Lepadella sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Euchlanidae																				
Euchlanis dilatata Ehrenberg	0	0	0	0	0	5	0	1	0	3	2	0	0	2	2	0	0	0	5	0
Euchlanis sp.	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diplois daviesiae Gosse	0	0	0	0	0	0	3	0	0	0	0	0	6	1	0	1	0	0	0	1
Family Brachionidae																				
Brachionus angularis Gosse	0	0	0	0	0	0	16	0	65	0	5	0	31	0	1	5	64	40	0	0
Brachionus urceus (Linnaeus)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachionus calyciflorus calicyflorus Pallas	0	0	0	0	0	0	4	0	0	0	26	0	0	0	0	0	2	1	0	0
Brachionus caudatus Apstein	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachionus forficula forficula Wierzejski	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Brachionus falcatus Zacharias	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0
Brachionus quadridentatus var. *quadridentatus* Hermann	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Schizocerca diversicornis Daday	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Platyias quadricornis Ehrenberg	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Platyias patulus patulus (Muller)	0	0	0	0	0	0	4	0	0	0	2	0	0	0	0	0	3	0	0	0
Keratella valga tropica (Apstein)	0	5	4	1	0	1	10	0	736	40	46	7	4	5	0	0	16	1	0	0
Keratella cochlearis cochlearis (Gosse)	0	0	0	506	12	4	41	0	249	3	124	6	1	15	5	5	287	178	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Keratella cochlearis tecta Gosse	0	0	0	9	0	0	8	0	0	0	14	0	0	36	1	4	47	84	0	0
Keratella cochlearis hispida Lauterborn	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keratella irregularis (Lauterborn)	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keratella quadrata (O.F.Muller)	0	0	0	0	0	0	0	0	0	2	0	0	0	10	0	0	2	0	0	0
Anuraeopsis fissa (Gosse)	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0
Anuraeopsis sp.	0	0	0	0	0	0	0	0	0	0	4	1	0	0	2	0	0	0	0	0
Family Flosculariidae																				
Sinantheria socialis (Linnaeus)	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Filiniidae																				
Filinia longiseta (Ehrenberg)	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3	0	0	0
Filinia longiseta var. passa (O. F. Muller)	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Filinia brachiata (Rousselet)	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0
Tetramastix opoliensis Zacharias	0	0	0	0	0	0	2	0	0	1	0	1	0	0	0	0	0	0	0	0
Family Hexathridae																				
Hexathra mira (Hudson)	0	0	0	1	0	0	2	0	10	0	8	3	2	0	0	0	28	8	0	0
PHYLUM SARCOMASTIGOPHORA																				
Class Lobosea																				
Family Arcellidae																				
Arcella vulgaris Ehrenberg	6	3	1	3	12	1	15	36	0	24	2	6	20	14	7	13	4	1	47	9
Arcella sp.	0	0	0	0	7	2	0	12	0	4	0	0	0	0	0	0	0	0	9	0
Family Centropyxidae																				
Centropyxis aculeata Stein	0	2	2	0	0	2	0	0	0	28	4	3	0	10	0	15	0	0	77	23

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Family Diffugiidae																				
Protocucurbitella coroniformis Gauthier-Lie'vre & Thomas	0	0	0	118	0	1	9	0	0	0	0	0	0	0	0	0	0	0	0	0
Protocucurbitella sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudodifflugia gracilis Schlumberger	78	12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudodifflugia fascicularis Penard	58	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Difflugia elegans Penard	0	1	10	0	1	472	6	1504	5	0	5	16	6	0	0	7	72	14	0	0
Difflugia urceolata Carter	0	0	0	8	1	0	11	0	26	0	2	2	0	2	0	0	4	0	3	2
Difflugia corona Wallich	0	0	0	2	0	0	0	0	0	0	1	1	1	2	3	0	0	0	2	1
Difflugia lobostoma Leidy	0	0	0	159	0	2	0	43	248	0	0	0	8	0	7	1	0	0	2	4
Difflugia acuminata Ehrenberg	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	2	6
Difflugia piriformis Ehrenberg	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Difflugia globulosa Dujardin	0	15	0	9	0	33	22	0	0	0	0	0	0	0	0	0	0	0	0	0
Difflugia tuberculatus (Wallich)	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diflugia scalpellum Penard	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Class Filosea																				
Family Euglyphidae																				
Euglypha alveorata Dujardin	0	0	0	0	0	2	2	0	2	2	0	0	2	2	0	5	0	0	4	1
Euglypha laevis Ehrenberg	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0	3	0	0	0	0
Euglypha sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CTU	CPS	CSS	CSP	CKT	VTC	VCD	VSS	VSP
Class Phytomastigophora																				
Family Peridiniidae																				
Ceratium spp	1	490	9	26	0	7	1471	0	0	0	0	0	0	0	0	0	1	1	0	0
Family Euglenidae																				
Euglena acus Ehrenberg	0	0	0	0	0	0	0	1	0	0	0	0	8	0	0	0	0	0	0	0
Phacus longicauda (Ehrenberg)	0	0	0	60	4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Family Volvocidae																				
Pleodorina californica Shaw	0	0	0	0	0	0	0	0	0	0	40	19	0	0	0	0	47	8	0	0
Volvox spermatosphaera Powers	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
LARVA																				
Nauplius copepoda	3	4	6	158	0	88	1956	244	346	9	542	998	35	12	5	8	252	135	9	3
Bivalvia	2	1	18	0	3	24	0	10	0	0	13	1	0	0	1	15	43	12	0	2
Chironomidae - Diptera	3	4	7	0	0	0	0	0	0	1	0	0	2	0	1	0	0	0	0	4
Ephemeroptera	1	0	0	0	0	0	0	0	0	12	0	0	0	2	0	2	0	0	0	1

Annex 4 Littoral macroinvertebrate counts

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CPS	CSP	CTU	CSS	CKT	VSP	VSS	VCD	VTC
PHYLUM MOLLUSCA																				
Order Bivlavia																				
Corbicula sp.	5	0	0	3	22	1	3	1	10	0	4	7	324	11	6	17	53	2	4	72
Limnoperna siamensis	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	14
Scabies sp.	0	0	0	0	0	0	4	0	0	0	0	7	0	0	17	0	0	0	0	1
Physunio sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ensidens sp.	0	0	0	0	0	0	0	0	4	0	0	0	2	0	0	0	0	0	0	0
Order Mesogastropoda																				
Assimineidae	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pila sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1
Mekongia sp.	0	0	0	0	1	19	0	0	0	0	0	0	1	0	0	0	6	0	3	0
Filopaludina polygramma	0	0	0	0	0	0	0	0	1	0	6	1	2	0	2	0	0	0	0	0
Filopaludina munensis	0	0	0	0	0	0	0	0	7	0	0	0	0	0	2	13	0	0	0	0
Clea helena	1	0	0	0	0	0	0	0	10	0	0	1	26	0	7	16	9	0	0	0
Melanodes tuberculata	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
Tarebia granifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0
Fairbankid sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
Bithynia sp.	0	0	0	14	38	43	0	0	0	0	0	0	529	0	118	0	18	0	2	0
Stenothyra sp.	427	5	2	0	35	86	20	30	984	0	7	0	604	0	5	378	252	0	2	19
Lymnaea sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	0
PHYLUM ARTHROPODA																				
Order Decapoda																				
Parathelphusa sp.	0	0	0	0	0	0	0	0	2	0	0	0	5	0	0	2	0	0	0	0
Macrobrachium pilimanus	8	0	5	1	0	0	0	1	0	0	0	0	22	0	2	0	24	0	0	0
Macrobrachium lanchesteri	33	0	0	6	15	1	2	26	4	4	7	164	7	1	19	256	21	16	4	7

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CPS	CSP	CTU	CSS	CKT	VSP	VSS	VCD	VTC
Atyid sp.	0	0	2	370	85	0	112	4	37	0	5	84	0	10	0	131	0	11	10	108
Order Amphidopa																				
Haustorus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	17
Order Isopoda																				
Sp.haeromatid sp.	1	0	1	0	0	0	5	6	1	0	0	6	0	0	0	6	0	0	0	0
Order Coleoptrea																				
Neomysid sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Laccophilus sp.	0	0	0	0	0	0	0	1	2	0	0	3	2	0	0	0	11	0	0	0
Hydrovatus sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dineutus sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Gyretes sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Derallus sp.	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Paracymus sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Oulimnius sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Macronichus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Heteroceridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Ancyronyx sp.	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Order Lepdipotera																				
Stenelmis sp.	1	0	0	0	0	0	0	0	1	0	0	0	0	0	7	0	0	0	0	0
Thinopinus sp.	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Order Odonata																				
Petrophila sp.	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Plathemis sp.	182	0	1	0	8	0	0	1	1	0	0	0	47	0	18	6	13	1	0	2
Macrothemis sp.	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epicordulia princeps	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CPS	CSP	CTU	CSS	CKT	VSP	VSS	VCD	VTC
Gomphus sp.	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Progomphus sp.	0	0	1	0	4	1	0	0	0	0	0	1	23	0	0	0	26	0	0	0
dromogomphus sp.	0	0	0	0	0	0	0	0	0	0	0	0	25	0	9	1	0	0	0	0
Erpetogomphus sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Meglogomphus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Aphylla williamsoni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	1	0	0	0
Hagenius brevistylus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Amphipteryx sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Protoneura sp.	14	0	0	4	6	0	0	3	1	0	0	2	12	0	3	1	5	15	3	0
Calopteryx maculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0
Hetaerina titia	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Argia sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5	1	0	0
Enallagma civile	0	0	0	0	0	0	0	0	0	0	0	0	5	0	1	0	0	2	0	0
Acanthagrion sp.	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aeshna sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0
Gynacantha sp.	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Order Hemipetra																				
Triacanthagyna trifida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
Naucoris scutellaris	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	1	4	0	0	0
Stenicoris sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Anisops sp.	0	0	0	0	0	0	0	0	0	0	0	12	1	0	1	0	0	0	0	0
Micronecta sp.	1	14	58	856	21	582	95	27	11	0	3	43	18	0	288	35	16	5	119	9022
Mesovelia sp.	0	0	0	2	2	0	0	0	0	0	0	1	1	0	1	0	1	2	0	0
Chenevelia stridulans	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Perittopus sp.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CPS	CSP	CTU	CSS	CKT	VSP	VSS	VCD	VTC
Rhagovelia sp.	1	0	0	0	0	0	0	0	0	1	0	0	2	0	0	5	2	0	0	0
Strongyvelia sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ventidius sp.	10	0	0	0	0	0	0	0	0	0	0	1	4	0	24	0	1	0	0	0
Ptilomera tigrina	0	0	0	0	0	0	0	2	0	0	0	0	5	0	1	2	10	0	0	0
Noegerris sp.	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0
Metrocoris sp.	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Limnogonus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0
Cryptobates sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0
Rheumatogonus intermedius	12	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	5	0	0	0
Cercomtus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Ranatra sp.	1	0	0	0	0	0	0	2	0	0	0	3	1	0	0	0	0	0	0	0
Order Ephemeroptera																				
Plea sp.	1	0	0	0	8	0	0	0	5	1	0	0	1	0	0	1	0	0	0	0
Leucrocuta sp.	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinygmina sp.	25	9	10	0	0	0	0	4	0	4	0	0	0	0	3	2	0	0	0	0
Thalerosp.hyrus sp.	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0
Choroterpes sp.	4	0	0	0	0	0	0	0	0	1	0	0	1	0	1	4	10	4	0	0
Arthroplea sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0
Caenodes sp.	23	4	0	0	4	0	1	6	0	0	0	0	8	0	9	2	2	0	0	0
Caenis sp.	11	0	0	0	0	1	0	4	1	1	4	6	4	0	5	0	4	0	0	1
Caenoculis sp.	3	0	3	1	5	0	0	0	0	0	0	0	8	0	4	1	8	0	0	0
Baetis sp.1	563	485	45	295	46	54	0	10	0	55	0	0	2	0	43	30	52	2	0	0
Baetis sp.2	501	85	0	72	0	83	6	19	0	30	0	2	1	0	8	42	64	0	0	0
Centroptilum sp.	15	13	10	45	0	0	2	1	0	8	0	10	2	0	3	0	18	0	0	0
Cloeon sp.	495	0	0	224	10	0	2	0	0	0	0	8	2	0	14	0	0	0	0	0
Palingenea sp.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CPS	CSP	CTU	CSS	CKT	VSP	VSS	VCD	VTC
Ephemera sp.	0	0	0	0	4	0	0	0	0	0	0	0	1	0	16	0	2	0	0	0
Afromera siamensis	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Crinitella sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ephacerella commodema	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Potamanthus formosus	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Potamanthellus caenodes	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Order Diptera																				
Teloganodes sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
Atherix sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Chaoborus sp.	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0
Chironomus sp.	13	32	8	33	23	0	42	7	12	2	0	2	55	9	22	19	151	45	251	461
Ablabesmyia sp.	1	9	1	8	90	0	0	0	1	0	0	0	13	0	3	0	2	0	0	2
Thaumalea sp.	0	0	0	18	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Odontomyia sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Bezzia sp.	4	0	0	1	3	4	5	0	1	0	0	0	1	2	0	1	0	0	5	12
Culicoides sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Sciomyzid sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Nanocladius sp.	0	0	0	8	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0
Limnophila sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Order Plecoptera																				
Tipula sp.	0	0	0	0	2	0	0	0	0	0	0	1	0	1	3	0	0	0	0	0
Crytopera sp.	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0
Eccoptura xanthenes	1	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Neoperla sp.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	11	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CPS	CSP	CTU	CSS	CKT	VSP	VSS	VCD	VTC
Order Trichoptrea																				
Peltoperlopsis sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	5	0	0	0
Micrasema sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0
Pseudogoera sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polycentropus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
Neureclipsis sp.	0	0	0	0	0	0	0	2	1	1	0	0	1	0	0	1	1	0	0	0
*Limnephilus*sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Cryptochia sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moselyana comosa	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Pseudostenophylax sp.	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Hydropsyche bettni	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	1	3	0	0	0
Agraylea sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Fattigia sp.	1	0	0	0	0	0	0	0	0	0	0	1	2	0	2	1	0	0	0	0
Leptocerus sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
Oecetis sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	1	0	0	0
PHYLIM ANNELIDA																				
Order Polycheta	0	0	3	0	4	0	0	4	3	0	0	2	19	1	6	4	4	0	36	4
Order Oligochaeta	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	2	3

Annex 5 Benthic macroinvertebrate count

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CPS	CSP	CTU	CSS	CKT	VSP	VSS	VCD	VTC
PHYLUM ANNELIDA																				
Order Polychaeta																				
Errantia																				
Nereidae																				
Namalycastis longicirris (Takahasi)	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Namalycastis abiuma Muller	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	4	18	0	0
Sedentaria																				
Spionidae																				
Polydora sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	102	5	0	0
Order Oligochaeta																				
Naididae																				
Pristina sp.	27	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetogaster sp.	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Genus sp.	0	44	0	3	0	0	0	0	0	18	0	0	0	0	0	12	0	0	0	0
Tubificidae																				
Limnodrilus hoffmeisteri Claparede	0	0	0	0	0	14	12	0	2	0	201	24	9	3	9	0	33	67	0	80
Branchiura sowerbyi Beddard	0	0	0	54	16	21	10	25	18	7	52	7	0	1	1	0	6	10	0	14
PHYLUM MOLLUSCA																				
Order Gastropoda																				
Genus sp.	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neritidae																				
Neritina rubida (Pease)	0	0	0	0	0	12	0	2	0	0	4	0	1	0	0	0	0	0	0	0
Stenothyiidae																				
Stenothyra mcmulleni Brandt	21	6	0	0	0	136	0	1	0	0	1	3	0	0	0	1	2	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CPS	CSP	CTU	CSS	CKT	VSP	VSS	VCD	VTC
Stenothyra koratensis holosculpta Brandt	0	0	0	0	0	31	0	11	1081	0	1	1	0	0	0	0	27	3	0	0
Stenothyra jiraponi Brandt	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stenothyra sp.	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrobiidae																				
Pachydrobia sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	2	0	20
Paraprososthenia sp.	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Assimineidae																				
Cyclotropic sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
Pyramidellidae																				
Morrisonietta spiralis Brandt	0	0	0	0	0	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viviparidae																				
Mekongia swainsoni braueri (Kobelt)	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Mekongia swainsoni flavida n.subsp	0	0	0	0	0	0	0	0	0	0	4	1	2	0	0	0	0	0	0	0
Angulyara sp.	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0
Bythiniidae																				
Bithynia sp.	0	0	0	0	0	1	0	0	6	0	0	0	0	0	0	0	0	0	0	0
Thiaridae																				
Thiara scabra (Muller)	0	0	0	0	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Sermyla tornatella (Lea)	0	0	0	0	0	0	0	0	3	0	1	33	0	0	1	0	4	4	0	3
Tarebia granifera (Lamarck)	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melanoides tuberculatus (Muller)	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0
Planorbidae																				
Gyraulus sp.	0	0	0	1	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CPS	CSP	CTU	CSS	CKT	VSP	VSS	VCD	VTC
Order Bivalvia																				
Arcidae																				
Scaphula pinna Benson	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Mytilidae																				
Limnoperna siamensis (Morelet)	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	120	18	0	0
Dreissenidae																				
Sinomytilus harmandi (Rochebrune)	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	510	6	0	0
Corbiculidae																				
Corbicula lamarckiana Prime	0	0	0	0	0	0	0	0	0	6	1	3	2	1	69	0	0	7	0	579
Corbicula leviuscula Prime	0	0	0	0	0	0	0	0	0	0	0	149	0	0	0	0	0	3	0	0
Corbicula tenuis Clessin	2	1	0	8	4	1	0	0	9	0	8	246	3	3	0	2	33	97	0	0
Corbicula baudoni Morlet	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	43	6	0	0
Corbicula blandiana Prime	0	0	0	0	4	0	18	19	28	0	6	131	0	0	0	0	57	39	0	0
Corbicula moreletiana Prime	0	0	0	0	0	0	0	1	17	0	0	3	0	0	0	0	34	14	0	0
Corbicula cyreniformis Prime	0	0	0	0	0	0	0	0	3	0	0	18	0	0	0	0	63	36	0	0
Corbicula arata (Sowerby)	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pisidiidae																				
Afropisidium clarkeanum (Nevill)	0	0	0	19	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amblemidae																				
Hyriopsis (Hyriopsis) bialatus Simpson	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Pilsbryoconcha exilis compressa (Martens)	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CPS	CSP	CTU	CSS	CKT	VSP	VSS	VCD	VTC
Pilsbryoconcha lemeslei (Morelet)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Physunio cambodiensis (Lea)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3
Physunio micropterus (Morelet)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Ensidens ingallsianus ingallsianus (Lea)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Uniandra contradens ascia (Hanley)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
CRUSTACEA																				
Amphipoda																				
Gammaridae																				
Melita sp.	0	0	0	0	0	0	0	0	0	0	62	2	0	0	0	0	452	6	0	0
Corophiidae																				
Kamaka sp.	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	992	8	0	0
Grandidierella vietnamica Dang	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	429	53	0	0
Grandidierella lignorum Barnard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	31	0	0
Isopoda																				
Anthuridae																				
Cyathura truncata Dang	0	0	0	0	0	0	0	0	0	0	16	2	0	0	0	0	14	29	0	0
Decapoda - Macrura																				
Palaemonidae																				
Macrobrachium pilimanus (De Man)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Atyidae																				
Caridina nilotica Roux	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CPS	CSP	CTU	CSS	CKT	VSP	VSS	VCD	VTC
INSECT AND INSECT LARVA																				
Ephemeroptera																				
Baetidae																				
Cloeon sp.	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baetis sp.	27	0	1	2	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Centroptilum sp.	5	1	2	7	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
Caenidae																				
Caenis sp.	10	0	1	0	4	3	0	8	0	1	0	0	0	0	0	1	0	0	0	1
Heptageniidae																				
Heptagenia sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Genus sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epeorus sp.	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptoplebiidae																				
Choropterpes sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeridae																				
Ephemera sp.	1	1	0	0	113	0	0	0	0	25	0	0	20	1	0	0	0	0	0	1
Hexagenia sp.	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Potamanthidae																				
Potamanthus sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Behningiidae																				
Genus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Palingeniidae																				
Pentagenia sp.	0	9	0	0	0	3	2	171	0	0	0	0	0	0	1	0	0	0	0	0
Plecoptera																				
Perlidae																				
Perla sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CPS	CSP	CTU	CSS	CKT	VSP	VSS	VCD	VTC
Odonata																				
Aeschnidae																				
Aeschna sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphidae																				
Dromogomphus sp.	3	6	0	0	0	3	0	1	0	2	0	0	1	1	4	1	0	1	0	9
Octogomphus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Progomphus sp.	7	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0
Aphylla sp.	0	0	0	0	0	0	0	0	0	1	0	2	0	0	1	0	0	0	0	9
Libellulidae																				
Libellula sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Hemiptera																				
Corixidae																				
Corixa sp.	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naucoridae																				
Naucoris sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Coleoptera																				
Gerridae																				
Genus sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elmidae																				
Genus sp.	0	0	0	0	0	0	0	2	1	1	0	0	0	0	1	0	0	0	0	2
Staphilinidae																				
Bledius sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Trichoptera																				
Rhyacophilidae																				
Rhyacophila sp.	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CPS	CSP	CTU	CSS	CKT	VSP	VSS	VCD	VTC
Hydroptilidae																				
Oxyethira sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agraylea sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Ecnomidae																				
Economus sp.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Psychomyiidae																				
Genus sp.	0	0	0	0	2	0	0	7	2	0	44	2	0	5	2	0	10	3	0	17
Hydropsychidae																				
Hydropsyche sp.	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidoptera																				
Pyralidae																				
Genus sp.	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diptera																				
Heleidae																				
Culicoides sp.	8	0	0	2	16	6	5	17	1	2	0	0	2	2	0	0	0	0	0	2
Limoniidae																				
Eriocera sp.	0	1	0	0	4	0	0	0	0	25	0	0	0	1	0	0	0	0	0	1
Tipulidae																				
Genus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Culicidae																				
Chaoborus sp.	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Tabanidae																				
Chrysops sp.	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae																				
Ablabesmyia sp.	0	21	0	22	169	37	12	12	13	43	0	6	0	9	14	0	4	5	0	11
Chironomus sp.	0	0	1	5	2	23	0	0	1	7	0	2	0	0	0	0	0	0	0	0
Tanytarsus sp.	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clinotanypus sp.	6	3	0	16	0	26	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Procladius sp.	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNO	LPB	LVT	LNG	LKD	LPS	TMU	TCH	TSK	TKO	CPP	CPS	CSP	CTU	CSS	CKT	VSP	VSS	VCD	VTC
Cryptochironomus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Goeldichironomus sp.	82	10	0	32	0	14	0	0	0	0	13	0	0	0	0	0	322	157	0	0
Smittia sp.	19	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polypedilum sp.	0	5	0	189	24	155	19	14	8	146	82	18	40	12	14	69	0	0	2	11
Pupa of Chironomidae	4	0	0	14	0	1	0	1	0	11	6	0	0	0	0	4	14	1	0	0

For further information please contact

Mekong River Commission
P.O. Box 6101, Vientiane 01000, Lao PDR.
Telephone: (856) (21) 263 263 Facsimile: (856) (21) 263 264
Email: mrcs@mrcmekong.org
Website: www.mrcmekong.org