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Mekong River Commission

Report on the 2007 biomonitoring survey of the lower Mekong River and selected tributaries

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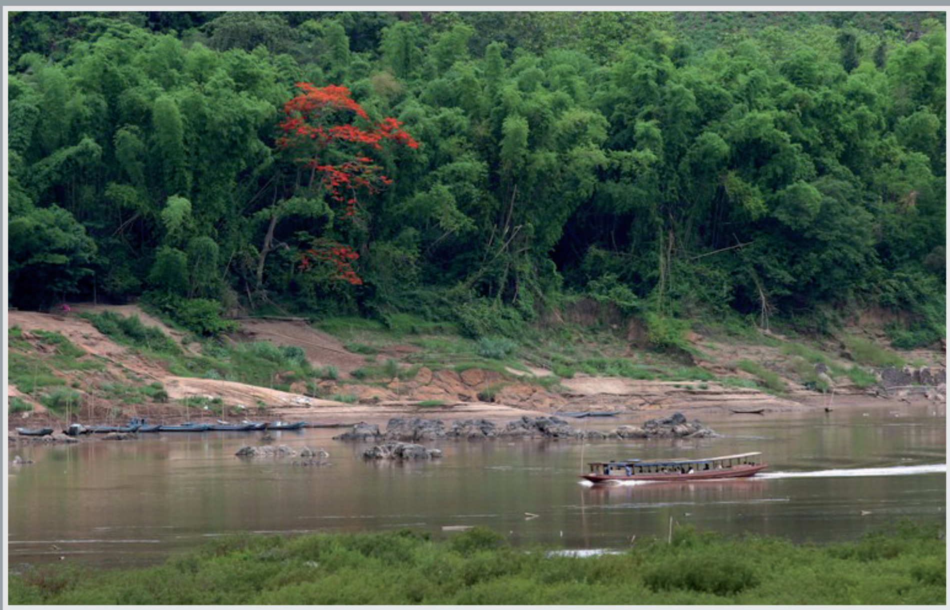

Meeting the Needs, Keeping the Balance

Mekong River Commission

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Abbreviations and acronyms

ATSPT:	Average Tolerance Score Per Taxon
BDP:	Basin Development Plan programme of the MRCS
BMWP:	Biological Monitoring Working Party
LMB:	Lower Mekong Basin
MRC:	Mekong River Commission
MRCS:	Mekong River Commission Secretariat
NMC:	National Mekong Committee
SDS:	Site Disturbance Score

Glossary of biomonitoring terms

Abundance: This is a measurement of the number of individual plants or animals belonging to a particular biological indicator group counted in a sample. Low abundance is sometimes a sign that the ecosystem has been harmed.

Average Tolerance Score per Taxon (ATSPT): Each taxon of a biological indicator group is assigned a score that relates to its tolerance to pollution. ATSPT is a measure of the average tolerance score of the taxa recorded in a sample. A high ATSPT may indicate harm to the ecosystem, as only tolerant taxa survive under these disturbed conditions.

Benthic macroinvertebrates: In this report, the use of this term refers to animals that live in the deeper parts of the riverbed and its sediments, well away from the shoreline. Because many of these species are not mobile, benthic macroinvertebrates respond to local conditions and, because some species are long living, they may be indicative of environmental conditions that are long standing.

Biological indicator group: These are groups of animals or plants that can be used to indicate changes to aquatic environments. Members of the group may or may not be related in an evolutionary sense. So while diatoms are a taxon that is related through evolution, macroinvertebrates are a disparate group of unrelated taxa that share the character of not having a vertebral column, or backbone. Different biological indicator groups are suitable for different environments. Diatoms, zooplankton, littoral and benthic macroinvertebrates, and fish are the most commonly used biological indicator groups used in aquatic freshwater environments. In addition, although not strictly a biological group, planktonic primary productivity can also be used as an indicator. However, for a number of logistical reasons fish and planktonic primary production are not suitable for use in the Mekong.

Diatoms: Single-celled microscopic algae (plants) with cell walls made of silica. They drift in river water (planktic/planktonic) or live on substrata such as submerged rocks and aquatic plants (benthic/benthonic). They are important primary producers in aquatic food webs and are consumed by many invertebrate animals. Diatoms are a diverse group and respond in many ways to physical and chemical changes in the riverine environment. Diatom communities respond rapidly to environmental changes because diatoms have short generation times.

Environmental variables: These are chemical and physical parameters that were recorded at each sampling site at the same time as samples for biological indicator groups were collected. The parameters include, altitude, water transparency and turbidity, water temperature, concentration of dissolved oxygen (DO), electrical conductivity (EC), activity of hydrogen ions (pH), and concentrations of chlorophyll-a, as well as the physical dimensions of the river at the site.

Littoral macroinvertebrates: In this report, the use of this term refers to animals that live on, or close to, the shoreline of rivers and lakes. This the group of animals is most widely used in biomonitoring exercises worldwide. They are often abundant and diverse and are found in a variety of environmental conditions. For these reasons littoral macroinvertebrates are good biological indicators of environmental changes.

Littoral organisms: Those organisms that live near the shores of rivers, lakes, and the sea.

Macroinvertebrate: An informal name applied to animals that do not have a vertebral column, including snails, insects, spiders, and worms, which are large enough to be visible to the naked eye. Biomonitoring programmes often use both benthic and littoral macroinvertebrates as biological indicators of the ecological health of water bodies.

Primary producer: Organisms at the bottom of the food chain, such as most plants and some bacteria (including blue-green algae), which can make organic material from inorganic matter.

Primary production: The organic material made by primary producers. Therefore, planktonic primary production is the primary production generated by plants (including diatoms) and bacteria (including blue-green algae) that live close to the surface of rivers, lakes, and the sea.

Primary productivity: The total organic material made by primary producers over a given period of time.

Reference sites: These are sampling sites that are in almost a natural state with little disturbance from human activity. To be selected as a reference site in the MRC biomonitoring programme, a site must meet a number of requirements including pH (between 6.5 and 8.5), electrical conductivity (less than 70 mS/m), dissolved oxygen concentration (greater than 5 mg/L) and average SDS (between 1 and 1.67). Reference sites provide a baseline from which to measure environmental changes.

Richness: This is a measurement of the number of taxa (types) of plants or animals belonging to a particular biological indicator group counted in a sample. Low species richness is often a sign that the ecosystem has been harmed.

Sampling sites: Sites chosen for single or repeated biological and environmental sampling. Although locations of the sites are geo-referenced, individual samples may be taken from the different habitats at the site that are suitable for particular biological indicator groups. Sites were chosen to provide broad geographical coverage of the basin and to sample a wide range of river settings along the mainstream of the Mekong and its tributaries.

Site Disturbance Score (SDS): This is a comparative measure of the degree to which the site being monitored has been disturbed by human activities, such as urban development, water resource developments, mining, and agriculture. In the MRC biomonitoring programme, the SDS is determined by a group of ecologists who attribute a score of 1 (little or no disturbance) to 3 (substantial disturbance) to each of the sampling sites in the programme after discussion of possible impacts in and near the river.

Taxon/taxa (plural): This is a group or groups of animals or plants that are related through evolution. Examples include species, genera, or families.

Zooplankton: Small or microscopic animals that drift or swim near the surface of rivers, lakes, and the sea. Some are single celled while others are multi-cellular. They include primary consumers than feed on phytoplankton (including diatoms) and secondary consumers that eat other zooplankton. Zooplankton can be useful biological indicators of the ecological health of water bodies because they are a diverse group that has a variety of responses to environmental changes. Zooplankton communities respond rapidly to changes in the environment because zooplankton species have short generation times.

Summary

The aquatic resources of the Mekong River and its tributaries are essential to the livelihoods of many of the 60 million or more people who live in the Lower Mekong Basin. Maintaining the ecological health of the river is the basis of the sustainable management of these resources. The Environment Programme of the Mekong River Commission (MRC) has monitored the Mekong River system using biological indicators since 2003. This report describes the Programme's biomonitoring activities in 2007. During that year the Programme's biologists sampled 20 localities in Cambodia, Lao PDR, and Thailand. The 2007 monitoring study sampled biological groups of benthic diatoms, zooplankton, littoral macroinvertebrates, and benthic macroinvertebrates, as recommended by a pilot study in 2003. At the same time, physical and chemical variables of the river were recorded at each of the sampling sites.

The objectives of this report are to (i) describe the biological indicator groups in the samples collected during 2007, (ii) use this information to derive indicators of the condition of the sites examined in 2007 and (iii) test the performance of these indicators against independent measures of environmental stress.

As in previous years, a wide variety of plants and animals was recorded, reflecting the high biodiversity of the Mekong River and its tributaries. Three biomonitoring metrics or indicators were calculated for each of the four biological assemblages sampled: taxon richness (the number of species or other types of organisms collected at a site), abundance (the number of individual organisms collected), and the average tolerance score per taxon (ATSPT). ATSPT is an indicator of the presence of environmental stressors such as water pollution because species that are sensitive to stress, which have low tolerance scores, tend to be absent from polluted sites. Stress-tolerant species, which are hardy and survive at polluted sites, have high tolerance scores. Consequently, the average score is higher at sites with more environmental stress. Tolerance scores were assigned from data analysis done during the 2006 programme.

Regression analysis was used to examine the relationships between biological metrics and environmental variables. Statistically significant relationships were found in 2007 for all groups except littoral macroinvertebrates, For diatoms, abundance and ATSPT were positively correlated with altitude, possibly because of lesser impact from human activities at higher altitudes. For zooplankton, abundance and ATSPT had positive relationships with electrical conductivity (an indicator of salinity), and abundance had a positive relationship with chlorophyll-a, probably indicating a response to nutrient enrichment. For benthic macroinvertebrates, richness had a negative relationship with turbidity, indicating that turbid waters were less conducive to a rich benthic fauna. Abundance had a positive relationship with water depth, being generally greater in the deeper rivers, and ATSPT had a positive relationship with electrical conductivity, indicating that intolerant species favour less saline sites.

This paper is a companion to three others in the MRC Technical paper series that provide details of the biomonitoring surveys carried out by the MRC in 2004, 2005, and 2006 (MRC,

2006; MRC 2009; MRC, in press). A fifth publication provides a synthesis of the whole MRC biomonitoring programme (MRC 2008). Together these publications will provide a complete overview of the entire Lower Mekong Basin, and the degree to which the aquatic ecosystems are impacted on by current levels of development.

1. Introduction

Arguably, the Mekong is the most important river in the world in terms of human dependency on riverine aquatic resources for sustenance and survival. The quality of life of the 60 million or more people living in the Lower Mekong Basin (LMB) depends on both the economic and the ecological health of the river. During period from 1999 to 2001, four localities in the basin were designated as Ramsar sites, and a number of possible future sites have been identified.

This 2007 report describes ongoing biomonitoring studies in the lower Mekong River that were conducted to contribute to evaluation of the overall ecological health of the river. It builds on activities initiated in 2003, when pilot studies determined which biological indicator groups should be used for biomonitoring. In 2004, a major component of the analysis was to compare both the biological variability within the individual sites and the biological variability among sites. This analysis confirmed that within-site variability is comparatively low and that the sampling effort used in the programme is sufficient to characterise each site adequately. The 2005 study then focused on testing the performance of assessment metrics developed and widely used elsewhere to describe community structure (species richness, abundance, a species diversity index, and a dominance index) when these approaches are applied to data from the Mekong River system. In many cases these metrics did not perform very well. In the 2006 programme, the emphasis was on developing tolerance values to stress, for each taxon (which included organisms identified to species, genus or family), that are specifically applicable to the Mekong River system. In addition, the other metrics were re-tested with the larger data set that was then available. In view of the results of previous studies, the 2007 study focused on three biological metrics (richness, abundance, and average tolerance score per taxon). Regression analyses were used to examine relationships between biological metrics and environmental variables.

The objectives of this report are to (i) describe the biological indicator groups sampled during 2007, (ii) use this information to derive biological metrics for the sites examined in 2007 and (iii) test the performance of these metrics against independent measures of environmental stress. Four biological indicator groups were used in this analysis: littoral and benthic macroinvertebrates, diatoms, and zooplankton.

Macroinvertebrates are the group of organisms that is most widely used for biological monitoring. The most frequently cited advantages of using these organisms include the following: their wide diversity, which includes the large number of species and their various responses to environmental change; their wide distribution; their limited mobility; the ease in sampling them; the long life-span of some species; and the fact that taxonomic keys, at least to higher identification levels, are available for most regions of the world. Because different species occur in the deeper parts of river channels and in the littoral zone, the survey sampled both zones, and this report presents data separately on the littoral and the benthic macroinvertebrates.

Although macroinvertebrates are the most widely used group of organisms in biomonitoring, they do not respond to all stressors and are very dependant on local habitat conditions. For this reason, we have also included two other groups of organisms in the analysis, benthic diatoms and zooplankton.

Benthic diatoms are increasingly used in biomonitoring programs, but usually in conjunction with macroinvertebrates rather than on their own. They offer some similar advantages to macroinvertebrates, including the ease in which they can be sampled, the diversity of their responses, and their widespread occurrence. However, because of their shorter generation time, they also often show more rapid responses to disturbance than do macroinvertebrates.

Riverine zooplankton are used less commonly in biomonitoring than either macroinvertebrates or diatoms, but the reason is that most programmes evaluate smaller, wadeable streams and rivers rather than large rivers like the Mekong. Zooplankton also have high diversity and clearly are an essential part of the ecosystem in large rivers. Their response time to disturbance is shorter than that of macroinvertebrates and longer than that of diatoms, and so they provide a complementary, intermediate role in the assemblages used in biomonitoring.

Biomonitoring programmes elsewhere in the world commonly include freshwater fish, with a frequency intermediate between macroinvertebrates and diatoms. Previous reports on the earlier Mekong surveys provide details of why, after pilot studies conducted in 2003, fish were not included in the biomonitoring programme. In short, fish were excluded for the present because they could not be sampled adequately in the short period (2–3 hours) allocated per site.

2. Sampling sites

The sites surveyed in 2007 cover the length of the lower Mekong River from central Lao PDR to northern Cambodia and the major Se Kong-Se San-Sre Pok tributary system in Cambodia and Lao PDR (Figure 2.1). They include localities from four of the BDP sub-areas. The sampling localities cover a range of river settings from bedrock-confined channels to alluvial channels and floodplains. The sites also exhibit varying disturbance from human activity. Some are located in or close by villages or towns, some are next to fields where crops are grown and livestock graze, some are upstream or downstream of dams and weirs, and at some there is moderate to heavy river traffic. Details of the 2007 survey sites are in Table 2.1.

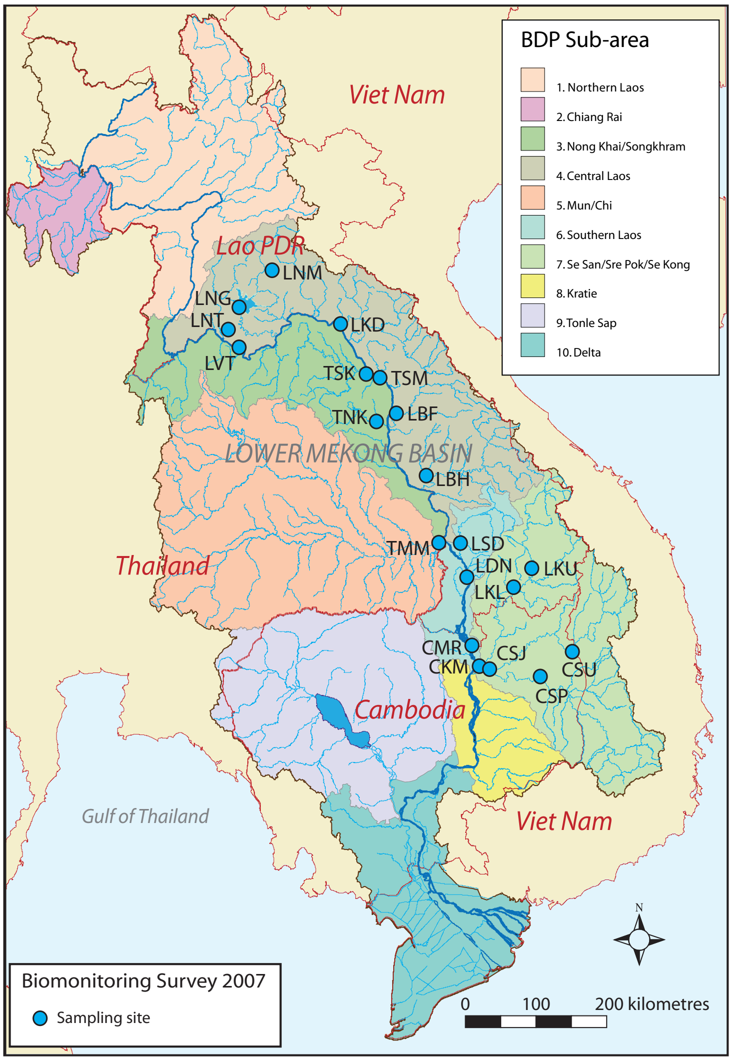

Figure 2.1. Location of the sites sampled during the 2007 biomonitoring survey.

Table 2.1. *Site descriptions for the biomonitoring survey in March 2007*

Site Name	Site code	Date sampled	Coordinates (UTM)		Elevation (m)	Water width (m)	Water depth (m)			Land cover		Substratum		Potential human impacts
			Right	Left			Left	Middle	Right	Left bank	Right bank	Littoral	Channel	
Nam Ton, 50 km from Vientiane	LNT	05/03/2007	48Q 208083 2016581		186	8 – 15	0.1	0.2 – 0.5	0.1	Forest, village, gardens	Forest, village, gardens	Sand, gravel, bedrock, boulders, concrete, wood	L – silt, sand, gravel, pebbles M – silt, sand, gravel, pebbles R – silt, sand, gravel, pebbles	Bank erosion, road runoff, washing and bathing, gold mine upstream
Mekong, upstream of Vientiane	LVT	06/03/2007		48Q 229378 1990015	178	790	1.4	1.5	5	Village, vegetable gardens (corn, chillies, bananas)	Village, vegetable gardens, palms	Sand, gravel, pebbles, reeds, refuse	L – silt, sand, refuse M – sand, pebbles, bedrock R – silt, sand	Cultivation of banks, washing and bathing
Nam Ngum, upstream of the confluence with Nam Lic	LNG	07/03/2007		48Q 237411 2049992	175	140	2.5	3	2.5	Forest, monastery	Forest	Sand, gravel, pebbles, cobbles	L – clay, silt, macrophytes M – boulders R – silt, macrophytes	Washing and bathing, fish cages, dam upstream
Nam Mo, upstream of bridge near mine	LNM	08/03/2007	48Q 280667 2088210		420	5 – 18	0.5	1	0.5	Forest, village	Forest, village, pasture, banana palms	Sand, gravel, pebbles, cobbles, boulders, reeds	L – silt, sand, detritus M – sand, cobbles R – silt, sand, detritus	Washing and bathing, gold mine upstream
Nam Kading	LKD	09/03/2007		48Q 398583 2023903	146	180	4	9.5	4	Forest, village	Village, scattered trees, bamboo, pasture, corn field, orchard	R – sand, detritus, algae L – sand, boulders, bedrock	L – silt, sand, gravel, detritus M – cobbles R – silt, sand, detritus, algae	Washing and bathing, bank erosion, boat traffic

Site Name	Site code	Date sampled	Coordinates (UTM)		Elevation (m)	Water width (m)	Water depth (m)			Land cover		Substratum		Potential human impacts
			Right	Left			Left	Middle	Right	Left bank	Right bank	Littoral	Channel	
Se Bang Fai	LBF	10/03/2007		48Q 498437 1888075	134	60–80	2.3	4.3	4.7	Village, bamboo, scattered trees	Village, bamboo, scattered trees	Sand, gravel, cobbles, bedrock, vegetation	L – clay, silt, sand, bedrock M – cobbles, bedrock R – silt, sand, bedrock, detritus	Washing and bathing, bank erosion, inter-basin water transfer upstream?
Se Bang Hieng	LBH	11/03/2007		48Q 540315 1779816	111	150	0.4–0.9	1.4	1.4	Village, scattered trees, eroded banks	Village, gardens, scattered trees	Sand, boulders, bedrock	L – clay, silt, sand, bedrock, algae M – sand, cobbles R – sand, algae	Washing and bathing, bank erosion, buffalo grazing
Se Done, Ban He upstream of Pakse	LSD	12/03/2007		48P 586345 1673985	101	130	1.5	1.9	1.4	Village, bamboo, scattered trees	Village, bamboo, scattered trees	Clay, silt, sand	L – silt, sand M – silt, sand R – silt, sand, bedrock, detritus	Washing and bathing, bank erosion, rubber plantation upstream
Se Kong, Cambodian border	LKL	14/03/2007	48P 670721 1623450		72	188	1.3	2.8	3.1	Forest, banana plantation, gold dredges	Village, trees, banana palms, livestock grazing, eroded banks	Sand, pebbles, cobbles, algae, vegetation	L – silt, sand, detritus M – sand, cobbles R – clay, silt, sand	Washing and bathing, boating, bank erosion, gold dredging
Se Kong, upper	LKU	15/03/2007	48P 702400 1653117		93	200	1.2	2.9	1	Forest, vegetable gardens, few houses	Village, vegetable gardens, scattered trees, bamboo, banana palms	Gravel, pebbles, cobbles, algae, vegetation	L – silt, sand, detritus, algae M – silt, sand, algae R – silt, sand, detritus	Washing and bathing, bank erosion, buffalo grazing

Site Name	Site code	Date sampled	Coordinates (UTM)		Elevation (m)	Water width (m)	Water depth (m)			Land cover		Substratum		Potential human impacts
			Right	Left			Left	Middle	Right	Left bank	Right bank	Littoral	Channel	
Mekong River, Done Ngieu	LDN	16/3/2007	48P 0596621 1650516		82	1300	6.8	3.7	4.0	Forest, bamboo, gardens	Forest, occasional house, banana palms, sugar cane, vegetable gardens	Sand, bedrock, algae	L – silt, sand, algae M – fine and coarse sand R – silt, sand, algae	Bank erosion, boating, sand dredging
Mekong River at Ramsar site	CMR	17/03/2007	48P 0605696 1539736		45	870	3.8	3.7	6	Some, small villages, agriculture, natural riparian vegetation	Few houses, agriculture, natural riparian vegetation	Sand, small gravel, mud, floating in algal	L – Sand M – Sand, some mud R – Sand and rocky	None
Se Kong mouth	CKM	18/03/2007	48P 0615573 1500696		45	373	1.45	2	1.5	Natural riparian vegetation, with scattered agriculture	Natural vegetation with few vegetable plantation, few buffalo	Bedrock, gravel, mud with sand	L – Sand, mud, debris, (leaves) M – Bedrock, cobble R – Sand, debris	None
Se San – Sre Pok junction	CSJ	19/03/2007	48P 0615573 1500688		40	652	4	1.9	1.7	Natural vegetation with bamboo	Natural vegetation with bamboo	Pebble, cobble, sand	L – Sand, clay M – Sand, cobble, bedrock R – Sand, clay,	None
Pam Pi (Se San at border)	CSU	20/03/2007	NA	48P 0764707 1526063	117	170	4.3	3.1	1.3	Few house, small agriculture, no sanitation	Small village, agriculture	Cobble, pebble, rock, littoral sand, good habitat	L – Sand, clay, debris M – Sand, R – Sand, mud, debris, (leaves)	Water level rises reach site at 7 am – 5 pm from dam release @ 7 km upstream
Sre Pok	CSP	21/03/2007	NA	48P 0717104 1490800	100	190	1.7	3.7	1.7	Natural bamboo, riparian vegetation few house, settlement	Same as left bank, some sugar cane	Rock, cobble on island	L – Sand, mud, leaf M – Sand R _ Sand, mud, leaf, bedrock	Bedrock, rock, cobble, sand

Site Name	Site code	Date sampled	Coordinates (UTM)		Elevation (m)	Water width (m)	Water depth (m)			Land cover		Substratum		Potential human impacts
			Right	Left			Left	Middle	Right	Left bank	Right bank	Littoral	Channel	
Mun–Chi Mekong (Mun–Kong Chiam)	TMM	23/03/2007	48P 0552854 1692378	NA	85	260	2	4.9	5.1	Agriculture on left bank complete	Natural	bedrock, grasses, agriculture	L – Algae, mud, sand M – Bedrock, sand R – Rock, mud, sand	Dam operations
Nam Kham (Na Kae)	TNK	24/03/2007	NA	48Q 08450473 1874626	12–15	133	1.5	0.7	0.3	Invaded bank with natural riparian vegetation, some cassava, rice	More natural vegetation, beach	Sandy	L – Sand, gravel M – Sand, gravel, R – Sand, clay	1.5 km below dam
Nam Songkhram mouth	TSK	25/03/2007	48Q 0440989 1948666	NA	95	127	4.8	4.8	2.15	Invaded forest, bamboo forest, natural vegetation	Less eroded. Riparian vegetation	Clay mud, (some algae) with gravel soft	L – Clay, mud M – Bedrock, cobble R – Bedrock, clay	Between fish cages, below a small dam
Nam Songkhram Mekong	TSM	26/03/2007	48Q 0444135 1951422	NA	131	1137		1.5–4	1.5			Village, crops on slop, fish cages	M – Sand R – Clay and sand, sand and mud	Sand

3. Environmental variables

3.1 Introduction

Variables describing the physical and chemical environment provide essential information for characterising aquatic ecosystems because these factors directly influence the structure and function of an ecosystem's biological components. Physical and chemical variables are widely used to set water-quality standards and can be used to assist in interpreting biological trends and patterns. Although the biological monitoring programme has only recently begun, the Mekong River Commission has been monitoring physical and chemical water quality in the Mekong River Basin for over 20 years (Campbell, 2007).

The objectives of the study of physical and chemical factors completed in 2007 were as follows: (i) to describe selected physical and chemical characteristics of sites in the lower Mekong River, and (ii) to provide environmental data that could be used to test the performance of biological assessment metrics. To address these objectives, the study collected data on altitude, river width, water depth, water transparency, turbidity, water temperature, dissolved oxygen (DO), electrical conductivity (EC), pH, and amounts of chlorophyll-a.

3.2 Methods

The sampling methods in the 2007 survey generally followed those used in the previous years. The map coordinates and altitudes of the sampling sites were determined with a Garmin GPS 12XL, and stream width was measured with a Newcon Optik LRB 7x50 laser rangefinder. At each site, water-quality measurements were made in three sections of the river: near the left bank, near the right bank, and in the centre of the river.

A Secchi disc was used to determine water transparency. The disc was slowly lowered into the water, and the depth at which it could no longer be seen was recorded. The disc was then lowered another metre and slowly pulled up until it reappeared. If it reappeared at a depth more than 0.05 m different from the depth at which it disappeared, the procedure was repeated.

Water turbidity was measured at the water surface with a Hach 2100P turbidity meter. Temperature, DO, EC, and pH were measured with YSI 556MP5 meter, calibrated according to the manufacturer's instructions. Readings were taken at the surface and at a depth of 3.5 m, or the maximum of the river, whichever was less. The amount of chlorophyll-a in water was measured at the surface with an Aquaflour handheld fluorimeter.

A Site Disturbance Score was calculated to rate human disturbance at each site. Each of 10 individuals rated each site that they had visited in terms of their perception of the human impact evident at that site. Light impact was rated 1, medium impact 2, and heavy impact 3. Sites were scored independently, followed by a discussion that resulted in a small percentage (~1% of scores) being changed. The 10 scores were averaged to obtain the overall Site Disturbance Score for each site.

The measured environmental variables were reported as average values.

3.3 Results and discussion

Most of the environmental variables showed a broad range of values across the 20 study sites (Table 3.1). For example, altitude varied from 40 masl (metres above sea level) at site CSJ to 420 masl at site LNM, and channel width varied from being as narrow as 11 m at LNM to as wide as 1,240 m at LDN. Water temperature varied greatly from site to site, with an average of 27.8 ºC (± 2.6 ºC). The lowest value of 20.9 ºC was recorded at a small high-altitude site LNM, and the highest value of 31.0 ºC at site CKM.

DO concentrations, however, were only slightly varied from site to site and generally high, even at those sites showing evidence of human disturbances from villages, agriculture, or dam construction, with an average of 7.71 mg/L (± 0.66 mg/L). The highest value of 8.87 mg/L was recorded at site LNM and the lowest value of 6.93 mg/L was recorded at site LNG. Electrical conductivity varied from 4.3 to 49.2 mS/m, with an average of 16.2 mS/m (± 11.5 mS/m). Lower conductivity was found in tributary sites whereas higher values were found at sites in the main channel and sites with human disturbance or limestone catchment (e.g. LVT, TSK, TSM, LBF). Water was slightly alkaline at most of the sites, with pH varying between 6.9 and 8.4 with an average of 7.6 (± 0.4).

Water transparency (Secchi depth) ranged from 0.36 m at LKL to 2.57 m at site LNG. Over the sites sampled, average transparency was 1.19 m (with a standard deviation of ± 0.64 m). Turbidity varied slightly at most of the sites, with an average value of 11.36 NTU (± 10.79). The lowest value of 2.38 NTU was recorded at LNG and the highest, 45.7 NTU, at LKL. The very high turbidity at LKL was caused by a heavy storm in the catchment before the samples were taken. Chlorophyll-a was generally low, and ranged between 0.17 and 0.84 µg/L with the average of 0.46 (± 0.16 µg/L). The average Site Disturbance Score for human disturbance suggested medium impact, with most of the sites having the scores lower than 2, except for LNM, TMM and TNK which had the scores slightly above 2.

The pH, DO, and temperature data were within the ranges defined for aquatic ecosystems according to the standards for surface water quality set by Thailand, Viet Nam, and Cambodia (MRC, 2005; PCD, 2004). Most of the sites had DO values higher or very close to 7 mg/L, falling within class 2 (very clean) of Thailand's water quality standards and within the range specified for biodiversity conservation for Cambodian rivers.

Table 3.1. *Environmental variables: altitude, river width, average water depth, temperature, dissolved oxygen, electrical conductivity, pH, water transparency (Secchi depth), turbidity, the amount of chlorophyll-a, and Site Disturbance Score at 20 sites sampled in 2007.*

Site	Altitude (m)	River width (m)	Depth (m)	Temperature (ºC)	DO (mg/L)	Conductivity (mS/m)	pH	Secchi depth (m)	Turbidity (NTU)	Chlorophyll-a (µg/L)	Site disturbance score
LNT	176	12	0.5	26.8	8.69	14.8	7.4	0.50	12.47	0.67	1.69
LVT	178	790	2.6	23.9	8.73	28.3	7.8	0.70	20.46	0.44	1.78
LNG	175	140	2.7	23.4	6.93	8.6	6.9	2.57	2.38	0.27	1.84
LNM	420	11	0.7	20.9	8.87	9.7	7.9	0.70	3.55	0.17	2.31
LKD	146	290	5.8	26.7	7.80	10.7	7.7	2.05	3.24	0.35	1.56
LBF	134	80	3.8	27.1	7.54	32.9	8.1	0.78	9.69	0.34	1.72
LBH	111	150	1.2	28.3	7.70	15.3	7.9	1.06	8.81	0.48	1.63
LSD	101	130	1.7	28.7	7.42	11.9	7.8	0.70	17.03	0.84	1.97
LKL	72	200	2.4	29.3	7.26	7.1	7.2	0.36	45.70	0.37	1.69
LKU	93	200	2.6	28.6	7.34	4.8	7.0	1.98	3.49	0.25	1.53
LDN	82	1240	4.8	28.6	8.51	22.9	8.3	1.83	4.47	0.51	1.53
CMR	45	870	4.4	30.5	8.34	22.5	8.4	1.58	4.42	0.39	1.61
CKM	45	373	1.7	31.0	7.33	7.3	7.8	1.13	7.24	0.43	1.31
CSJ	40	652	2.5	30.3	7.41	4.9	7.5	1.47	5.40	0.59	1.28
CSU	117	170	2.9	26.1	6.98	4.3	7.3	1.40	5.48	0.45	1.97
CSP	100	190	2.4	29.8	7.19	6.8	7.5	1.15	7.94	0.51	1.39
TMM	85	260	4.0	30.1	7.25	20.9	7.5	2.03	2.93	0.53	2.17
TNK	133	12	0.8	28.4	7.11	16.9	7.2	0.43	25.61	0.45	2.44
TSK	120	95	3.9	29.0	7.15	49.2	7.5	0.82	12.60	0.60	1.97
TSM	131	1137	1.6	28.1	8.65	25.0	8.1	0.58	24.31	0.63	1.86
Average	125.2	350.1	2.6	27.8	7.71	16.2	7.6	1.19	11.36	0.46	1.76
S.D.	80.9	376.7	1.4	2.6	0.66	11.5	0.4	0.64	10.79	0.16	0.31

4. Benthic diatoms

4.1 Introduction

Algae, including diatoms, are important primary producers in aquatic ecosystems. These small photosynthetic organisms provide pathways by which energy and materials are transferred into aquatic food-webs. Moreover, algae are used in areas such as aquaculture, environmental monitoring, and medicine. Diatoms have been studied in Southeast Asia since the late 19th century, when early taxonomic studies were undertaken by scientists from outside the region. Ostrup recorded 81 species of diatoms from Koh Chang Island, after the Danish expeditions to Thailand in 1899–1900 (Peerapornpisal et al., 2000). Patrick (1939) recorded 185 diatom species in her study of the intestinal contents of tadpoles from Thailand and the Federal Malay States. In 1961-1962, Hirano, working on material collected by the Joint Thai-Japanese Biological Expedition to Southeast Asia, produced a species list that still provides a valuable reference for the diatoms of the region.

The objective of this chapter is to (i) describe the characteristics of the diatom community that was quantitatively sampled at 20 sites in 2007, (ii) report bioassessment metrics based on the diatom community present at each of the sites examined in 2007, and (iii) relate metric values to independent measures of environmental stress.

4.2 Methods

Locations for sampling of benthic diatoms were chosen where the water depth was less than 1 m and suitable substrata extended over a distance of 100 m. The most appropriate substrata were cobbles and other grades of stones with a surface area greater than 10 cm^2, but that were still small enough to fit in a 20–30 cm diameter sampling bowl. At sites where the river bed was predominantly muddy or sandy and lacked suitable sized stones, samples were taken from bamboo sticks, aquatic plants, and artificial materials.

At each site, ten samples were recovered at intervals of about 10 m. Samples were removed from a stone chosen because it was coated with a thin brownish film or had a slippery feel. These characteristics are often indicative of the presence of an abundance of benthic diatoms. Where there were no suitable stones, the nearest hard substratum was sampled instead. To sample the diatoms, a plastic sheet with a square, 10 cm^2 cutout was placed on the upper surface of the stone or other substratum, and benthic diatoms were brushed and washed off into a plastic bowl until the cutout area was completely clear. Each sample was transferred to a plastic container and labelled with the name of the site, a location code, the date of sampling, and replicate number. The collector's name and substratum type were also noted. Samples were preserved with Lugol's solution.

In the laboratory, the samples were cleaned by digestion in concentrated acid, and then centrifuged at 3500 rpm for 15 minutes. The diatom cells (the brown layer between the supernatant and solid particles) were siphoned into an 18 cm core tube. Strong acid (H_2SO_4, HCl or HNO_3) was added and the tubes were heated in a boiler (70 – 80 ºC) for 30-45 minutes. The samples were then rinsed with de-ionized water 4 – 5 times and adjusted to a volume of 1 mL. A drop of each sample (0.02 mL) was placed on a microscope slide and dried. A mounting agent such as Naphrax or Durax was added to make a permanent slide for diatom identification and counting; these were done under a compound microscope. Identification was based on frustule type, size, special characteristics, and structure, as described and illustrated in textbooks, monographs and other publications on tropical and temperate diatoms (Foged, 1971, 1975, 1976; Krammer & Lange-Bertalot, 1986, 1988, 1991a, 1991b; Pfister, 1992). In many cases identification to species-level was not possible and presumptive species were designated by numbers. The total count of cells on the slide was used to estimate total numbers per sample, i.e. the number of cells counted multiplied by 5 is the number per cm^2 sampled. The permanent slides are kept in the Applied Algal Research Laboratory Collection at Chiang Mai University.

The following metrics were calculated for all sites sampled in 2007: taxon richness (the number of species of diatoms collected at a site), abundance (the number of individual organisms collected), and the average tolerance score per taxon (ATSPT). ATSPT is an indicator of the presence of environmental stressors such as water pollution. Species that are sensitive to stress, and tend to be absent at stressed sites, have low tolerance scores. Stress-tolerant species, which are hardy and survive at stressed sites, have high tolerance scores. Consequently, the average score is higher at sites with environmental stress. The tolerance scores for individual taxa were assigned during the 2006 season and are available in the biomonitoring report for that year (MRC, 2009b).

4.3 Results

Biota collected

The 20 sites sampled in 2007 yielded a total of 102 species of benthic diatoms out of the 2,000 cm^2 of algal samples collected (Appendix 1). *Achnanthes minutissima*, *Nitzschia palea*, and *Navicula symmetrica* had the widest distribution and each occurred at all sites sampled.

Table 4.1. *Diatom metrics for sites sampled in 2007.*

Site	No. of species	Density (cell/cm^2)	ATSPT
LNT	26	70	37.34
LVT	21	1338	39.32
LNG	19	554	43.65
LNM	28	1019	50.49
LKD	28	309	32.59
LBF	16	46	36.69
LBH	22	257	35.91
LSD	21	108	37.62
LKL	19	63	37.71
LKU	16	139	35.12
LDN	20	266	33.28
CMR	27	58	35.77
CKM	20	71	32.62
CSJ	16	655	30.61
CSU	12	287	35.98
CSP	23	532	34.04
TNM	21	720	47.11
TNK	25	101	46.77
TSK	7	451	42.84
TSM	16	128	39.38

Richness (number of taxa)

Species richness per site ranged from 7 to 28 at the 2007 sites (Table 4.1). The highest richness occurred at sites LNM and LKD (28 species), while the lowest richness was found at the lower Mekong River tributary sites that had sandy and muddy substrata, such as site TSK (7 species).

Abundance

The average density of diatoms ranged from 46 to 1,138 cells/cm^2 at the 2007 sites (Table 4.1). The highest abundance occurred at site LVT (1,338 cells/cm^2), while the lowest abundance was found at the lower Mekong River tributary sites in Lao PDR that had muddy substrata, such as site LBF (46 cells/cm^2).

Average Tolerance Score Per Taxon

The tolerance values for individual taxa of benthic diatoms varied from 13.9 (*Nitzschia acicularis*) to 72.2 *(Frustulia* sp.). The ATSPT varied greatly among the sites examined in 2007, ranging from 30.6 to 50.5. There was a general trend of increasing ATSPT in a north to south direction indicating a decrease in pollution-sensitive species. Generally, the tolerance scores calculated for the benthic diatoms in sites in the upper Mekong River and the tributaries were lower than those of sites in the lower Mekong River.

Relationships to environmental factors

The richness of benthic diatoms showed a slight, and statistically non-significant, positive correlation (Figure 4.1) with altitude and DO ($R^2 = 0.11$ and 0.20 respectively). In contrast, species richness was negatively correlated with conductivity ($R^2 = 0.11$). Again, the relationship was not statistically significant. The abundance of benthic diatoms showed a statistically significant positive correlation (Figure 4.2) with altitude and non-significant correlations with average site disturbance score, turbidity and chlorophyll-a. There was a strong, statistically significant and positive relationship between ATSPT and altitude (Figure 4.3).

4.4 Discussion

There was a statistically significant relationship between diatom abundance and altitude but richness was not significantly related to the environmental variables tested. Values of these metrics were highly variable among the sites, probably because of the different habitats at sites situated in the upper and lower parts of the river system. For example, the higher species richness recorded at sites located on tributaries of the Mekong River such as LKD (28 species) and CMR (27 species) was at localities with suitable substrata (e.g. cobbles and stones), which made these sites conducive to a rich flora of benthic diatoms. In contrast, the coarse sandy, muddy and clay substrata at main channel sites like TSK (7 species) were an obvious limiting factor to the species richness of the benthic diatom assemblages.

The range of ATSPT of the benthic diatom species represents a flora that has some sensitive species but is predominantly composed of species with mid-range tolerance to pollution. Some stress-sensitive species were numerically dominant in sites that showed little evidence of human impacts. For example, *Achnanthes minutissima* (which has a tolerance score of 35 indicative of a stress-sensitive species) was found in high abundance at site CSJ, which had a somewhat lower ATSPT (31). However, in sites with higher ATSPT such as TMM, species such as *Achnanthes minutissima* were co-dominant with species such as *Nitzschia tropica*, which has a tolerance score of 60.4, indicative of a tolerant species. This could suggest that the addition of abundance (as in the ATSPI used in 2006), rather than just presence-absence as in ATSPT, might be explored in more detail in the future. The distribution of ATSPT values at the sites visited reflects a gradient of increasing stress from the north and tributaries to the south.

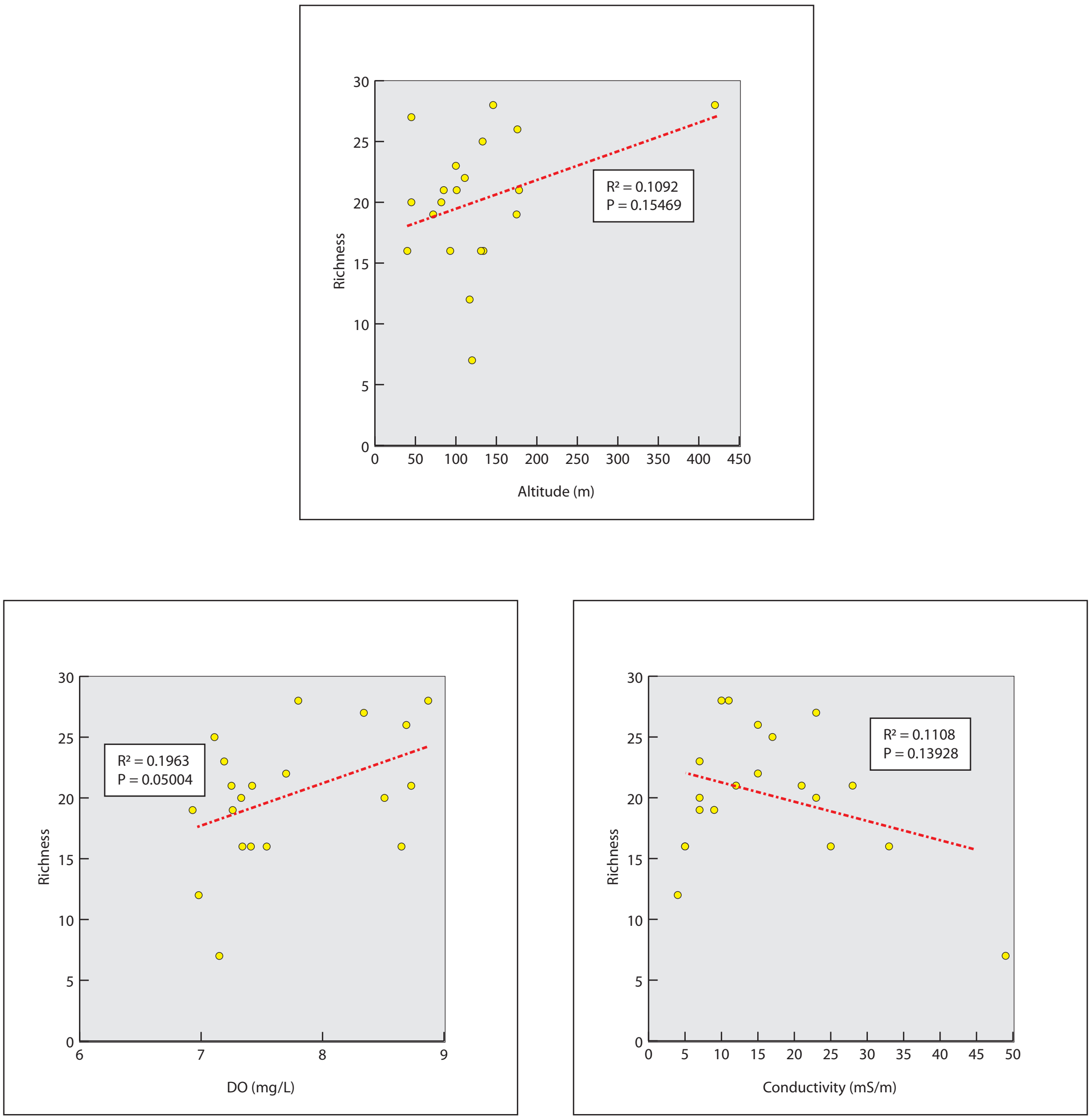

Figure 4.1. Regression relationship between the richness of benthic diatoms and environmental variables sites sampled during 2007.

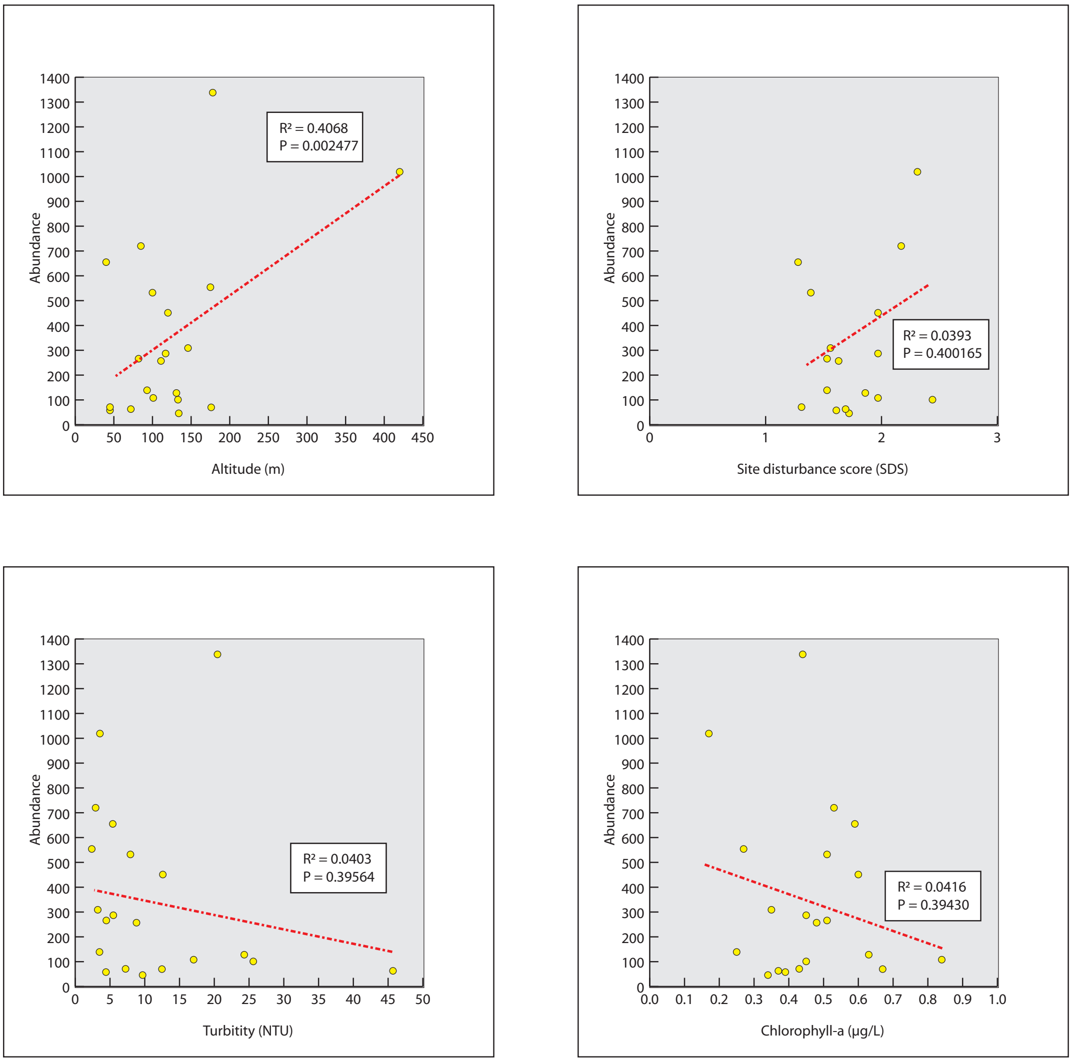

Figure 4.2. Regression relationship between abundance of benthic diatoms and altitude, SDS, turbidity, and planktonic chlorophyll-a of sites sampled in 2007.

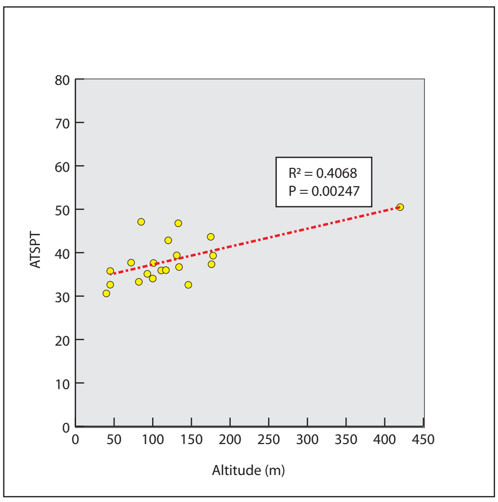

Figure 4.3. Regression relationship between the ATSPT of benthic diatoms and altitude at sites sampled in 2007.

5. Zooplankton

5.1 Introduction

Zooplankton are widely distributed and present in most water bodies in the world. In rivers, the smallest members of the zooplankton are protozoans and rotifers (Kudo, 1963), and the larger zooplankton are mostly crustaceans (Hynes, 1970). The zooplankton community is composed of both primary consumers, which feed on bacteria and phytoplankton, and secondary consumers, which feed on other zooplankton. Zooplankton link the primary producers (phytoplankton) with larger organisms at higher trophic levels, and they are important as food for forage fish species and for larval stages of all fish.

Zooplankton are excellent indicators of environmental conditions because they respond to low concentrations of dissolved oxygen, high levels of nutrients and non-living organic matter, and toxic contaminants. The main groups of zooplankton, especially Crustacea and Eurotatorea, have long been assessed quantitatively and considered useful in evaluating environmental quality (Crivelli and Catsadorakis, 1997). Recently, zooplankton have been increasingly used in biological monitoring programs. For example, properties of the zooplankton community were used as indicators in an ecological health assessment for estuaries in Australia (Deeley and Paling, 1999). However, in the Mekong River system, studies of zooplankton have been limited. Most studies have concerned the Mekong Delta in Viet Nam (e.g. Doan, 2000; Le and Pham, 2002) and have focused on taxonomy and food resources for fisheries.

The objectives of this chapter are to (i) describe the characteristics of the zooplankton community that was quantitatively sampled at 20 sites in 2007, (ii) report bioassessment metrics based on the zooplankton community present at each of the sites examined in 2007, and (iii) relate metric values to independent measures of environmental stress.

5.2 Methods

Three samples were collected at each site. One was taken near the left bank of the river, at a distance of about 4 – 5 m from the water's edge. A separate sample was taken at a similar distance from the right bank, and another in the middle of the river. 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. At sites where the water current was too fast to sample exactly in the mid-stream, samples were collected closer to the left or the right bank, but not as close to the bank as where the 'side samples' were taken.

Before sampling at each site, the sampling equipment (a net, bucket, and plastic jar) was washed to remove any organisms and other matter left from the previous site. Quantitative samples were collected at a depth of 0 to 0.5 m in a bucket having a volume of 10 L. The 10 L of river water collected was filtered slowly through a plankton net (mesh size of 20 µm) to avoid any overflow. When the water volume remaining in the net was about 150 mL, the water was transferred to a plastic jar (250 mL volume). The samples were immediately fixed in the field with 4% formaldehyde. The sample jars were labelled with the site name, site code, sampling position, sampling date, and the sample number.

In the laboratory, large debris particles were removed from the samples with forceps. Each sample was filtered via a net with a mesh size of 10 µm and rinsed with distilled water, and then settled in a graduated cylinder. Excess water was discarded until about 50 mL of water and settled material remained. This was transferred into a petri dish and examined under a stereomicroscope at a magnification of 40x to identify the large species of zooplankton (> 50 µm in diameter). The smaller species and details of larger species were examined on a microscope slide under a compound microscope at a magnification of 100–400x. All individuals collected were counted and identified to lowest level of taxonomy possible, generally species. Identification was based on morphology as described in Vietnamese and international references (e.g. Dang *et al*., 1980; Eiji, 1993). After analysis, samples were returned to the bottles and preserved. All specimens are kept at Ton Duc Thang University, Ho Chi Minh City, Viet Nam.

The following metrics were calculated for all sites sampled in 2007: taxon richness (the number of types of organisms collected at a site), abundance (the number of individual organisms collected), and the average tolerance score per taxon (ATSPT). The ATSPT is an indicator of the presence of environmental stressors such as water pollution. Species that are sensitive to stress, and tend to be eliminated from stressed sites, have low tolerance scores. Stress-tolerant species, which are hardy and survive at stressed sites, have high tolerance scores. Consequently, the average score is higher at sites with environmental stress. Tolerance scores for individual taxa were assigned in the 2006 biomonitoring report.

5.3 Results

Biota collected

A total of 43,907 individuals was collected in the zooplankton samples taken at the 20 sites examined in 2007. These comprised 118 species in 61 genera and 31 families, and five forms of larva (Appendix 2). The zooplankton included four main groups: Crustacea (including Copepoda, Brachiopoda, and Ostracoda), Eurotatorea, Protozoa and larvae (Table 5.1). Eurotatorea had the most taxa (30 genera and 15 families making up 54.5% of the total zooplankton taxa collected). The Brachionidae (Eurotatorea), Difflugiidae (Protozoa) and Lecanidae (Eurotatorea) were the richest families with 14, 12 and 9 taxa, respectively.

Table 5.1. *Numbers of taxa within each major group of zooplankton recorded for sites sampled in 2007.*

Group	Number of taxa
Crustacea	24
Copepoda	9
Ostracoda	1
Branchiopoda	14
Eurotatorea	67
Protozoa	27
Larvae	5

Most groups (Copepoda, Branchiopoda, Eurotatorea, Protozoa, and larvae) were recorded at all 20 sites while Ostracoda were found at only two sites. The Ostracoda had only one taxon, which normally occurs in water with fast currents, high levels of nutrients and high turbidity, and was recorded at sites TMM and TSK in Thailand. Copepod nauplii (larval forms) had the widest distribution of the individual taxa, occurring at all sites, but *Keratella cochlearis cochlearis* (Eurotatoria: Brachionidae), *Arcella vulgaris* (Protozoa: Arcellidae) and *Difflugia lobostoma* and *Difflugia globulosa* (Protozoa: Difflugiidae) also had a wide distribution and occurred at 16 – 18 sites.

Some 53 taxa were found at only one or two sites. This reflects the differences in environmental characteristics of the 20 sites. For example, *Alona rectangula*, which is typical of waters with low current and high transparency, was recorded at sites LNG and TMM, while *Notommata aurita* and *Cephalodella tenuior*, which mainly characterise low-nutrient water with high current velocities and transparency, were found only at site LNT. In contrast, the tolerant species *Euglena acus* was recorded only at TNK.

The sensitive species of Eurotatorea such as *Dissotrocha aculeata* (Philodinidae), *Notommata aurita*, *Cephalodella tenuior*, and *Cephalodella catellina* (Notommatidae), *Trichocerca pusilla* (Trichocercidae), *Asplanchna girodi* (Asplanchnidae), *Mytilina ventralis* (Mytilinidae), *Lepadella patella* (Lepadellidae), *Diplois daviesiae* (Euchlanidae), and *Anuraeopsis fissa* (Brachionidae) were found only at sites LNT, LKD, LBH, LSD, LKU, LDN, CSJ, and CSP.

Richness (number of taxa)

Taxon richness varied widely at the 20 sites sampled in 2007, from 13 to 43 taxa per site (Table 5.2). The number of taxa was highest at sites CSU and TNK where the richness of Eurotatorea was the highest encountered at the 20 sampling sites (CSU: 53.5% of total taxa; TNK: 54.1% of total taxa). Richness was lowest at site LNM, where Ostracoda and Brachiopoda were absent from the samples (Table 5.2).

Table 5.2. *Zooplankton taxon richness and abundance (individuals/10 L) recorded at sites sampled in 2007.*

Site	No. of taxa		Abundance	
	Total per site	Range per sample	Mean per sample	Range per sample
LNT	16	6–13	35	15–65
LVT	18	10–11	160	121–213
LNG	25	14–19	83	69–90
LNM	13	8–9	30	26–33
LKD	14	4–8	8	6–9
LBF	23	16–19	222	154–257
LBH	28	15–19	473	365–552
LSD	35	25–27	1408	1358–1487
LKL	19	9–10	17	13–24
LKU	35	19–22	142	124–177
LDN	35	20–23	194	154–247
CMR	23	8–20	35	13–51
CKM	25	11–16	35	27–42
CSJ	26	16–17	52	39–63
CSU	43	20–33	113	49–164
CSP	26	13–18	62	44–75
TMM	30	12–24	114	45–198
TNK	37	16–32	473	276–785
TSK	27	20–22	8394	3309–14741
TSM	33	15–26	2586	1023–5332

Abundance

Abundance also varied among the 20 sites sampled in 2007, averaging from 8 to 8,394 individuals per sample (Table 5.2). The number of individuals was highest at site TSK (3,309–14,741 individuals/sample), and site TSM also had high abundance (1,023–5,332 individuals/sample). The dominant species present were those well adapted to nutrient-rich conditions, belonging to the families Synchaetidae and Brachionidae (Eurotatorea). Species of Difflugiidae (Protozoa) were numerically dominant, and characteristically occurred in sites with high turbidity and slow water currents. The lowest abundance was at LKD (6–9 individuals/sample) where few or no eurotatoreans or crustaceans were present. Filter feeders in the families Brachionidae (Eurotatorea) and Difflugiidae (Protozoa), which are characteristic of nutrient-rich water, were most abundant at sites CSU, TNK, TSK, and TSM.

Average Tolerance Score Per Taxon

The tolerance scores for individual taxa of zooplankton varied from 0 to 94. The ATSPT varied greatly among the sites examined in 2007 (Table 5.3), ranging from 39 (site LKL) to 48 (site TNK).

Table 5.3. *ATSPT values for zooplankton recorded at sites sampled in 2007.*

Site	ATSPT
LNT	41
LVT	43
LNG	45
LNM	41
LKD	42
LBF	46
LBH	43
LSD	45
LKL	39
LKU	40
LDN	43
CMR	44
CKM	42
CSJ	41
CSU	43
CSP	43
TNM	46
TNK	48
TSK	46
TSM	45

Relationships to environmental factors

The number of zooplankton taxa at the 20 sites had negative relationships with DO and altitude (Figures 5.1 and 5.2). However, these relationship were not statistically significant. The number of individuals of zooplankton did not have a statistically significant relationship with any environmental variable. However, a logarithmic transformation of abundance had a significant positive relationship with conductivity ($P = 0.003$) (Figure 5.3) and chlorophyll-a ($P = 0.021$) (Figure 5.4). The ATSPT of zooplankton had a statistically significant positive relationship with conductivity ($P = 0.008$) (Figure 5.5).

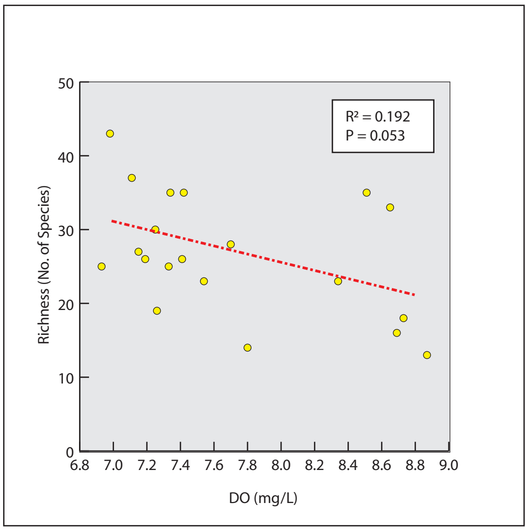

Figure 5. 1. Regression relationship between the richness of zooplankton and DO at sites sampled in 2007.

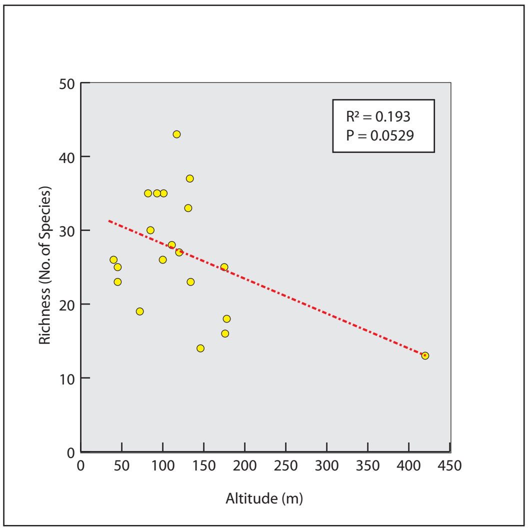

Figure 5. 2. Regression relationship between the richness of zooplankton and altitude at sites sampled in 2007.

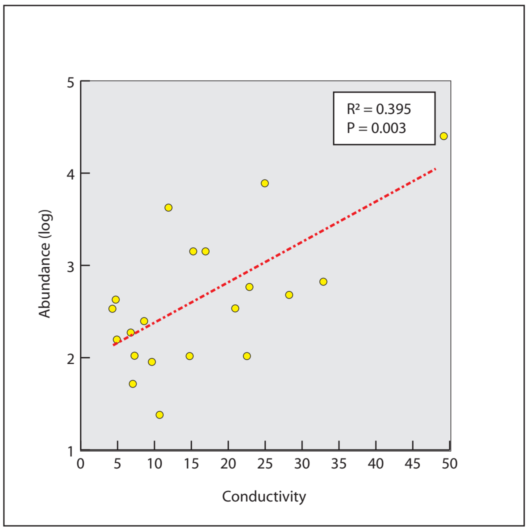

Figure 5. 3. Regression relationship between the abundance (log transformation) of zooplankton and conductivity at sites sampled in 2007.

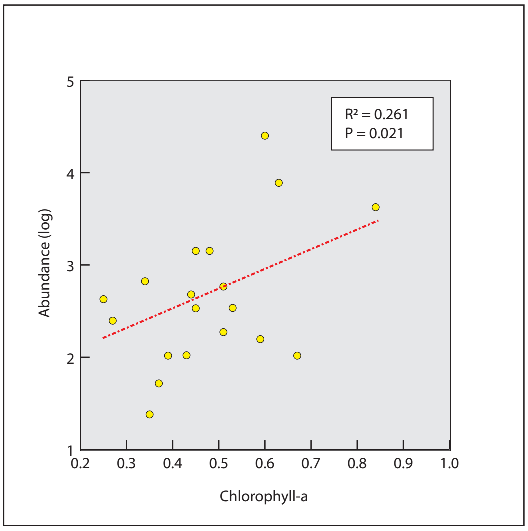

Figure 5. 4. Regression relationship between the abundance (log transformation) of zooplankton and chlorophyll-a at sites sampled in 2007.

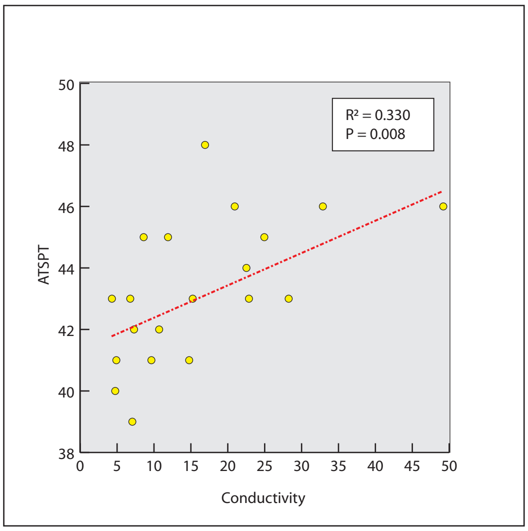

Figure 5. 5. Regression relationship between the ATSPT of zooplankton and conductivity at sites sampled in 2007.

5.4 Discussion

The number of zooplankton individuals was significantly higher where conductivity and chlorophyll-a values were higher, and ATSPT was also higher where conductivity was greater. This may have been a response to an increase in nutrient concentrations at some sites, such as TSK, TSM, as a result of human activities. Thus these activities may promote the development of some species in the zooplankton community.

6. Littoral macroinvertebrates

6.1 Introduction

Littoral macroinvertebrates have been used widely in bioassessment, primarily in temperate areas but also in tropical countries. For example, Thorne and Williams (1997) applied a variety of rapid assessment methods for macroinvertebrates in Brazil, Ghana, and Thailand. They tested 20 analytical methods that have been used in temperate regions, including representatives of the five major types identified by Resh and Jackson (1993): richness indices, enumerations, diversity and similarity measures, biotic indices, and functional measures. Seven of the 20 methods behaved as expected in response to pollution gradients, but these did not include any enumeration or 'functional feeding' measures. Two diversity indices also failed to respond to pollution gradients in the predicted manner, whereas three 'similarity/ loss indices' all met the test criteria. The Biological Monitoring Working Party (BMWP) score and the Average Score Per Taxon (ASPT) performed satisfactorily.

Mustow (1997) studied the macroinvertebrate community at 23 sites on the Mae Ping River in northern Thailand and suggested some modifications of the BMWP score to suit local conditions. According to Mustow (1997), 71 of the 85 BMWP families 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 addition, Pinder (1999) applied similar approaches to biomonitoring that are applicable to other areas of Southeast Asia.

The objectives of this chapter are to (i) describe the characteristics of the littoral macroinvertebrate community that was quantitatively sampled at 20 sites in 2007, (ii) report bioassessment metrics based on the littoral macroinvertebrate community present at each of the sites examined in 2007, and (iii) relate metric values to independent measures of environmental stress.

6.2 Methods

At each site, littoral macroinvertebrate samples usually were taken on only one side of the river. In most instances this was the depositional side where sampling was easier because of the gradual shelving of the bottom that occurs in this setting in contrast to the steeper bottom that is characteristic of the erosional side. In addition, the depositional side tends to support more aquatic vegetation, which also provides more habitat suitable for invertebrates. Because the study area was large, a wide range of littoral habitat types was sampled. As far as possible, similar habitats were selected at each site to facilitate comparisons among sites.

In 2007, as in most previous years, both sweep and kick sampling methods were used. A D-frame net with 30 cm x 20 cm opening and mesh size of 475µm was used for both sweep and kick sampling. Sweep samples were taken along the shore at intervals of about 20 m. To obtain each sweep sample, the collector stood in the river about 1.5 m from the water's edge and swept the net toward the bank 10 times near the substrate surface. Each sweep was done for about 1 m at right angles to the bank, in water no deeper 1.5 m, and did not overlap the previous sweep. Kick sampling was done off-riverbank in areas of rapid current. Sampling involved kicking the substrate in an area of 30 x 30 cm, or using fingers to disturb this area, for about 20 seconds. A range of substrates was sampled, including cobbles, gravel, sand, silt, mud, and aquatic plants. Five kick and five sweep samples were taken per site, unless there was no suitable habitat for kick sampling, in which case ten sweep samples were taken.

After sample collection, the net contents were washed to the bottom of the net. The net was inverted and its contents were emptied into a metal sorting tray, with any material adhering to the net being washed off with clean water. Invertebrates were picked from the tray with forceps and placed in a jar of 70% ethanol. Small samples were kept in 30 mL jars and large samples were kept in 150 mL jars. During the picking process, the tray was shaken from time to time to redistribute the contents, and tilted occasionally to look for animals adhering to it. Sorting proceeded by working back and forth across the tray until no more animals were found. The sample jars were labelled with the site location code, date, and sample replicate number. The collector's name, the sampling site, and replicate characteristics (including substrate types sampled) were recorded in a field notebook.

In the laboratory, the samples were identified under a stereomicroscope with a 2x–4x objective lens and a 10x eyepiece. Identification was done to the lowest taxonomic level that could be applied accurately, which was usually to genus. The references used for identification included Sangpradub and Boonsoong (2004), Nguyen *et al*. (2000), Morse *et al*. (1994) and Merritt and Cummins (1996). Specimens were divided into orders, kept in separate jars. All specimens were stored in the Department of Biology at the National University of Laos.

The following metrics were calculated for all sites sampled in 2007: taxon richness (the number of types of organisms collected at a site), abundance (the number of individual organisms collected), and the average tolerance score per taxon (ATSPT). The ATSPT is an indicator of the presence of environmental stressors such as water pollution. Species that are sensitive to stress, and tend to be eliminated from stressed sites, have low tolerance scores. Stress-tolerant species, which are hardy and survive at stressed sites, have high tolerance scores. Consequently, the average score is higher at sites with environmental stress. Tolerance scores for individual taxa were assigned in the 2006 biomonitoring report.

6.3 Results

Biota collected

In 2007, 21,993 individuals and 197 taxa of littoral macroinvertebrates were collected at the 20 sites sampled (Appendix 3). The Trichoptera, Ephemeroptera, Mesogastropoda, and Hemiptera were the richest orders of littoral macroinvertebrates with 37, 34, 25 and 23 taxa, respectively. Diptera, Ephemeroptera and Hemiptera had the widest distribution, being found at all sites, while species of some small groups (Collembola, Megaloptera, Nematoda, and Orthoptera) were found at only one site and Lepidoptera and Sphaeromatidae were found at only two sites (Table 6.1). A number of the groups that were widespread have some taxa occurring in nutrient-rich conditions. All of the 20 sites examined in 2007 had more than 20 taxa and high abundance.

Table 6.1. *Numbers of taxa within each major group of littoral macroinvertebrates recorded at sites sampled in 2007.*

Order	Arcoida	Coleoptera	Collembola	Decapoda	Diptera	Ephemeroptera	Hemiptera	Lepidoptera	Megaloptera	Mesogastropoda	Mytiloida	Nematoda	Neogastropoda	Odonata	Oligochaeta	Orthoptera	Plecoptera	Polychaeta	Sphaeromatida	Trichoptera	Unioroida	Veneroida	Total species/Site
LNT	0	4	0	2	7	18	11	0	0	4	0	0	0	7	0	0	1	0	0	15	0	1	70
LVT	0	1	0	2	7	7	2	0	0	3	0	0	0	4	1	0	1	0	0	1	0	0	29
LNG	0	0	0	3	3	4	5	0	0	2	0	0	0	4	0	0	0	0	0	4	0	1	26
LNM	0	7	0	0	9	24	7	1	1	0	0	0	0	8	1	0	2	1	0	18	0	0	79
LKD	0	1	0	3	7	12	2	0	0	0	0	0	0	4	1	0	0	0	0	2	0	1	33
LBF	1	2	0	3	5	7	3	0	0	9	0	0	1	7	0	0	0	0	0	0	1	1	40
LBH	1	3	0	3	3	11	3	0	0	10	0	0	0	5	1	0	0	0	0	5	0	1	46
LSD	0	1	0	3	4	2	5	0	0	6	0	0	1	6	1	0	0	1	0	3	0	1	34
LKL	0	5	0	4	4	19	6	0	0	3	0	0	1	4	1	0	2	0	0	11	0	1	61
LKU	0	7	0	2	3	12	6	0	0	4	0	0	0	7	1	0	2	0	0	13	0	1	58
LDN	1	1	0	2	4	5	2	0	0	12	0	0	1	5	1	0	0	0	0	2	1	1	38
CMR	0	3	0	3	1	3	3	0	0	11	0	0	1	0	1	0	0	0	0	1	0	0	27
CKM	0	4	0	3	3	10	6	0	0	5	1	0	1	4	1	0	1	1	0	8	1	0	49
CSJ	1	5	0	3	9	13	7	0	0	10	1	1	0	6	1	0	1	0	0	14	0	1	73
CSU	0	2	1	0	7	5	6	0	0	0	0	0	0	0	0	0	0	0	0	7	0	1	29
CSP	1	9	0	3	9	12	7	1	2	6	0	0	1	8	1	0	2	0	0	13	0	1	76
TMM	0	0	0	3	5	4	1	0	0	3	1	0	0	5	1	0	0	2	1	2	0	1	29
TNK	0	2	0	4	1	6	4	0	0	1	0	0	0	2	0	0	0	1	0	0	0	1	22
TSK	1	1	0	4	3	5	4	0	0	4	1	0	1	7	0	0	1	0	1	3	0	1	37
TSM	0	1	0	1	5	6	2	0	0	1	0	0	0	3	0	1	0	0	0	2	0	1	23
Species/Taxa	1	20	1	7	18	34	23	1	2	25	1	1	1	15	1	1	3	2	1	37	1	1	197

Richness

The number of taxa collected per site ranged from 22 to 79, with richness highest at sites having stony substrata, such as site LNM (79 species), CSP (76 species), CSJ (73 species), and LNT (70 species). In contrast, the lowest richness was at sites with muddy substrata, such as at sites TNK, TSM, LNG, and CMR (22, 23, 26, and 27 species, respectively) (Table 6.1). Species of Trichoptera and Ephemeroptera were abundant at the richest sites, where they occurred among cobbles, pebbles and gravels.

Abundance

The number of individuals per site was highly variable, ranging from 112 (CSU) to 3,404 (LDN). As with numbers of taxa, the highest abundances occurred at sites with sandy substrata, macro-algae and aquatic vegetation, while the lowest abundances occurred at sites with muddy, clay and debris substrata such as TNK and TSM (Table 6.2). In the sites with the highest abundance, such as LDN, LBF, and CSP, species of Trichoptera, Ephemeroptera, Mesogastropoda, Hemiptera and Coleoptera were dominant. These common species occurred both on rocky substrata and in the water column.

Table 6.2. *Number of individual littoral macroinvertebrates recorded at sites sampled in 2007.*

Order	Arcoida	Coleoptera	Collembola	Decapoda	Diptera	Ephemeroptera	Hemiptera	Lepidoptera	Megaloptera	Mesogastropoda	Mytiloida	Nematoda	Neogastropoda	Odonata	Oligochaeta	Orthoptera	Plecoptera	Polychaeta	Sphaeromatida	Trichoptera	Unioroida	Veneroida	Abundance/Site
LNT	0	43	0	14	54	643	179	0	0	48	0	0	0	23	0	0	9	0	0	86	0	13	1,112
LVT	0	1	0	29	105	383	34	0	0	454	0	0	0	9	1	0	1	0	0	1	0	0	1,018
LNG	0	0	0	385	85	60	41	0	0	53	0	0	0	13	0	0	0	0	0	18	0	44	699
LNM	0	50	0	0	166	573	77	2	4	0	0	0	0	47	2	0	18	1	0	355	0	0	1,295
LKD	0	2	0	9	96	228	165	0	0	0	0	0	0	34	1	0	0	0	0	3	0	93	631
LBF	2	2	0	77	125	81	146	0	0	1959	0	0	45	80	0	0	0	0	0	0	2	23	2,542
LBH	1	5	0	55	37	152	198	0	0	106	0	0	0	7	2	0	0	0	0	11	0	3	577
LSD	0	2	0	86	111	31	99	0	0	111	0	0	5	10	7	0	0	10	0	9	0	20	501
LKL	0	45	0	10	42	401	44	0	0	16	0	0	1	49	39	0	55	0	0	139	0	31	872
LKU	0	30	0	11	38	358	172	0	0	89	0	0	0	50	2	0	11	0	0	128	0	107	996
LDN	1	6	0	10	159	85	679	0	0	2325	0	0	2	60	24	0	0	0	0	3	1	49	3,404
CMR	0	3	0	1213	10	12	7	0	0	584	0	0	3	0	5	0	0	0	0	3	0	0	1,840
CKM	0	12	0	50	50	283	28	0	0	44	2	0	2	6	20	0	1	1	0	25	1	0	525
CSJ	1	19	0	73	151	799	170	0	0	219	1	19	0	46	32	0	18	0	0	249	0	148	1,945
CSU	0	2	1	0	11	32	44	0	0	0	0	0	0	0	0	0	0	0	0	20	0	2	112
CSP	2	71	0	18	212	990	75	4	3	481	0	0	5	50	3	0	19	0	0	455	0	50	2,438
TMM	0	0	0	113	100	33	59	0	0	27	1	0	0	28	3	0	0	14	1	3	0	9	391
TNK	0	2	0	151	10	26	28	0	0	1	0	0	0	6	0	0	0	2	0	0	0	3	229
TSK	1	1	0	55	6	14	19	0	0	412	13	0	27	21	0	0	1	0	12	15	0	28	625
TSM	0	1	0	9	51	40	107	0	0	2	0	0	0	20	0	2	0	0	0	8	0	1	241
Abundance /Taxa	8	297	1	2,368	1,619	5,224	2,371	6	7	6,931	17	19	90	559	141	2	133	28	13	1,531	4	624	21,993

Average Tolerance Score Per Taxon

The Average Tolerance Score Per Taxon (ATSPT) of littoral macroinvertebrates in sweep samples taken in 2007 ranged from 32 to 41, with the highest value found at site TMM and the lowest at sites CSP and CSJ (Table 6.3).

Table 6.3. *ATSPT values for littoral macroinvertebrates recorded at sites sampled in 2007.*

Site	River	Description	Littoral sweep ATSPT mean	Littoral sweep ATSPT SD
LNT	Nam Ton	50 km from Vientiane	34	2.2
LVT	Mekong River	Upstream of Vientiane	34	2.0
LNG	Nam Ngum	Upstream of the mouth of the Nam Lik	39	1.4
LNM	Nam Mo	Upstream of a bridge near a mine	37	0.4
LKD	Nam Ka Ding	Haad Sai Kam	35	1.1
LBF	Se Bang Fai	Se Bang Fai bridge, Khammouan province	36	1.1
LBH	Se Bang Hieng	Se Bang Hieng bridge, Savannnakhet province	34	3.1
LSD	Se Done	Se Done, Ban He upstream of Pakse	38	1.8
LKL	Se Kong	Ban Xou Touat, Attapeu Province	34	1.4
LKU	Se Kong	Ban Xakhe, Attapeu Province	34	2.6
LDN	Mekong	Done Ngieu island	34	1.1
CMR	Mekong	Stung Treng Ramsar site	34	1.9
CKM	Se Kong	Mouth	35	2.5
CSJ	Se San	Downstream of junction with the Sre Pok	32	1.6
CSU	Se San	Pum Pi village, Rattanakiri Province	34	7.0
CSP	Sre Pokr	Kampong Saila, Lumpat District	32	0.8
TMM	Mun-Chi	Mekong (Mum Kong Chiam)	41	2.8
TNK	Nam Kham	Na Kae	39	1.9
TSK	Songkhram	Mouth	39	1.5
TSM	Songkhram	Mekong	38	1.5

Relationships to environmental factors

There was no statistically significant correlation ($P < 0.05$) between the values of the physical and chemical variables measured and taxonomic richness, number of individuals, or ATSPT among the 20 sites sampled during 2007.

6.4 Discussion

None of the metrics used to describe the community structure and composition of littoral macroinvertebrates (taxonomic richness, number of individuals, and the ATSPT) showed any statistically significant relationships with the environmental parameters measured. Values of species richness and abundance were highly variable among the sites, probably because of differences in habitat. For example, high richness was found at sites with suitable habitat such as cobble, pebble and gravel substrata.

Both Nam Mo (LNM) and Nam Tone (LNT) are new sites on tributaries that had not been sampled previously. Both sites were proposed by the LNMC because they are downstream of gold mining operations. In 2005, an accident at Nam Mo killed all of the organisms living in the river (Earth System Lao, 2005). The samples of aquatic fauna collected during 2007 showed recovery and contained very rich assemblages of macroinvertebrates. Se Bang Hieng, Se Bang Fai, and Se Don were also new sites that in the future may be impacted on by dams and other developments, and so the samples of 2007 will be a useful baseline for future monitoring.

Species richness and abundance at 11 of the 20 sites showed a slight decline when compared to samples taken during earlier surveys. This may have been due of changes in the environmental conditions at those sites. Site CSU had high species richness in 2005 (73 species) but in 2006 and 2007 the species richness and abundance had decreased to 33 and 29 species respectively. This decrease may have been the result of water fluctuations caused by a dam upstream.

7. Benthic macroinvertebrates

7.1 Introduction

Like littoral macroinvertebrates, the benthic macroinvertebrates occurring at the bottom of river channels are widely sampled in biomonitoring studies. The objectives of this chapter are to (i) describe the characteristics of the benthic macroinvertebrate community that was quantitatively sampled at 20 sites in 2007, (ii) report bioassessment metrics based on the benthic macroinvertebrate community present at each of the sites examined in 2007, and (iii) relate metric values to independent measures of environmental stress.

7.2 Methods

Sample locations at each site were selected in each of the right, middle, and left parts of the river. Five locations were sampled at each of these parts of the river. At some sites, the middle of the river could not be sampled because of the presence of hard beds or fast currents. Also, some sites narrower than 30 m were not sampled in the middle portion. Prior to sampling, all the equipment to be used was thoroughly cleaned to remove any material left from the previous sampling site. At each sampling location, a composite of four samples was taken with a Petersen grab sampler, covering a total area of 0.1 m^2. Grab contents were discarded if the grab did not close properly because material such as wood, bamboo, large water-plants, or stones jammed the grab's jaws. In these cases the sample was retaken.

The samples were washed through a sieve (0.3 mm mesh) with care taken to ensure that macroinvertebrates did not escape. The contents of the sieve were then placed in a white sorting tray and dispersed in water. All the animals in the tray were picked out with forceps and pipettes, placed in jars, and fixed with formaldehyde. Samples of less experienced sorters were checked by an experienced sorter. The sample jar was labelled with site name, location code, date, position within the river, and replicate number. The sampling location conditions, collector's name and sorter's name were recorded on a field sheet. Sometimes, samples could not be sorted on site because the boat was poorly balanced, because a very large number of animals was collected, because there was insufficient time at a site, or because the presence of lumps of clay caused the samples to cloud continually. In these cases, samples were sorted in the laboratory.

All individuals collected were identified and counted under a compound microscope (with magnifications of 40 – 1200x) or a dissecting microscope (16 – 56x). Oligochaeta, Gastropoda, Bivalvia, and Crustacea were generally identified to species level. Insecta and Insecta larvae were classified only to genus level. The results were recorded on data sheets and specimens are kept at the Ton Duc Thang University, HCMC, Viet Nam.

The following metrics were calculated for all sites sampled in 2007: taxon richness (the number of types of organisms collected at a site), abundance (the number of individual organisms collected), and the average tolerance score per taxon (ATSPT). The ATSPT is an indicator of the presence of environmental stressors such as water pollution. Species that are sensitive to stress, and tend to be eliminated from stressed sites, have low tolerance scores. Stress-tolerant species, which are hardy and survive at stressed sites, have high tolerance scores. Consequently, the average score is higher at sites with environmental stress. Tolerance scores for individual taxa were assigned in the 2006 biomonitoring report.

7.3 Results

Biota collected

In 2007, 4,327 individuals and 79 taxa of benthic macroinvertebrates were collected (Appendix 3). The Insecta was the most species-rich group and occurred at each of the sites (Table 7.1). Molluscs also were widely recorded, at 18 sites.

Table 7.1. *Numbers of taxa within each major group of benthic macroinvertebrates recorded at sites sampled in 2007.*

Sampling Site	Annelida	Mollusca		Arthropoda		Total
	Oligochaeta	Gastropoda	Bivalvia	Crustacea	Insecta	
LNT	-	1	2	-	16	19
LVT	1	-	-	-	7	8
LNG	1	1	1	3	9	15
LNM	-	-	-	-	12	12
LKD	3	2	-	-	14	19
LBF	2	3	3	-	15	23
LBH	-	2	5	1	7	15
LSD	1	4	2	-	11	18
LKL	-	-	1	-	8	9
LKU	1	1	4	-	12	18
LDN	2	7	2	-	9	20
CMR	1	4	-	-	6	11
CKM	2	5	2	-	8	17
CSJ	1	3	2	-	9	15
CSU	1	-	1	-	15	17
CSP	1	1	1	-	13	16
TMM	1	-	2	-	6	9
TNK	-	1	3	-	5	9
TSK	-	4	4	-	7	15
TSM	1	1	2	-	8	12

The Oligochaeta were widely distributed, with species of the families Tubificidae and Naididae found at 14 sites. Chironomid midge larvae had the widest distribution of any taxon collected in 2007, and occurred at all sites. Several other taxa were also widely distributed: tubificid worms, the clam *Corbicula tenuis*, larvae of the dragonfly family Gomphidae, larvae of the caddis fly family Philopotamidae, and larvae of the diptera *Culicoides* sp. and *Eriocera* sp. Many widespread species are characteristic of nutrient-rich conditions, including the oligochaetes *Branchidrilus semperi* (Naididae), *Limnodrilus hoffmeisteri* and *Branchiura sowerbyi* (Tubificidae), species of Stenothyridae and Hydrobiidae (Mollusca, Gastropoda), the phantom midge *Chaoborus* sp. (Diptera, Chaoboridae), and the non-biting midge larvae *Chironomus* sp., *Cryptochironomus* sp., *Sergentia* sp., and *Polypedilum* sp. (Diptera, Chironomidae).

Many taxa were found at only one or two sites, usually in low abundance. Some of these uncommon taxa belong to groups that are not normally associated with soft sediments. For example, neritid snails (Mollusca, Gastropoda), hydrobiid snails (Mollusca, Gastropoda), leptophlebiid mayflies (Insecta, Ephemeroptera), perlid stoneflies (Insecta, Plecoptera), agrionid dragonflies (Insecta, Odonata), and haliplid beetles (Insecta, Coleoptera) normally occur on rocks, stones, and water plants. They could be considered ‘vagrants’ in soft-sediment habitats. Relatively few species of Crustacea were encountered. Usually, crustaceans were absent from soft substrates and tended to occur in sites having water plants or rocky substrata.

Richness

Taxon richness ranged widely at the 20 sites sampled in 2007, from 8 to 23 taxa per site (Table 7.1). The highest richness occurred at sites having substrata of mud, debris and some sand, such as LBF (23 species) and LDN (20 species), while the lowest richness was at sites with sandy and rocky substrata, such as sites LVT (8 species), LKL (9 species), TMM (9 species) and TNK (9 species) (Table 7.1). In the sites with highest richness, such as sites LNT, LKD, LBF, and LDN, species in the families Tubificidae (Oligochaeta), Stenothyiidae and Hydrobiidae (Mollusca, Gastropoda), Corbiculidae and Amblemidae (Mollusca, Bivalvia), Gomphidae (Insecta, Odonata) and Chironomidae (Insecta, Diptera) were dominant. These common species occurred in mixed substrata containing mud, debris and some sand.

Abundance

Abundance at a given site was highly variable, ranging from 30 to 510 individuals/m^2 (Table 7.2). As with numbers of taxa, the highest abundances occurred at sites with mixed substrata containing mud, debris and some sand such as LKD (360 indv./m^2), LBF (380 indv./m^2), and LDN (510 indv./m^2), while the lowest abundances occurred at sites with sandy and rocky substrata, such as sites CSJ (50 indv./m^2), CSU (50 indv./m^2) and TNK (30 indv./m^2) (Table 7.2). In the sites with highest abundances, such as LKD, LBF, LKU and LDN, species in the families Tubificidae (Oligochaeta), Stenothyiidae and Hydrobiidae (Mollusca, Gastropoda), Corbiculidae (Mollusca, Bivalvia), and Ephemeridae (Insecta, Ephemeroptera) were dominant. These common species occurred in mixed substrata containing mud, debris and some sand.

Table 7.2. *Density (individuals/m^2) of benthic macroinvertebrates recorded at sites sampled in 2007.*

Site	Right	Middle	Left	Average
LNT	30 – 130	-	80 – 190	110
LVT	-	10 – 30	30 – 170	60
LNG	10 – 110	0	40 – 200	100
LNM	20 – 170	-	60 – 200	110
LKD	120 – 990	0	60 – 220	360
LBF	540 – 1370	0	10 – 260	380
LBH	40 – 110	0	30 – 110	70
LSD	130 – 260	10 – 40	110 – 230	130
LKL	10 – 60	0	50 – 80	40
LKU	30 – 290	150 – 500	220 – 600	300
LDN	270 – 800	30 – 380	320 – 1180	510
CMR	20 – 330	20 – 230	10 – 50	110
CKM	20 – 140	0	10 – 40	40
CSJ	10 – 70	0	30 – 90	50
CSU	20 – 90	10 – 30	50 – 120	50
CSP	30 – 210	10	30 – 140	70
TMM	60 – 140	10 – 90	60 – 220	100
TNK	10 – 50	10 – 50	10 – 50	30
TSK	80 – 300	10 – 30	140 – 1210	270
TSM	20 – 410	10 – 20	-	90

Average Tolerance Score Per Taxon

The tolerance scores for taxa of benthic macroinvertebrates collected in 2007 varied from 14 to 64. The ATSPT varied to a moderate degree among the sites examined in 2007, ranging from 33 to 44 (Table 7.3).

Table 7.3. *ATSPT of benthic macroinvertebrates recorded at sites sampled in 2007.*

Site	ATSPT	Site	ATSPT	Site	ATSPT	Site	ATSPT
LNT	35	LBF	38	LDN	34	CSP	33
LVT	38	LBH	37	CMR	36	TMM	43
LNG	37	LSD	38	CKM	37	TNK	44
LNM	40	LKL	38	CSJ	36	TSK	44
LKD	35	LKU	38	CSU	37	TSM	38

Relationships to environmental factors

Statistically significant relationships (where $P < 0.05$) were observed between taxonomic richness and turbidity (Figure 7.1), abundance and water depth (Figure 7.2), and ATSPT and conductivity (Figure 7.3). No other significant relationships were observed between any metric and environmental variable.

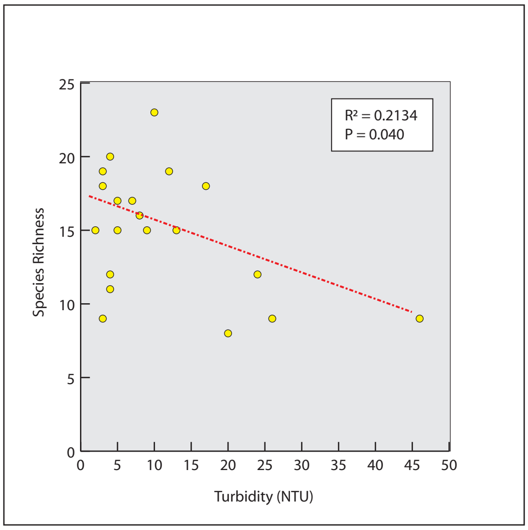

Figure 7. 1. Regression relationship between the richness of benthic macroinvertebrates and turbidity at sites sampled in 2007.

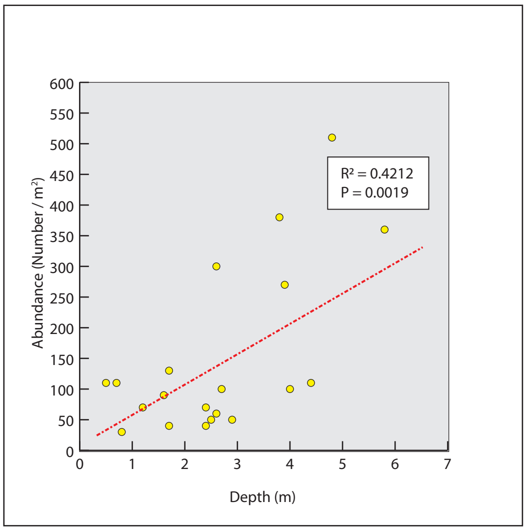

Figure 7. 2. Regression relationship between the abundance of benthic macroinvertebrates and water column depth at sites sampled in 2007.

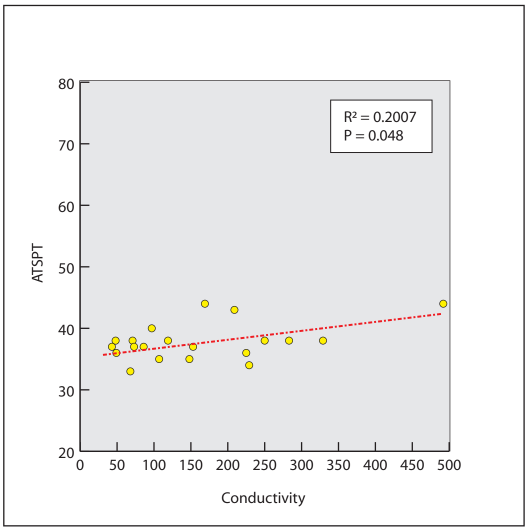

Figure 7. 3. Regression relationship between the ATSPT of benthic macroinvertebrates and EC at sites sampled in 2007

7.4 Discussion

The sites sampled during 2007 were situated far enough from the Mekong Delta not to be affected by intrusion of brackish waters, and benthic macroinvertebrate faunas sampled were made up entirely of freshwater taxa of insects, oligochaetes, molluscs, and some crustaceans. The taxa recorded were typical of the fauna from this region.

The statistically significant, negative relationship between taxonomic richness and the turbidity of river water may have occurred because high turbidity limits the number of taxa of benthic macroinvertebrates that can occur at a site. Human activities such as sand exploitation at sites LKL may have contributed to this relationship. The statistically significant relationship between the number of individuals and the depth of the water column suggests that those sites with more stable flows and currents support a more abundant fauna of benthic macroinvertebrates. The statistically significant relationship between the ATSPT values and the EC probably reflects a gradient of increasing human impact.

8. General conclusions

Statistically significant relationships between biological metrics (richness, abundance and ATSPT) and environmental variables were found for all biological groups except littoral macroinvertebrates. For diatoms, abundance and ASPT were positively correlated with altitude. While this might be a natural phenomenon, it more likely occurred because human activities were greater at the sites at higher altitudes sampled in 2007, as indicated by the site disturbance scores. For zooplankton, abundance and ATSPT had positive relationships with electrical conductivity (an indicator of salinity) and abundance had a positive relationship with chlorophyll-a. This probably indicates a positive effect of human activities on the concentration of zooplankton, many species of which are tolerant of moderate levels of nutrient enrichment and can benefit from an increased food supply of microscopic algae and small particles of decaying organic matter.

For benthic macroinvertebrates, richness had a negative relationship with turbidity. Turbid waters are likely to be less conducive to a rich benthic fauna because they are associated with lower light penetration, and hence less algal growth to provide a food source for invertebrates. In addition, turbidity can be associated with suspended particles that abrade sensitive body structures such as gills and smother benthic habitats. The abundance of benthic macroinvertebrates had a positive relationship with water depth, being generally greater in the deeper rivers, and ATSPT had a positive relationship with electrical conductivity, indicating that intolerant species favour less saline sites.

Overall, rather few significant relationships with the measured environmental factors were found in 2007. This is likely to be because the sites sampled in 2007 were mostly in areas with low levels of development and probably only minor human impacts on aquatic ecosystems. In the next and final phase of the current biomonitoring programme, data will be amalgamated from all surveys from 2004 to 2007. This will provide a complete overview of the entire Lower Mekong Basin, and provide a much more broadly based picture of the degree to which the aquatic ecosystems in different rivers are impacted on by current levels of development.

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Appendix 1. Total counts of benthic diatom taxa recorded at each site in 2007

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
CLASS Bacillariophyceae																				
ORDER Achnanthales																				
FAMILY Achnanthaceae																				
Achnanthes biasolettiana	0	0	0	4682	0	0	0	0	208	23	0	0	0	0	0	0	0	0	0	0
Achnanthes crenulata	0	0	0	6	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	0
Achnanthes lanceolata var *rostrata*	55	0	8	2	9	2	124	43	10	26	39	36	47	0	1	32	0	10	0	0
Achnanthes minutissima var affinis	0	0	554	8	0	0	0	0	0	0	0	0	0	10	0	0	0	18	0	0
Achnanthes oblongella	0	0	0	0	0	0	0	0	0	0	0	1	2	0	1	3	0	0	0	0
Achnanthes sp1	0	27	0	0	68	0	0	0	0	0	158	35	13	0	10	5	0	0	1891	0
Achnanthes sp3	0	0	0	0	0	0	99	0	2	0	0	0	0	0	0	0	0	0	0	0
FAMILY Achnanthidiaceae																				
Achnanthes lanceolata	9	264	0	0	16	6	100	73	2	0	138	58	24	0	2	61	0	0	0	45
Achnanthes minutissima	116	5231	2590	0	1897	121	1135	295	40	330	691	0	307	6017	2766	4753	4166	14	2432	0
FAMILY Cocconeidaceae																				
Cocconeis pediculus	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0
Cocconeis placentula	55	9	0	337	14	1	11	8	3	38	182	6	11	0	0	0	0	0	0	27
ORDER Bacillariales																				
FAMILY Bacillariaceae																				
Bacillaria paradoxa	4	13	0	0	2	0	4	3	0	11	3	1	2	0	0	13	0	0	0	12
Nitzschia acicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Nitzschia calida	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	4	0	0
Nitzschia clausii	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	112	8	0	43
Nitzschia coarctata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Nitzschia dissipata	9	54	0	0	0	8	48	46	4	0	24	0	8	0	0	19	3	8	0	0
Nitzschia palea	197	322	27	32	18	0	69	166	40	0	287	181	43	18	0	55	6	41	3	706
Nitzschia pseudofonticola	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	272	18	6
Nitzschia reversa	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	2	0	0
Nitzschia sinuata var tabellaria	0	0	49	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitzschia sp2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	0	0	0
Nitzschia sp3	0	0	0	0	470	25	0	0	0	0	0	0	177	12	8	61	6	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
Nitzschia sp4	0	0	0	0	0	0	633	121	61	0	0	0	0	0	0	0	0	0	0	0
Nitzschia subacicularis	4	0	0	0	2	0	20	3	0	0	0	0	2	0	0	0	0	0	0	0
Nitzschia tropica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1302	170	53	0
ORDER Cymbellales																				
FAMILY Cymbellaceae																				
Cymbella cistula	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella sp1	0	0	0	0	0	74	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella sp3	0	0	0	0	25	0	0	0	20	0	21	6	1	0	3	0	9	0	0	0
Cymbella tumida	0	3	0	24	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0
Cymbella turgidula	8	2619	0	179	13	0	0	5	1	5	132	48	0	0	10	0	0	0	0	151
Encyonema minuta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	7	0	0	0	0
Encyonema sp3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	429	29	0	0
Encyonema sp4	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	76	0
Encyonema sp5	0	0	279	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Encyonema sp6	0	0	0	0	64	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0
Encyonema sp7	0	0	0	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0	0	0
Encyonopsis leei var *leei*	0	0	68	182	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Encyonopsis subminuta	0	0	1211	0	0	0	0	0	0	440	0	0	0	0	0	0	498	117	0	0
Placoneis clementis	0	0	0	0	4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
FAMILY Gomphonemataceae																				
Gomphonema augur var *turris*	0	0	0	0	0	158	0	0	0	0	0	0	0	0	0	0	33	0	0	0
Gomphonema entolejum	0	0	0	0	0	0	0	0	0	0	0	0	22	301	0	0	0	0	0	0
Gomphonema gracile	0	0	3	8	0	0	0	0	0	62	0	0	0	0	0	0	0	3	0	0
Gomphonema minutum	0	0	0	206	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema olivaceum	0	0	0	256	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema parvulum	3	0	3	4	4	5	0	41	39	0	0	43	4	56	2	20	0	40	0	0
Gomphonema sp1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	0	36	0
Gomphonema sp3	0	0	0	248	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0
Gomphonema sp5	0	0	0	0	149	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema sp6	0	0	0	0	0	0	0	0	109	0	0	0	0	0	0	0	0	0	0	0
Gomphonema sp7	0	0	0	0	0	0	0	0	0	0	640	0	0	0	0	0	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
ORDER Naviculales																				
FAMILY Amphipleuraceae																				
Frustulia sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0
FAMILY Brachysiraceae																				
Brachysira neoexilis	0	0	258	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachysira sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	108	0	0
FAMILY Diadesmidaceae																				
Luticola goeppertiana	13	24	0	40	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luticola nivalis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diploneis oblongella	0	0	0	13	0	0	6	0	0	0	0	1	0	0	0	0	0	7	0	0
Diploneis puella	15	4	7	10	0	0	5	0	0	0	0	0	0	0	0	0	0	86	0	0
FAMILY Naviculaceae																				
Geissleria decussis	4	0	0	0	1	0	34	34	1	0	4	0	3	4	0	9	0	0	0	90
Geissleria paludosa	7	0	0	0	0	0	0	0	0	55	0	0	6	0	0	15	0	0	0	0
Geissleria sp1	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula capitatoradiata	0	0	0	411	0	15	0	0	0	0	0	0	6	2	6	90	107	0	0	1
Navicula cryptocephala	13	0	0	0	0	0	0	0	0	361	0	136	0	106	6	123	78	0	0	0
Navicula flabellata	9	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula microcari	0	0	0	3232	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula obtecta	0	0	0	93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp1	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp3	0	448	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Navicula sp4	0	0	0	0	263	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp5	0	0	0	0	0	0	178	68	0	0	0	0	0	0	0	0	0	0	0	0
Navicula sp6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Navicula symmetrica	97	11	212	12	4	2	12	30	3	2	29	0	10	1	14	0	9	4	0	76
Navicula trivialis	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula viridula var *germainii*	2	3321	3	0	0	1	0	0	0	0	21	1	0	0	0	0	0	0	0	90
Navicula viridula var *rostellata*	5	9	2	12	1	0	0	65	0	0	3	0	0	0	0	0	6	10	0	3
Navicula viridula var *viridula*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
FAMILY Neidiaceae																				
Neidium dubium	0	0	0	0	4	0	0	0	0	9	0	0	0	0	0	0	0	1	0	0
FAMILY Pinnulariaceae																				
Pinnularia mesolepta	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pinnularia sp1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
FAMILY Pleurosigmataceae																				
Gyrosigma scalproides	2	0	0	0	0	0	0	0	0	0	6	0	0	0	0	3	0	0	0	0
Gyrosigma spencerii	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Sellaphoraceae																				
Sellaphora pupula	45	0	0	28	6	0	15	20	0	0	0	2	15	0	0	0	3	0	0	0
ORDER Rhopalodiales																				
FAMILY Rhopalodiaceae																				
Epithemia adnata	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhopalodia gibberula	0	0	0	0	25	0	18	0	1	0	200	7	0	0	0	0	0	0	0	0
ORDER Surirellales																				
FAMILY Surirellales																				
Cymatopleura solea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cymatopleura sp1	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surirella roba	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surirella sp1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surirella splendida	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
ORDER Thalassiophysales																				
FAMILY Catenulaceae																				
Amphora montana	2	990	0	0	0	12	0	8	0	0	0	1	0	0	0	0	3	29	0	0
CLASS Coscinodiscophyceae																				
ORDER Aulacoseirales																				
FAMILY Aulacoseiraceae																				
Aulacoseira granulata	0	0	0	0	0	0	0	21	0	8	0	0	1	4	4	2	6	0	0	0
Aulacoseira muzzanensis	0	0	3	0	0	0	0	0	0	0	0	2	0	0	0	0	285	0	0	0
Aulacoseira sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
ORDER Melosirales																				
FAMILY Melosiraceae																				
Melosira varians	0	6	6	44	0	0	0	0	0	0	1	0	0	4	0	0	0	0	0	0
ORDER Thalassiosirales																				
FAMILY Stephanodiscaceae																				
Cyclotella meneghiniana	0	22	0	0	0	0	0	0	0	0	0	0	0	2	3	0	3	0	0	25
Cyclotella stelligera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0
ORDER Triceratiales																				
FAMILY Triceratiaceae																				
Pleurosira laevis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
ORDER Fragilariales																				
FAMILY ragilariaceae																				
Fragilaria capucina	0	0	145	0	0	0	0	26	75	0	0	0	0	10	4	15	18	4	0	4
Fragilaria crotonensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Synedra cf *inaequalis* var *jumlensis*	0	0	0	55	0	0	0	0	0	8	0	0	0	0	0	2	0	0	0	0
Synedra ulna	0	3	0	31	4	0	2	0	7	7	3	1	0	0	1	0	0	0	0	0
Synedra ulna var *aequalis*	0	0	0	0	0	0	0	0	0	6	70	1	0	0	0	8	0	0	0	0

Appendix 2. Total counts of zooplankton taxa recorded at each site in 2007

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
PHYLUM Arthropoda																				
CLASS Acariformes																				
ORDER unkown																				
FAMILY unknown																				
Hydracarina sp (larva)	0	0	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0
CLASS Crustacea																				
ORDER Calanoida																				
FAMILY Diaptomidae																				
Allodiaptomus calcarus	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Allodiaptomus raoi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
Neodiaptomus botulifer	0	0	4	0	0	0	0	0	0	0	3	0	0	0	2	0	0	0	0	0
FAMILY Bosminidae																				
Bosmina longirostris	0	0	4	0	0	0	2	0	0	0	4	0	0	0	9	0	18	0	0	0
Bosminopsis deitersi	0	0	0	0	0	0	6	83	0	0	2	0	1	1	5	3	0	5	22	279
FAMILY Chydoridae																				
Alona davidi	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	1
Alona guttata guttata	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alona rectangula	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Chydorus ovalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Chydorus sphaericus sphaericus	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	5	0
Disparalona rostrata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Leydigia acanthocercoides	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
FAMILY Daphniidae																				
Ceriodaphnia laticaudata	0	0	10	0	0	0	1	0	0	1	2	1	0	0	0	0	5	0	0	0
Ceriodaphnia rigaudi	0	0	17	0	0	0	2	0	0	2	7	0	0	0	3	0	16	1	0	9
Moina sp	0	0	0	0	0	0	2	14	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Sididae																				
Diaphanosoma sarsi	0	0	5	0	0	0	1	9	0	0	0	1	0	0	0	0	1	1	0	0
Sida crystallina	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
ORDER Cyclopoida																				
FAMILY Cyclopidae																				
Ectocyclops phaleratus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Mesocyclops leuckarti	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	12
Microcyclops varicans	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thermocyclops hyalinus	1	0	21	0	0	6	0	21	1	3	0	10	1	0	3	0	4	21	1	71
Thermocyclops taihokuensis	0	1	8	1	3	5	3	4	0	0	10	0	0	0	0	1	0	0	254	0
ORDER Harpacticoida																				
FAMILY Canthocamptidae																				
Canthocamptus staphylinus	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	1
ORDER Ostracoda																				
FAMILY Cyprididae																				
Heterocypris anomala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0
ORDER unknown																				
FAMILY unknown																				
Copepoda sp (nauplius)	12	8	86	1	4	19	8	108	1	20	38	44	1	1	10	2	82	202	398	465
CLASS Insecta																				
ORDER Diptera																				
FAMILY unknown																				
Chironomidae sp	5	1	1	8	0	1	4	2	3	0	7	0	3	2	6	1	0	2	0	0
ORDER Ephemerpotera																				
FAMILY unknown																				
Ephemeroptera sp (larva)	0	0	0	0	0	0	2	1	4	0	0	0	0	0	0	0	0	0	0	0
PHYLUM Ciliophora																				
CLASS Cileatea																				
ORDER Oligotrichida																				
FAMILY Codonellidae																				
Tintinnopsis spp	0	2	0	0	0	19	62	621	0	0	16	0	7	0	0	0	4	23	0	1
ORDER Peritrichida																				
FAMILY Epistylidae																				
Epistylis sp	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
PHYLUM Dinophyta																				
CLASS Dinophyceae																				
ORDER Peridinales																				
FAMILY Ceratiaceae																				
Ceratium spp	0	0	11	0	0	0	0	0	1	290	7	0	0	0	10	0	51	192	0	0
PHYLUM Euglenozoa																				
CLASS Euglenophyceae																				
ORDER Euglenales																				
FAMILY Euglenaceae																				
Euglena acus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0
Phacus longicauda	0	0	10	0	0	0	0	1	0	0	0	0	0	0	11	0	0	4	0	0
PHYLUM Mollusca																				
CLASS Bivalvia																				
ORDER unknown																				
FAMILY unknown																				
Bivalvia sp (larva)	0	10	0	0	0	53	13	11	0	0	16	1	3	39	0	0	3	13	2	4
PHYLUM Protozoa																				
CLASS Lobosa																				
ORDER Arcellinida																				
FAMILY Arcellidae																				
Arcella discoides	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0
Arcella gibbosa	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arcella hemisphaerica	2	0	0	15	2	0	0	1	2	4	0	0	0	0	0	0	0	0	0	0
Arcella sp	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arcella vulgaris	47	3	0	23	2	7	1	4	2	15	7	3	4	7	6	8	5	14	2	0
FAMILY Centropyxidae																				
Centropyxis aculeata	9	4	0	20	0	2	6	1	9	4	1	7	7	8	7	0	2	0	0	3
Centropyxis constricta	0	0	0	12	0	0	0	0	0	2	2	2	2	2	0	1	0	0	0	1
Centropyxis sp	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclopyxis arcelloides	0	0	0	0	0	0	0	0	7	0	0	0	0	0	5	0	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
FAMILY Difflugiidae																				
Difflugia amphora	3	0	3	0	0	1	0	0	0	0	6	2	0	3	0	2	33	0	0	1
Difflugia elegans	3	427	0	1	0	0	1261	0	0	3	369	1	1	0	0	2	13	1	0	2790
Difflugia globulosa	0	2	1	0	1	22	13	4	1	4	0	3	2	0	5	3	18	5	6442	34
Difflugia lanceolata	0	0	0	2	0	0	0	0	3	0	0	0	0	0	0	0	4	0	0	0
Difflugia lobostoma	8	6	2	2	3	9	6	1	10	3	6	4	4	6	4	15	0	166	0	0
Difflugia piriformis	3	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Difflugia scalpellum	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Difflugia tuberculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	23	2	24
Difflugia urceolata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0
Pontigulasia bigibbosa	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Protocucurbitella coroniformis	1	0	8	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0
Pseudodifflugia fascicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
PHYLUM Rhizopoda																				
CLASS Filosia																				
ORDER Aconchulinida																				
FAMILY Euglyphidae																				
Euglypha tuberculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
PHYLUM Rotifera																				
CLASS Eurotatoria																				
ORDER Bdelloidea																				
FAMILY Philodinidae																				
Dissotrocha aculeata	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Philodina roseola	1	0	1	0	1	0	2	9	0	0	1	4	11	14	11	1	0	0	4	1
Philodina sp	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Rotaria rotatoria	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0
ORDER Flosculariaceae																				
FAMILY Filiniidae																				
Filinia brachiata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	9	0	11
Filinia longiseta	0	0	0	0	0	0	1	11	0	0	0	0	0	0	0	17	0	0	59	733
Filinia longiseta var *passa*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Tetramastix opoliensis	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	3

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
FAMILY Flosculariidae																				
Sinantherina socialis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
FAMILY Hexarthridae																				
Hexarthra mira	0	0	0	0	0	4	0	32	0	0	0	0	1	1	3	0	3	72	581	609
FAMILY Testudinellidae																				
Pompholyx complanata	0	0	0	0	0	0	0	3	0	23	0	0	0	0	0	0	3	5	0	0
Pompholyx sulcata	0	0	0	0	0	0	0	0	0	0	0	0	2	11	15	4	0	0	0	0
ORDER Ploima																				
FAMILY Asplanchnidae																				
Asplanchna girodi	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Asplanchna sieboldi	0	0	0	0	0	0	0	152	0	0	0	0	0	0	0	0	0	0	67	428
Asplanchnopus multiceps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
FAMILY Brachionidae																				
Anuraeopsis fissa	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Brachionus angularis	0	0	0	0	0	1	2	937	0	0	50	4	1	4	0	10	8	0	2565	226
Brachionus calyciflorus cf *calyciflorus*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Brachionus caudatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0
Brachionus falcatus	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	16	6290	1030
Brachionus forficula forficula	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Brachionus quadridentatus var *quadridentatus*	0	0	0	0	0	0	0	0	0	6	0	0	0	0	1	0	0	0	0	2
Keratella cochlearis cochlearis	0	4	47	0	1	66	8	226	0	1	8	6	10	22	90	3	16	110	3524	480
Keratella cochlearis hispida	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Keratella cochlearis tecta	0	0	2	0	0	0	0	0	0	0	1	0	0	12	44	0	0	0	0	0
Keratella irregularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	299	2418	22
Keratella valga tropica	0	1	2	0	0	5	0	0	0	1	2	0	1	0	3	2	10	13	295	165
Platyias patulus patulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Platyias quadricornis	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
FAMILY Euchlanidae																				
Diplois daviesiae	0	0	0	0	1	0	0	0	0	9	1	1	0	0	0	1	0	0	0	0
Euchlanis dilatata	0	2	0	0	0	0	0	0	0	6	0	0	0	0	5	0	0	0	0	0
Euchlanis sp	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Gastropodidae																				
Ascomorpha agilis	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ascomorpha ecaudis	0	0	0	0	0	5	3	41	0	0	0	0	0	1	11	0	0	87	0	0
Ascomorpha saltans	0	0	0	0	0	19	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Ascomorpha sp	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Lecanidae																				
Lecane curvicornis	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	3	0	0
Lecane hastata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Lecane luna	0	1	1	0	0	0	0	3	0	3	0	0	0	0	1	1	2	0	0	2
Lecane signifera ploenensis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0
Monostyla bulla	0	0	0	1	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0
Monostyla closterocerca	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Monostyla crenata	0	0	0	0	0	0	1	0	0	0	0	0	5	0	2	0	0	0	0	0
Monostyla lunaris	0	0	0	0	0	0	0	0	1	1	0	1	0	0	3	0	0	2	0	0
Monostyla stenroosi	0	1	0	0	0	0	0	1	0	0	0	0	0	0	2	1	0	1	0	0
FAMILY Lepadellidae																				
Lepadella patella	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
FAMILY Mytilinidae																				
Mytilina compressa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Mytilina ventralis	0	0	0	0	1	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0
FAMILY Notommatidae																				
Cephalodella catellina	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Cephalodella exigua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Cephalodella gibba	0	0	0	0	2	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Cephalodella tenuior	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monommata longiseta	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	1
Notommata aurita	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
FAMILY Scaridiidae																				
Scaridium longicaudum	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
FAMILY Synchaetidae																				
Ploesoma hudsoni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Polyarthra mira	0	0	0	0	0	380	0	1041	0	0	0	0	0	0	0	0	0	26	0	0
Polyarthra vulgaris	1	0	0	0	0	36	2	723	0	3	2	1	21	0	34	55	0	53	2219	316
FAMILY Trichocercidae																				
Trichocerca capucina	0	0	0	0	0	0	0	4	0	0	1	0	0	0	0	47	0	0	0	0
Trichocerca cylindrica	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	7	0	0
Trichocerca gracilis	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Trichocerca longiseta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Trichocerca pusilla	0	0	0	0	0	0	0	86	0	1	0	4	10	8	4	1	0	0	6	0
Trichocerca similis	0	0	1	0	0	0	1	16	0	2	0	0	3	0	0	3	0	6	2	0
Trichocerca tigris	0	0	0	0	0	1	1	46	0	0	0	0	0	3	0	0	0	1	4	0
Trichocerca weberi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	12	9
FAMILY Trichotriidae																				
Trichotria tetractis	0	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0

Appendix 3. Total counts of littoral macroinvertebrate taxa recorded at each site in 2007

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
PHYLUM Annelida																				
CLASS Oligochaeta																				
ORDER unknown																				
FAMILY unknown																				
Oligochaeta sp	0	1	0	2	1	0	2	7	39	2	24	5	20	32	0	3	3	0	0	0
Polychaeta sp1	0	0	0	1	0	0	0	10	0	0	0	0	1	0	0	0	11	2	0	0
Polychaeta sp2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
PHYLUM Arthropoda																				
CLASS Crustacea																				
ORDER Decapoda																				
FAMILY Atyidae																				
Caridina sp	4	6	310	0	3	56	34	34	1	2	8	904	2	0	0	0	67	86	18	9
FAMILY Palaemonidae																				
Macrobrachium dienbienphuense	0	0	1	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Macrobrachium hirsutimanus	0	0	0	0	3	0	3	0	2	0	2	0	0	1	0	5	2	4	6	0
Macrobrachium lanchesteri	10	23	74	0	0	20	18	50	6	9	0	305	47	39	0	0	44	58	30	0
Macrobrachium thai	0	0	0	0	0	0	0	0	0	0	0	0	1	33	0	10	0	0	0	0
FAMILY Parathelphusidae																				
Parathelphusidae sp	0	0	0	0	0	1	0	2	0	0	0	4	0	0	0	0	0	3	1	0
FAMILY Potamonidae																				
Potamon sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
ORDER Isopoda																				
FAMILY Sphaeromatidae																				
Sphaeromatidae sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	12	0
CLASS Insecta																				
ORDER Coleoptera																				
FAMILY Carabidae																				
Carabidae sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
FAMILY Dryopidae																				
Helichus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0
FAMILY Dytiscidae																				
Laccophilus sp	24	0	0	0	0	0	3	0	0	4	0	1	0	0	0	0	0	1	0	0
Rhantus sp	0	0	0	0	0	0	1	0	3	1	0	0	0	1	0	3	0	0	0	0
FAMILY Elmidae																				
Ancyronyx sp	0	0	0	17	0	0	0	0	1	0	0	0	0	0	0	14	0	0	0	0
Cleptelmis sp	16	0	0	6	0	0	0	0	0	6	0	0	4	4	0	0	0	0	0	0
Lara sp	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	2	0	0	0	0
Macronychus sp	1	0	0	14	0	0	0	0	15	7	0	0	3	6	0	1	0	0	0	0
Oulimnius sp	0	0	0	6	2	0	1	0	24	9	0	0	0	0	0	40	0	0	0	0
FAMILY Georyssidae																				
Georyssus sp	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Gyrinidae																				
Dineutus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Gyretes sp	0	0	0	0	0	0	0	2	2	2	0	0	0	0	0	0	0	0	0	0
FAMILY Haliplidae																				
Haliplidae sp	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
FAMILY Hydrophilidae																				
Derallus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Enochrus sp	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0
Hydrochara sp	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
FAMILY Lampyridae																				
Lampyridae sp	2	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Psephenidae																				
Psephenus sp	0	0	0	1	0	0	0	0	0	0	0	0	3	7	1	0	0	0	1	0
FAMILY Scirtidae																				
Scirtidae sp	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0
FAMILY Staphylinidae																				
Staphylinidae sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
FAMILY Isotomidae																				
Isotomidae sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
ORDER Diptera																				
FAMILY Athericidae																				
Atrichops sp	3	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0
FAMILY Ceratopogonidae																				
Bezzia sp	0	4	0	3	7	4	0	0	5	0	0	0	2	10	0	4	9	0	0	2
Culicoides sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Dasyhelea sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
FAMILY Chaoboridae																				
Chaoborus sp	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Chironomidae																				
Ablabesmyia sp	9	6	0	6	16	17	2	0	0	2	30	0	0	25	1	26	13	0	3	1
Chironomus sp	29	78	83	102	59	102	34	88	33	35	110	10	46	90	3	112	71	10	2	46
Kiefferulus sp	2	1	0	3	5	0	0	2	0	1	0	0	2	1	0	0	5	0	1	0
Orthocladius sp	0	0	0	0	1	0	0	0	0	0	0	0	0	6	0	2	2	0	0	0
FAMILY Culicidae																				
Culicinae sp	0	0	0	0	7	0	0	0	0	0	15	0	0	0	0	0	0	0	0	1
FAMILY Empididae																				
Empididae sp	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Simuliidae																				
Simulium fenestratum	0	0	0	25	0	0	0	0	0	0	0	0	0	14	0	46	0	0	0	0
Simulium inthanonense	0	11	0	13	0	0	0	0	0	0	0	0	0	3	0	6	0	0	0	0
FAMILY Tabanidae																				
Tabaninae sp	0	0	1	5	0	0	0	20	0	0	4	0	0	0	0	0	0	0	0	0
FAMILY Tipulidae																				
Antocha sp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	12	0	0	0	0
Arctotipula sp	0	1	0	0	0	0	0	0	1	0	0	0	0	1	2	0	0	0	0	0
Limnophila sp	5	4	0	5	0	0	1	0	3	0	0	0	0	1	1	2	0	0	0	0
Pedicia sp	5	0	0	4	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
ORDER Ephemeroptera																				
FAMILY Baetidae																				
Baetiella sp	48	99	0	75	0	0	8	1	0	0	0	0	0	0	0	0	0	0	0	0
Baetis sp	0	0	0	81	16	0	0	0	0	0	0	0	0	17	1	0	0	0	0	0
Centroptilum sp	0	0	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cloeon sp	167	0	11	31	32	14	0	0	0	15	9	0	0	0	0	0	10	7	3	1
Gratia narumonae	16	0	0	15	0	0	0	0	8	15	0	0	0	17	0	4	0	0	0	0
Heterocloeon sp	100	41	42	103	35	0	14	30	133	62	20	6	182	153	14	64	15	2	2	2
Platybaetis sp	96	204	0	36	40	11	82	0	61	65	3	3	9	36	0	33	0	2	0	3
Procloeon sp	0	0	0	20	1	7	0	0	1	5	0	0	0	0	0	0	0	0	0	4
FAMILY Caenidae																				
Caenoculis sp	56	15	0	13	74	29	0	0	15	20	28	0	48	26	0	34	7	7	5	29
Caenodes sp	1	1	6	5	14	0	0	0	10	2	25	3	0	16	0	10	0	0	2	0
Cercobrachys sp	19	0	0	0	1	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0
FAMILY Ephemerellidae																				
Cincticostella sp	0	0	0	2	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Crinitella sp	0	0	0	3	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Ephacerella commodema	9	0	0	2	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0
Uracanthella sp	0	0	0	6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
FAMILY Ephemeridae																				
Afromera siamensis	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Ephemera sp	26	0	1	20	8	0	0	0	0	6	0	0	0	0	1	0	1	0	0	1
FAMILY Heptageniidae																				
Asionurus sp	0	0	0	7	0	0	0	0	9	24	0	0	0	0	0	0	0	0	0	0
Cinygmina sp	18	12	0	2	3	16	3	0	20	5	0	0	11	27	7	58	0	7	0	0
Epeorus sp	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhithrogena sp	0	0	0	8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Thalerosphyrus sp	0	11	0	3	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
FAMILY Isonychiidae																				
Isonychia sp	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
FAMILY Leptophlebiidae																				
Choroterpes sp	46	0	0	26	0	1	15	0	10	30	0	0	24	23	9	64	0	1	0	0
Choroterpides sp	0	0	0	64	0	0	18	0	77	109	0	0	5	339	0	583	0	0	0	0
Habrophlebiodes sp	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Thraulus sp	2	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	2	0
FAMILY Neoephemeridae																				
Potamanthellus caenoides	5	0	0	4	3	0	0	0	12	0	0	0	0	98	0	85	0	0	0	0
Potamanthellus edmundsi	6	0	0	3	1	0	0	0	8	0	0	0	0	1	0	32	0	0	0	0
FAMILY Polymitarcyidae																				
Ephoron sp	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0
FAMILY Potamanthidae																				
Potamanthus formosus	25	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Rhoenanthus sp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Prosopistomatidae																				
Prosopistoma annamense	0	0	0	0	0	0	5	0	5	0	0	0	1	45	0	0	0	0	0	0
Prosopistoma funanense	2	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0
ORDER Hemiptera																				
FAMILY Aphelocheiridae																				
Aphelocheirus sp	0	4	0	24	0	0	0	0	26	56	0	0	2	0	0	0	0	0	0	0
FAMILY Belostomatidae																				
Diplonychus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
FAMILY Geridae																				
Ptilomera tigrina	3	0	0	3	0	0	4	2	1	19	0	1	0	7	2	1	0	0	0	0
FAMILY Gerridae																				
Amemboa sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Cryptobates japonicus	4	0	0	0	0	0	6	0	5	27	0	0	0	24	0	0	0	0	0	0
Limnogonus sp	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naboandelus signatus	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleciobates sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Rheumatogonus intermedius	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
Tenagogonus sp	0	0	4	9	0	1	0	0	2	0	4	1	0	0	0	0	0	1	0	0
Trepobates sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Ventidius sp	3	0	0	1	0	0	0	0	1	1	0	0	1	32	27	7	0	2	0	0
FAMILY Helotrephidae																				
Trephotomas sp	4	0	0	0	0	0	0	0	0	0	0	5	4	1	1	0	0	0	0	0
FAMILY Hydrometridae																				
Hydrometra sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
FAMILY Micronectidae																				
Micronecta sp	155	30	28	0	164	137	188	58	9	68	675	0	18	102	12	61	59	23	16	106
FAMILY Naucoridae																				
Limnocoris sp	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naucoris sp	1	0	0	30	0	0	0	4	0	0	0	0	0	0	0	0	0	0	1	0
FAMILY Nepidae																				
Cercometus sp	0	0	2	0	0	0	0	7	0	1	0	0	0	0	0	0	0	0	0	0
Ranatra sp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0
FAMILY Notonectidae																				
Nychia sappho	5	0	0	0	0	0	0	28	0	0	0	0	2	1	0	0	0	0	0	1
FAMILY Veliidae																				
Chenevelia stridulans	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Microvelia sp	0	0	2	1	0	8	0	0	0	0	0	0	1	3	1	0	0	0	1	0
Xiphovelia sp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ORDER Lepidoptera																				
FAMILY Crambidae																				
Petrophila confusalis	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
ORDER Megaloptera																				
FAMILY Corydalidae																				
Protohermes sp	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
FAMILY Sialidae																				
Sialis sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
ORDER Odonata																				
FAMILY Amphipterygidae																				
Amphipterygidae sp	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
FAMILY Calopterygidae																				
Calopterygidae sp	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
FAMILY Chlorocyphidae																				
Chlorocyphinae sp	1	1	0	2	0	1	1	1	2	3	0	0	0	2	0	2	1	5	1	0
FAMILY Coenagrionidae																				
Coenagrionidae sp	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	17	0	9	2
FAMILY Corduliidae																				
Corduliinae sp	5	0	3	3	8	8	0	2	0	9	22	0	1	2	0	4	1	1	2	0
FAMILY Euphaeidae																				
Euphaeidae sp	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
FAMILY Gomphidae																				
Aphylla williamsoni	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Erpetogomphus sp	11	1	0	14	0	3	3	1	0	0	14	0	3	3	0	19	0	0	0	0
Gomphus sp	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	2	0
Octogomphus sp	1	5	0	3	5	0	0	0	35	31	0	0	0	34	0	5	0	0	3	1
Ophiogomphus sp	1	0	1	7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Paragomphus sp	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Progomphus sp	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
FAMILY Libellulidae																				
Libellulinae sp	0	0	6	1	18	48	1	1	4	2	3	0	0	1	0	11	3	0	1	0
FAMILY Protoneuridae																				
Protoneura sp	3	2	3	0	3	16	1	4	8	3	20	0	0	4	0	5	6	0	3	17
ORDER Orthoptera																				
FAMILY Tridactylidae																				
Tridactylidae sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
ORDER Plecoptera																				
FAMILY Neoperlidae																				
Neoperla sp	9	1	0	10	0	0	0	0	53	10	0	0	1	18	0	16	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
FAMILY Peltoperlidae																				
Peltoperla sp	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	3	0	0	1	0
FAMILY Perlidae																				
Kamimuria sp	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ORDER Trichoptera																				
FAMILY Apataniidae																				
Pedomoecus sp	1	0	1	0	0	0	2	0	0	0	0	0	1	0	0	0	1	0	0	0
FAMILY Brachycentridae																				
Micrasema sp	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
FAMILY Calamoceratidae																				
Anisocentropus sp	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ganonema extensum	42	0	0	3	0	0	0	4	3	1	0	0	0	1	0	10	0	0	0	0
FAMILY Dipseudopsidae																				
Dipseudopsis sp	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Ecnomidae																				
Ecnomus sp	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Goeridae																				
Goera sp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Hydropsychidae																				
Arctopsyche sp	0	0	0	0	0	0	0	0	17	0	0	0	2	25	0	75	0	0	0	0
Hydromanicus sp	0	0	0	26	0	0	1	0	0	0	0	0	0	80	0	22	0	0	0	1
Hydropsyche sp	0	0	0	21	0	0	3	0	0	0	0	0	0	0	0	34	0	0	0	0
Macrostemum sp	0	0	0	2	0	0	2	0	0	0	0	0	0	103	2	234	0	0	0	0
Polymorphanisus sp	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0
Potamyia sp	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0
Trichomacronema sp	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Hydroptilidae																				
Hydroptila sp	0	0	0	0	0	0	0	0	0	4	0	3	0	0	0	0	0	0	0	0
Orthotrichia sp	2	0	0	0	0	0	0	0	6	13	0	0	0	6	1	32	0	0	0	0
Oxyethira sp	1	0	0	0	0	0	0	0	4	7	0	0	0	0	0	14	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
FAMILY Lepidostomatidae																				
Lepidostoma sp	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Leptoceridae																				
Ceraclea sp	8	0	0	31	0	0	0	0	5	3	0	0	1	1	0	0	0	0	12	0
Leptocerus sp	0	0	0	187	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Oecetis sp	10	0	5	7	0	0	0	0	16	44	0	0	2	3	11	1	0	0	0	0
Setodes sp	1	0	12	0	0	0	0	0	0	13	1	0	0	3	0	0	0	0	0	0
Triaenodes sp	0	0	0	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
FAMILY Limnephilidae																				
Arctopora sp	7	0	0	31	2	0	0	2	3	7	0	0	0	1	0	0	0	0	0	0
Cryptochia sp	1	1	0	0	1	0	0	0	1	0	0	0	0	2	0	1	0	0	0	0
Limnephilus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
FAMILY Limnocentropodidae																				
Limnocentropus sp	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Molannidae																				
Molanna sp	0	0	0	4	0	0	0	0	0	7	0	0	0	10	0	0	0	0	0	0
FAMILY Odontoceridae																				
Psilotreta sp	5	0	0	14	0	0	0	0	2	4	0	0	0	1	1	0	0	0	0	0
FAMILY Philopotamidae																				
Chimarra sp	1	0	0	9	0	0	0	0	80	21	0	0	0	0	1	0	2	0	0	0
Dolophilodes sp	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Wormaldia sp	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
FAMILY Polycentripodidae																				
Pseudoneureclipsis sp	2	0	0	0	0	0	0	0	0	0	0	0	6	12	0	14	0	0	0	0
Nyctiophylax sp	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0
FAMILY Psychomyiidae																				
Psychomyia sp	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
FAMILY Rossianidae																				
Rossiana sp	3	0	1	0	0	0	0	0	0	0	2	0	9	0	0	0	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
FAMILY Sericostomatidae																				
Sericostoma sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
PHYLUM Mollusca																				
CLASS Bivalvia																				
ORDER Arcoida																				
FAMILY Arcidae																				
Scaphula sp	0	0	0	0	0	2	1	0	0	0	1	0	0	1	0	2	0	0	1	0
ORDER Mytiloida																				
FAMILY Mytilidae																				
Limnoperna sp	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	1	0	13	0
ORDER Unionoida																				
FAMILY Amblemidae																				
Scabies crispata	0	0	0	0	0	2	0	0	0	0	1	0	1	0	0	0	0	0	0	0
ORDER Veneroida																				
FAMILY Corbiculidae																				
Corbicula sp	13	0	44	0	93	23	3	20	31	107	49	0	0	148	2	50	9	3	28	1
CLASS Gastropoda																				
ORDER Architaenioglossa																				
FAMILY Ampullariidae																				
Pila pesmi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
FAMILY Viviparidae																				
Filopaludina polygramma	0	0	0	0	0	0	0	11	0	0	0	0	4	0	0	0	4	0	7	0
Idiopoma sp	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mekongia sp	0	0	0	0	0	0	0	0	0	0	3	0	0	1	0	0	0	0	0	0
ORDER Basommatophora																				
FAMILY Ancylidae																				
Ferrissia sp	0	0	0	0	0	9	0	0	0	0	5	4	0	0	0	0	0	0	0	0
FAMILY Lymnaeidae																				
Lymnaea sp	0	0	0	0	0	0	1	0	0	0	0	0	11	0	0	0	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
ORDER Caenogastropoda																				
FAMILY Stenothyridae																				
Stenothyra sp1	0	249	0	0	0	320	5	0	2	0	1504	185	7	65	0	222	20	1	353	0
ORDER Mesogastropoda																				
FAMILY Pomatiopsidae																				
Hubendickia sp	0	0	0	0	0	79	6	3	0	0	210	83	0	0	0	0	0	0	0	0
Hydrorissoia sp	0	0	0	0	0	0	0	0	0	0	9	9	11	53	0	0	0	0	0	0
Jullienia sp	0	0	0	0	0	0	36	0	0	4	4	3	0	1	0	0	0	0	0	0
Karelainia sp	23	0	2	0	0	0	0	0	0	0	67	0	0	0	0	0	0	0	0	0
Lacunopsis sp	0	179	0	0	0	236	0	0	4	0	102	144	0	36	0	58	0	0	6	0
Pachydrobiella brevis	0	0	0	0	0	0	1	59	10	82	17	97	11	40	0	0	0	0	0	2
Pachydrobiella sp	3	0	0	0	0	0	0	0	0	0	291	34	0	4	0	0	0	0	0	0
Paraprososthenia sp	0	0	0	0	0	0	0	6	0	1	76	12	0	0	0	0	0	0	0	0
FAMILY Buccinidae																				
Clea helena	0	0	0	0	0	45	0	5	1	0	2	3	2	0	0	5	0	0	27	0
ORDER Neotaenioglossa																				
FAMILY Assimineidae																				
Assimineidae sp	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Bithyniidae																				
Bithynia sp	19	0	0	0	0	717	0	0	0	0	0	0	0	3	0	103	0	0	0	0
Wattebledia sp	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	50	0	0	0	0
FAMILY Hydrobiidae																				
Rehderiella sp	0	0	0	0	0	1	28	0	0	0	0	7	0	0	0	0	0	0	0	0
FAMILY Thiaridae																				
Brotia sp	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Melanoides sp	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paracrostoma sp	0	0	0	0	0	81	7	30	0	0	0	6	0	6	0	0	0	0	46	0
Tarebia granifera	0	0	51	0	0	0	17	2	0	2	0	0	0	0	0	0	0	0	0	0
Thiara sp1	0	26	0	0	0	514	0	0	0	0	0	0	0	0	0	46	3	0	0	0
Thiara sp2	0	0	0	0	0	0	0	0	0	0	37	0	0	0	0	0	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
PHYLUM Nematoda																				
CLASS unknown																				
ORDER unknown																				
FAMILY unknown																				
Nematoda sp	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0

Appendix 4. Total counts of benthic macroinvertebrate taxa recorded at each site in 2007

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
PHYLUM Annelida																				
CLASS Oligochaeta																				
ORDER Haplotaxida																				
FAMILY Naididae																				
Branchiodrilus semperi	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naididae sp	0	0	7	0	0	23	0	0	0	0	0	0	2	6	0	11	0	0	0	22
FAMILY Tubificidae																				
Branchiura sowerbyi	0	0	0	0	1	2	0	0	0	33	9	0	2	0	0	0	19	0	0	0
Limnodrilus hoffmeisteri	0	14	0	0	100	0	0	21	0	0	75	14	0	0	2	0	0	0	0	0
PHYLUM Arthropoda																				
CLASS Crustacea																				
ORDER Decapoda																				
FAMILY Atyidae																				
Caridina nilotica	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Palaemonidae																				
Macrobrachium lanchesteri	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macrobrachium secamense	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Parathelphusidae																				
Somanniathelphusa germaini	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CLASS Insecta																				
ORDER Coleoptera																				
FAMILY Elmidae																				
Elmidae sp	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Haliplidae																				
Haliplus sp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Ceratopogonidae																				
Culicoides sp	1	0	0	2	39	5	46	21	0	0	5	7	2	0	1	1	2	4	0	0
FAMILY Chaoboridae																				
Chaoborus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
FAMILY Chironomidae																				
Ablabesmyia sp	4	17	21	23	50	26	3	13	2	98	28	0	1	4	3	0	36	1	3	4
Chironomidae sp (pupa)	0	1	2	0	0	1	2	0	1	2	0	1	0	0	0	1	0	0	0	2
Chironomus sp	0	0	0	8	0	0	0	0	0	17	0	2	0	0	3	4	0	0	0	11
Cryptochironomus sp	0	0	0	36	0	0	0	0	9	10	0	6	7	9	2	5	12	16	0	0
Goeldichironomus sp	6	37	24	0	0	0	0	50	6	30	21	0	0	24	0	3	0	0	0	11
Polypedilum sp	0	16	56	9	30	25	17	0	18	33	40	4	24	8	25	2	30	13	3	15
Sergentia sp	0	3	0	0	0	18	11	11	0	0	0	0	0	0	0	0	0	0	0	0
Smittia sp	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Tabanidae																				
Tabanidae	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Tipulidae																				
Eriocera sp	1	0	0	1	11	27	0	21	0	4	0	0	0	1	16	2	0	0	1	0
ORDER Ephemeroptera																				
FAMILY Baetidae																				
Baetis sp	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2
Cloeon sp	3	0	2	8	0	0	2	0	0	0	7	0	0	0	0	0	0	0	0	0
FAMILY Caenidae																				
Caenis sp	6	0	0	5	35	0	0	0	0	2	0	0	2	1	3	0	0	0	1	0
FAMILY Ephemeridae																				
Afromera sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Ephemera sp	0	0	0	11	97	1	0	0	0	14	0	0	0	0	0	0	1	0	0	0
FAMILY Heptageniidae																				
Thalerosphyrus sp	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0
FAMILY Leptoplebiidae																				
Choropterpes sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
FAMILY Oligoneuriidae																				
Chromarcys sp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Palingeniidae																				
Pentagenia sp	0	2	0	0	0	0	9	18	0	0	5	0	0	0	0	6	1	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
FAMILY Polymitarcyidae																				
Ephoron sp	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	3
Povilla sp	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Potamanthidae																				
Potamanthus sp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Prosopistomatidae																				
Prosopistoma sp	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
ORDER Hemiptera																				
FAMILY Corixidae																				
Corixa sp	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0
FAMILY Naucoridae																				
Naucoris sp	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
ORDER Odonata																				
FAMILY Calopterygidae																				
Agrion sp	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
FAMILY Corduliidae																				
Cordulia sp	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macromia sp	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FAMILY Gomphidae																				
Aphylla sp	0	0	0	0	0	2	0	3	1	0	0	0	2	2	0	3	0	0	1	0
Dromogomphus sp	2	0	0	1	5	1	0	2	2	1	3	3	5	0	1	0	0	0	0	0
Progomphus sp	3	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0
FAMILY Libellulidae																				
Libellula sp	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ORDER Plecoptera																				
FAMILY Perlidae																				
Perla sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0
ORDER Trichoptera																				
FAMILY Ecnomidae																				
Economus sp	0	0	0	0	0	0	2	0	0	2	0	0	0	0	2	0	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
FAMILY Hydropsychidae																				
Hydropsyche sp	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macronema sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
FAMILY Leptoceridae																				
Leptocerus sp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
FAMILY Philopotamidae																				
Philopotamidae sp	0	0	0	0	2	28	1	8	8	1	1	0	2	0	5	4	0	0	0	0
PHYLUM Mollusca																				
CLASS Bivalvia																				
ORDER Arcoida																				
FAMILY Arcidae																				
Scaphula pinna	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0
ORDER Mytiloida																				
FAMILY Mytilidae																				
Limnoperna siamensis	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
ORDER Unionida																				
FAMILY Amblemidae																				
Hyriopsis (Hyriopsis) bialatus	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Indonaia pilata	0	0	0	0	1	5	0	3	0	1	0	0	2	1	0	0	0	4	0	1
Physunio micropterus	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pilsbryoconcha exilis exilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Scabies scobinata	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ORDER Veneroida																				
FAMILY Corbiculidae																				
Corbicula blandiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Corbicula castanea	0	0	0	0	30	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Corbicula cyreniformis	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0
Corbicula leviuscula	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Taxon	LNT	LVT	LNG	LNM	LKD	LBF	LBH	LSD	LKL	LKU	LDN	CMR	CKM	CSJ	CSU	CSP	TMM	TNK	TSK	TSM
Corbicula moreletiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	1	4	0
Corbicula tenuis	20	0	1	0	119	13	5	1	9	178	19	0	5	4	5	43	33	0	34	3
CLASS Gastropoda																				
ORDER Architaenioglossa																				
FAMILY Viviparidae																				
Angulyagra sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Mekongia sp	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
Mekongia swainsoni braueri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Mekongia swainsoni flavida	0	0	0	0	0	0	0	5	0	0	0	0	1	3	0	0	0	0	0	0
ORDER Caenogastropoda																				
FAMILY Stenothyridae																				
Stenothyra sp	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Stenothyra koratensis holosculpta	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	300	4
Stenothyra koratensis koratensis	0	0	0	0	2	0	0	0	0	0	38	0	0	0	0	0	0	0	0	0
Stenothyra mcmulleni	0	0	0	0	0	0	0	0	0	0	372	0	0	0	0	0	0	0	27	0
CLASS Mesogastropoda																				
FAMILY Pomatiopsidae																				
Hubendickia crooki	0	0	0	0	0	4	0	0	0	0	34	49	1	0	0	0	0	0	0	0
Hubendickia sp	0	0	0	0	3	326	0	6	0	0	48	21	1	0	0	0	0	0	0	0
Pachydrobia sp	0	0	0	0	0	0	0	5	0	0	15	0	0	0	0	0	0	0	0	0
CLASS Neotaenioglossa																				
FAMILY Bythiniidae																				
Bithynia sp	0	0	0	0	0	2	0	5	0	0	36	52	1	3	0	0	0	0	0	0
FAMILY Thiaridae																				
Melanoides tuberculata	1	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Sermyla tornatella	0	0	0	0	0	17	0	0	0	0	0	0	1	0	0	2	0	0	4	0
Tarebia granifera	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
CLASS Neritopsina																				
FAMILY Neritidae																				
Neritina rubida	0	0	0	0	0	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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