ISSN: 1683-1489

Mekong River Commission

Report on the 2008 biomonitoring survey of the lower Mekong River and selected tributaries

MRC Technical Paper
No. 27

February 2010

Meeting the Needs, Keeping the Balance

ISBN : 1683 – 1489

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Published in Vientiane, Lao PDR in February 2010 by the Mekong River Commission

Cite this document as:

DAO Huy Giap, Tatporn KUNPRADID, Chanda VONGSOMBATH, DO Thi Bich Loc, and PRUM Somany (2010) Report on the 2008 biomonitoring survey of the lower Mekong River and selected tributaries, MRC Technical Paper No. 27. Mekong River Commission, Vientiane. 69 pp.

The opinions and interpretation expressed within are those of the authors and do not necessarily reflect the views of the Mekong River Commission.

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Acknowledgements

The authors thank the staff of the Environment Programme of the Mekong River Commission for their assistance in coordinating the sampling programme in 2008. The authors also express their appreciation for the support given to the study by representatives from the National Mekong Committees of Cambodia, Lao PDR, Thailand, and Viet Nam, particularly for the help they provided in the field.

The authors are indebted to Prof. Vincent Resh and Dr. Bruce Chessman for their guidance during the field programme and their help with drafting this report. The authors also express their appreciation to Dr. Vithet Srinetr, Dr. Pornsook Chongprasith and Dr. Hakan Berg for their comments and suggestions when reviewing the report.

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 richness: This measurement refers to the mean number of taxa (types) of plants or animals belonging to a particular biological indicator group (e.g. diatoms, zooplankton) counted in a sample.

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 immobile, 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 groups: 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 characteristic 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 biological indicator groups most commonly 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: These are 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 of their 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 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: These are organisms that live near the shores of rivers, lakes, and the sea.

Macroinvertebrates: An informal name applied to animals that do not have a vertebral column, including snails, insects, shrimps, 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 producers: These are 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: This refers to 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: This refers to the total organic material made by primary producers over a given period of time.

Reference sites: These are sampling sites that are in an almost 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.

Sampling sites: These are 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.

Total richness: This measurement refers to the total number of taxa (types) of plants or animals belonging to a particular indicator group (e.g. diatoms, zooplankton) collected at a site.

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 that 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 with a variety of responses to environmental changes. Zooplankton communities respond rapidly to changes in the environment because of their short generation times.

Summary

The Mekong River is one of the most important rivers 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 resources and the ecological health of the river.

This report describes the biomonitoring survey conducted in 2008 in the lower Mekong River and which contribute to the evaluation of the overall ecological health of the river. These studies build on the development of the methods used for sampling and analysis in the biomonitoring programme that evolved during the 2003 - 2007 studies when various approaches were tested and modified. In 2008, the biomonitoring programme was transferred to the Mekong River Commission (MRC) Member Countries so, in contrast to the previous organisation of sampling, identification, analysis and reporting from 2004 - 2007, each of the National teams with support from the MRC Secretariat (MRCS) performed all of these processes in the eight sites examined within their own countries. Three types of biometric indicators of the health of the Mekong aquatic ecosystem were calculated for each of four groups of organisms: benthic diatoms, zooplankton, littoral macroinvertebrates and benthic macroinvertebrates included in the biomonitoring programme. These indicators were abundance, average richness, and the Average Tolerance Score per Taxon (ATSPT). A healthy ecosystem is indicated by high abundance, high average richness, or a low ATSPT (signifying of the presence of pollution-sensitive species). Each indicator was calculated for individual samples of each group of organisms collected during a site examination. The collection of multiple samples per site enables the assessment of within-site variability of the indicators and also allows for statistical testing of the significance of differences both within and between the same sites over multiple years.

The objectives of this report are to (i) describe the biological indicator groups sampled during 2008, (ii) use this information to derive biological indicators for the sites examined in 2008 and (iii) use biometric indicators to evaluate these sites.

The total of 32 sites were assessed and classified into four class groupings. Of the 2008 sites, 9 were in Class A (‘excellent ecological health’), 12 in Class B (‘good’), 10 in Class C (‘moderate’) and 1 in Class D (‘poor’). A temporal change of ecological health over the period of 2004 - 2008 was found in many locations. Lower scores may have resulted from an increase in human disturbance, and declines in habitats and water quality. Some locations indicate improvement, others indicate degradation. The temporal trend of ecological health of the Mekong River sounds a warning that environmental impacts, such as human disturbance. and degradation of habitats and water quality are occurring in some parts of the Mekong River. Further investigations to identify the causes and effects on biological components are needed to suggest remedial actions.

1. Introduction

The Mekong River is one of the most important rivers in the world in terms of human dependency on riverine aquatic resources for sustenance and survival. For the 60 million or more people living in the Lower Mekong Basin (LMB) their quality of life depends on both the economic resources and the ecological health of the river.

This report describes the biomonitoring survey in the lower Mekong River conducted in 2008 and which contribute to the evaluation of the overall ecological health of the river. These activities were initiated in 2003, when pilot studies determined the biological indicator groups which could be used for biomonitoring. In 2004, a major part of the analysis was the comparison of the biological variability both within and between individual 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. In 2005, the study focus was 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 2006, 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 2007, the study focus was on three biological metrics (richness, abundance, and ATSPT). Regression analyses were used to examine relationships between biological metrics and environmental variables. The results of the development of the biomonitoring survey are published in the MRC Technical Paper Series (Sangpradub and Boonsoong, 2006; Davison *et al.*, 2006; MRC, 2008; Vongsombath *et al.*, 2009a; and Vongsombath *et al.*, 2009b). In 2008, the biomonitoring programme was transferred to the MRC Member Countries. In contrast to the organisation of sampling, identification, analysis and reporting in 2004 - 2007, each of the National teams with support from the MRCS performed all of these processes at the eight sites examined within their own countries. These initial surveys, together with the information collected in 2008 produced a large body of information (109 sampling events, 60 sites) on the Mekong River and its tributaries. Figure 1.1 illustrates the development of the monitoring activities through time.

The objectives of this report are to (i) describe the biological indicator groups sampled during 2008, (ii) use this information to derive biological indicators for the sites examined in 2008 and (iii) use biological indicators to evaluate sites.

Three types of indicators of the health of the Mekong aquatic ecosystem were calculated for each of four groups of organisms: benthic diatoms, zooplankton, littoral macroinvertebrates and benthic macroinvertebrates included in the biomonitoring programme. These indicators were abundance, average richness, and ATSPT of each of the four groups. A healthy ecosystem is indicated by high abundance, high average richness, or a low ATSPT (signifying the presence of

pollution-sensitive species). Each indicator was calculated for individual samples of each group of organisms collected when a site was examined. The collection of multiple samples per site enables an assessment of within-site variability of the indicators and also allows for statistical testing of the significance of differences both within and between the same sites over multiple years.

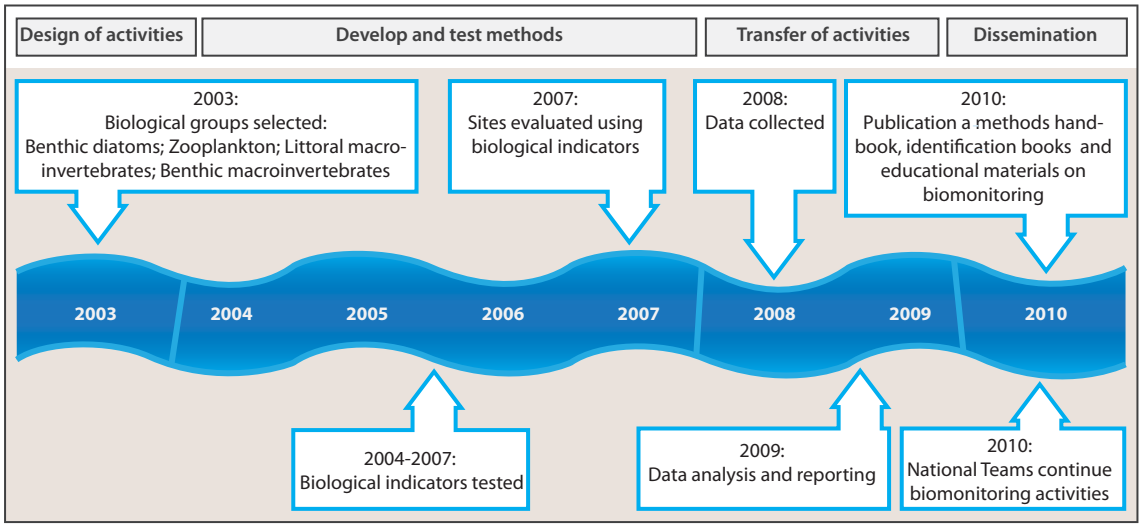

Figure 1.1 Timeline for biomonitoring in the Mekong River and its tributaries

2. Materials and methods

2.1 Sampling sites

For the 2008 biomonitoring survey, a team of national experts in consultation with the MRCS and the National Mekong Committees of the four LMB countries of Cambodia, Lao PDR, Thailand and Viet Nam selected a total of 32 sites to be sampled during March 2008. Eight sites were selected in each country. Some of these had been sampled in the previous years' biomonitoring surveys but nine were new; four in Thailand and five in Viet Nam (Table 2.1). Details of the 2008 survey sites are given below, and summarised in Table 2.2 and Figure 2.1.

Table 2.1 *Sites sampled in 2008 and during previous years' biomonitoring surveys*

Country	Site	Location	2004	2005	2006	2007	2008
Cambodia	CKT	Mekong River, Kampi pool, Kratie province	X		X		X
	CMR	Mekong River, Stung Treng Ramsar site		X	X	X	X
	CSJ	Se San River, downstream of Srepok River junction		X	X	X	X
	CKM	Se Kong River, Kbal Koh village, Stung Treng province		X	X	X	X
	CSP	Sre Pok River, Phik village, Ratanakiri province	X	X	X	X	X
	CSU	Se San River, Dey It village, Rattanakiri Province		X	X	X	X
	CKL	Bassac River, Koh khel			X		X
	CSK	Stoeng Sangke River, Battambang			X		X
Lao PDR	LDN	Mekong River, Done Ngiew				X	X
	LSD	Se Done River, Ban Hae				X	X
	LKL	Se Kong River, Ban Xou		X		X	X
	LBH	Se Bang Hieng River, under bridge				X	X
	LBF	Se Bang Fai River, under bridge				X	X
	LVT	Mekong River, Ban Huayhome	X			X	X
	LMX	Mekong River, Ban Xiengkok		X			X
	LPB	Mekong River, Done Chor	X	X			X
Thailand	TNP	Mekong River, Nakorn Panom					X
	TSM	Songkhram River, Mekong junction				X	X
	TNK	Nam Kam River, Na Kae				X	X
	TMU	Nam Mun River, Ban Tha Phae, Ubon Ratchathani	X				X
	TKC	Nam Mun River, Mekong junction					X
	TUN	Nam Mun River, Ubonrachathani					X
	TCS	Mekong River, Chiang San, Chiang Rai					X
	TKO	Nam Kok River, Chaing Sean Water Quality Station	X	X			X
Viet Nam	VCT	Bassac River, Phu An, Can Tho			X		X
	VLX	Bassac River, Long Xuyen, An Giang			X		X
	VDP	Bassac River, Da Phuoc, An Giang					X
	VKB	Bassac River, Khanh Binh, An Giang					X
	VTP	Mekong River, Thuong Phuoc, Dong Thap					X
	VTT	Mekong River, Thuong Thoi, Dong Thap					X
	VCL	Mekong River, Cao Lanh, Dong Thap			X		X
	VVL	Mekong River, My Thuan, Vinh Long					X

Cambodia

In March 2008, the Ecological Health Monitoring Team conducted its annual sampling at eight sites in Cambodia's Mekong system. Six sites, CKT, CRM, CSJ, CKM, CSP, and CSU were in the Upper Mekong mainstream and its tributaries, one site (CKL) was in the Tonle Bassac River downstream of the Mekong, and one site (CSK) was in the Tonle Sap Great Lake. The sites were selected in an attempt to include a diversity of habitats and the three types of localities of the Mekong system present in Cambodia, i.e. upstream, downstream, and in the Great Lake area.

CKT (Mekong River, Kampi pool, Kratie province)

The CKT site on the Mekong mainstream is at Kampi Village, Sam Bok Commune, Kratie District, Kratie. Here there are a few houses on the left bank and a tourist site for dolphin watching on the right bank. The riverbank has a moderate slope and shows evidence of some erosion. The banks are covered with various grasses and trees. The substratum is composed of sandstones, rocks, rocks with algae, and some debris. There is a large, deep pool nearby, which is believed to be the main habitat of the dolphins.

CMR (Mekong River, Stung Treng Ramsar site)

The CMR site, in Sdao Village, Sdao Commune, Stung Treng District, Stung Treng Province, is on the Mekong mainstream where the Se San River joins the Mekong. It site is characterised by many trees and some houses on the bank. The substratum is composed of sand, cobbles, bedrock covered by filamentous algae, and some debris. There is noticeable human and animal waste flowing down a damaged bank into the river.

CSJ (Se San River, Downstream of Srepok River junction)

The CSJ site, in Kam Phon Village, Kam Phon Commune, Se San District, Stung Treng Province, is at the confluence of the Se San and Sre Pok Rivers. It is characterised by forests and some houses. The substratum is composed of sand, pebbles, cobbles, bushes, some rocks and debris. There are small areas showing evidence of bank erosion.

CKM (Se Kong River, Kbal Koh Village, Stung Treng Province)

The CKM site on the lower Se Kong River is in Kbal Koh Village, Cheuteal Thom Commune, Thalab Rovath District, Stung Treng Province. The site is characterised by a few houses and many trees. There is small-scale agriculture, livestock raising, a ferry port, and a small amount of bank erosion. The substratum is composed of sand, rocks, mud, and a little debris.

CSP (Sre Pok River, Phik Village, Ratanakiri Province)

The CSP site upstream on the Sre Pok River, is in Phik Village, Ratanakiri Commune, Ratanakiri District, Ratanakiri Province. The site is characterised by some forested areas, small-scale agriculture, a ferry crossing, and sewage inputs from the village. The substratum is composed of bedrock and cobbles, clay and mud, sand, debris, and bamboo leaves.

CSU (Se San River, Dey It Village, Rattanakiri Province)

The CSU site on the Se San River is in Dey It Village, Chey Udom Commune, Lum Phat District, Ratanakiri Province and is about 500 m from the ferry port. It is characterised by a few houses and some erosion on the left bank, with small-scale agriculture, abundant vegetation and bamboo stands, and some cultivation such as that of cashew nut and fruit trees alongside the riparian zone. The riverbed substratum contains boulders on bedrock, sand, rock, and debris. There is some sewage and bank erosion. Local people report that two days before our sampling visit there was no flow in the river, possibly the result of upstream dam activities.

CKL (Bassac River, Koh Khel Village, Kan Dal Province)

The CKL site on the Bassac River is in Koh Khel Village, Koh Khel Commune, Koh Phom District, Kan Dal Province. This is a dense residential area with agricultural villages. Large amounts of human and livestock waste flow into the river. The substratum is composed of sand, mud, debris, and a few pebbles. The water surface is completed covered by water hyacinths.

CSK (Stoeng Sangke River, Battambang Province)

The CSK site, in Unlung Taua Village, Anling Taua Commune, Battabang Province, lies at the point where the Stoeng Sangke River enters the Tonle Sap Great Lake. The Stoeng Sangke River flows through many residential areas of the three north-western provinces of the country. The site is characterised by flooded forests, water hyacinths, fish pens, floating huts and a floating village. The substratum is composed of deep layers of mud and debris.

Lao PDR

Sampling sites in Lao PDR include localities on the Mekong and its major tributaries, and cover a range of river settings from bedrock-confined channels in northern Lao PDR through to the alluvial channel systems of central and southern Lao PDR. The sites also exhibit varying levels of disturbance from human activity. Most are located in or close to villages or towns. Some are next to fields where crops are grown, others are upstream of dams, and in areas (LKL) where for the past two years gold has been collected. At some sites, bank erosion, sand or gravel excavation, fishing and river transport occur.

LDN (Mekong River, Done Ngiew)

The LDN site on the Mekong River is in Done Ngiew, a part of Ban Muang, Pathumphone District, Champasack Province. The sampling point is about 800 m above the ferry crossing to Watphu Champasack. The right bank is quite steep. Bank erosion is present in some areas where there are a few maize gardens, vegetable cultivation and the growth of riparian shrubs (Homonia riparia). About 100 m from the bank, there are plantations and rice fields. The slope on the left bank is covered with tobacco and vegetable gardens and there are houses about 200 m from the bank. Substrata at the site are almost completely bedrock, with sandy areas and some small islands in the channel. A large area is covered by floating and attached filamentous algae.

LSD (Se Done River, Ban Hae, Pakse)

The LSD site is on the Se Done River, a tributary of the Mekong, in Ban Hae, Pakse Town and is approximately 4 km upstream from the mouth of the Se Done River. There are maize and vegetable gardens on the right bank, with houses, a school, and vegetable gardens on the left bank. This site is often disturbed by people fishing and pumping water. Substrata of the site are bedrock, with sandy and muddy areas.

LKL (Se Kong River, Ban Xou Touat, Attapeu)

The LKL site on the lower Se Kong River, a tributary of the Mekong, is in Ban Xou Touat, Sanamxay District, Attapeu Province. On the right bank, there is a town and gardens. Large areas of bank erosion and boat docks are present. On the left bank, there are banana gardens, and stands of bamboo. There is some bank erosion. For the past two years, gold mining has taken been taking place on the right bank and on an island in the middle of the river. Substrata in faster-flowing areas are cobbles, pebbles and gravel, with sand and debris accumulating in the pond or areas with slow currents.

LBH (Se Bang Hieng River, Ban Se Bang Hieng, Savannakhet)

The LBH site in Ban Se Bang Hieng, Songkhone District, Savannakhet Province, lies under the bridge over the Se Ban Hieng River, a tributary of the Mekong. There are houses and small vegetable gardens on both banks. The substratum is a mix of boulders, concrete, sand, mud, and debris. This location is frequently disturbed by villagers' activities.

LBF (Se Bang Fai River, Ban Se Bang Fai, Khammouan)

The LBF site in Ban Se Bang Fai, Se Bang Fai District, Khammouan Province, lies under the bridge over the Se Bang Fai River, a tributary of the Mekong. There are houses and small vegetable gardens on both banks. The substratum is a mix of boulders, concrete, sand, mud and debris. This location is frequently disturbed by villagers' activities.

LVT (Mekong River, Vientiane)

The LVT site is on the Mekong River, with the sampling being carried out in Ban Huayhome, Sikhottabong District, about 5 km upstream from Vientiane Capital. Thailand lies on the right bank and Lao PDR on the left where there is a village, large vegetable gardens and a boat dock. Some sampling problems related to national boundaries were experienced here making sampling impossible on the right side of the river. Other problems arose from the presence of a bedrock substratum and strong currents in the middle of the river. Therefore samples were taken only from the left side of the river .

LMX (Mekong River, Ban Xiengkok, Luangnamtha)

The LMX site is on the Mekong River, at upper Ban Xiengkok, Long District, Luangnamtha Province. Myanmar lies on the right bank and Lao PDR on the left where there are villages, guesthouses, an immigration office and a port. Sampling could be done only along the left bank. In general, this site experiences strong currents and is much disturbed by human activities and river traffic. The substratum close to the bank is clay and sand; with cobbles and pebbles about 5 m from the bank.

LPB (Mekong River, Ban Done Chor, Luangprabang)

The LPB site is at Done Chor on the Mekong River, about 1.5 km above Suphanuvong University. It is on an island belonging to Ban Done Chor, Luangprabang District. There is secondary forest on the right of the island with some grass and sandy areas on the island itself. There are villages, roads, and sand and gravel excavation on the left of the island. The substrata of running water areas are cobbles, pebbles, and gravel with attached algae. There is a pond below the island and this standing water habitat has a substratum composed of clay, mud and sand. In general, this site experiences a great deal of disturbance from various activities such as those related to water use, sand and gravel excavation, and river traffic.

Thailand

The selected sampling sites include sites sampled during the 2004 - 2007 biomonitoring programme and some new sites in north-eastern Thailand. These include localities on the Mekong and its major tributaries and are mostly in the north and north-east of Thailand with two sites in the north and six in the north-east. The sites exhibit various disturbances reflecting low to high human-activity impacts. Some sites are in or close to villages or towns; some are next to fields where crops are grown and livestock graze; some are upstream or downstream of dams or weirs, and some are exposed to moderate to heavy river traffic.

TNP (Mekong River, Nakorn Panom)

The TNP site is on the border between Thailand and Lao PDR and is about 1.5 km upstream of the Nakorn Phanom downtown area. There are many small villages of about 100 inhabitants around the site. The left bank on the Lao side is steep with a slope of 30°; the slope on the right bank on the Thai side is 45°. The river substratum is mud and clay near both banks with bedrock and cobbles in the middle of the river. There is some agriculture in the riparian zone,with a few houses, some open shoreline, trees, and small-scale fish farms. The impact from human

activities appears to result from rubbish disposal, agricultural runoff, and fish farming. There is some bank erosion.

TSM (At the confluance of the Songkram and Mekong Rivers)

The TSM site lies on the border between Thailand and Lao PDR at the confluence of the Songkram and Mekong Rivers. The left bank is relatively level with a flat sand bar while the right has a 40° slope. The riparian vegetation is bamboo forest. This site is surrounded by small villages with about 80 inhabitants. The riparian zone includes some forest, landslide areas, a few houses, aquatic plants, algae such as river weed (called 'Kai' or Cladophora glomerata), small scale agriculture, pear trees, floating houses and fish cages. The substrata are composed of sand and clay, and firm mud and sand. The human impact appears to come from a restaurant, fish cages, the disposal of human and animal wastes, agricultural runoff and damage to banks by livestock.

TNK (Nam Kam River, Mukdaharn)

The TNK site is about 20 km downstream from the water pumping station. The river at this site is shallow (<0.5-1.5 m deep) with 20 - 30° slopes on both banks. The vegetation on the right bank is bamboo and grasses. The substrata are composed of wood and leaf debris, but include areas with material from soil erosion and land slides, and sand and clay mixed with gravel, sand and mud. The human activities include human waste and rubbish disposal, and there is some bank erosion.

TMU (Nam Mun River, Kong Chiam District, Ubonrachathani)

The TMU site is about 2 km above the confluence of the Mun and Mekong Rivers. It is surrounded by moderate-sized communities of about 300 inhabitants. Both banks have 30° slopes. In the riparian zone there are rice fields, agriculture, houses, soil erosion areas, cattle grazing, fish farms and floating houses. The substratum is almost all sand and gravel. The human impact appears to be related to the disposal of human and animal wastes, agricultural and urban runoffs.

TKC (Nam Mun River, Kong Chiam District, Ubonrachathani)

The TKC site lies on the border between Thailand and Lao PDR at the confluence of the Mun and Mekong Rivers. There is a flat sand bar near the steep left bank which slopes at 40° (Lao

side); the right bank has a 45° slope (Thai side). The riparian vegetation is bamboo forest. This site is surrounded by fishing villages with about 800 inhabitants. The riparian zone includes some forest, land slides, tourist sites, pear trees, floating houses and fish cages. The substratum is composed of sand and clay, with some firm mud and sand. The human impacts come from a restaurant, fish cages, and the disposal of human and animal wastes.

TUN (Nam Mun River, Ubonrachathani)

The TUN site is about 10 km from downtown Ubon Rachathani and surrounded by a few houses of fishermen. Both banks have slopes of 15°. The riparian zone includes cattle grazing areas, soil erosion areas, and algae and aquatic plants. The substratum is composed of mud and aquatic plants, sand and clay, and firm sand and gravel. The human impact appears to come from the disposal of human and animal wastes, river traffic and agriculture.

TCS (Mekong River, Chiang San District, Chiang Rai)

The TCS site, on the border between Thailand and Lao PDR, is in Chiang San District. This site is the most important dock for river traffic, and for the transportation of imports and exports between Thailand and the other countries in the Mekong Region. There is a flat sand bar on the left bank (Lao PDR) while the right bank consists of an artificial bank and concrete wall. This site is surrounded by large communities of about 10,000 inhabitants. The riparian zone includes some forest, land slide areas, pastures for large animals such as water buffalo, areas of soil erosion, algae and aquatic plants, and a local market. The substratum is composed of sand, clay, mud and gravel. The human impacts at this site come from river traffic, construction, domestic waste, and disposal of rubbish resulting from human and trading activities.

TKO (Nam Kok River, Chiang, Chiang Rai)

The TKO site was also sampled in 2004 and 2005. The left bank has a 30° slope while the right is flat. Both banks are eroded and the riparian areas are cleared forest, with agricultural development on the left bank and a village on the right. There is a cobble and gravel island in the centre of the river. Human influences are related to agricultural runoff, river traffic (particularly to the effects on the banks from the wakes created by tourist boats), and a small village. The substratum is composed of sand, cobbles and gravel.

Viet Nam

The sampling sites in Viet Nam are on the Mekong and Bassac Rivers. Four sites are on the Bassac River near Can Tho City, Long Xuyen City, and Khanh Binh, An Giang Province. Three sites are on the Mekong River in Dong Thap Province. The remaining site is in an urban area of Vinh Long Province. Two new sites near the border between Viet Nam and Cambodia were selected. These new sites are not significantly impacted by human activities and have strong current flows. The substratum of one of these consists of fine sand and alluvia, while that of the other consists of sand and hard clay. The other six sites are affected by tides. There are alluvial deposits in the littoral zones and the bottom of the river is sand.

VCT (Bassac River, Phu An, Cai Rang, Can Tho)

The VCT site is in the lowermost segment of the Bassac River, near the rapidly developing city of Can Tho. There are many houses and orchards on both sides of this site. The littoral substratum is mainly a thin layer of mud, while that right bank consists of sand, mud, and organic material. On the left side of the river it is mainly clay, mud and organic matter. In midstream areas, there is sand and a little mud. The My Thuan bridge in this region is under construction. There are many different activities involving humans; such as transportation by ships and barges, the operations of a river port and of oil storage facilities, the treatment and discharge of urban sewage water, fishing and bathing.

VLX (Bassac River, Long Xuyen, An Giang)

The VLX site is in Long Xuyen city. The flows here are rather strong, and the left bank is eroded. Agricultural production is both diverse and large, and there are some rice processing factories. Littoral areas consist of mud, organic matter, and rubbish (such as plastic bags, wood, decaying bodies of dead animals). The right bank substratum is composed of sand and organic matter, while the left bank is soil, mud and clay. The midstream is sand. This site is near Long Xuyen River Port, so there are many ships, boats, and barges. There are many other human related activities including rice processing plants and the sewage treatment and discharge.

VDP (Bassac River, Da Phuoc, An Phu, An Giang)

The VDP site is in an agricultural area, with many houses and orchards on the left bank, and rice, maize, beans and other plants growing on the right bank. At the river, there is alluvium on the right side and sand and clay on the left. There is sand in midstream areas. There are

boats, fishing, and washing activities, as well as houses along the banks. At some places, soil is eroding into the river.

VKB (Bassac River, Khanh Binh, An Phu, An Giang)

The VKB site is on the Bassac River on the border between Cambodia and Viet Nam. On the left bank areas of natural land alternate with agricultural land. On the right bank, there are markets and shops. The littoral area is sand and detritus. The right river bed contained rubbish, sand, and sewage. The left river bed is clay, sand and silt. In midstream there is sand and silt. A lot of sewage water and rubbish from the market are discharged into the river. Many other activities occur including agriculture, sand excavation, fish farming, washing and boating.

VTP (Mekong River, Thuong Phuoc, Hong Ngu, Dong Thap)

The VTP site is near the border between Cambodia and Viet Nam. A border checkpoint and areas of natural land lie on the left bank and on the right bank are houses, gardens and another border checkpoint. The littoral area consists of sand and alluvium. The right river bed is sand and clay, while the left is sand, as is the midstream area. The human activities are limited here, only sand excavation and small transport boats are evident.

VTT (Mekong River, Thuong Thoi, Hong Ngu, Dong Thap)

The VTT site is on the Mekong River. On the left bank areas of natural land alternate with agricultural land. There is natural land on the right bank, and in some places the soil is eroded. Littoral areas consist of alluvium and organic matter. On the river bed, there is clay on the right, alluvium and organic matter on the left, and sand in midstream areas. Some human activities such as fishing, farming and boat transportation are evident. There is some soil erosion.

VCL (Mekong River, Tan Hau, Tan Thuan Tay, Cao Lanh, Dong Thap)

The VCL site is on the Mekong River, near Cao Lanh City. Many areas of agricultural land alternate with natural land on the left bank, with houses and gardens on the right bank. Littoral areas consist of mud, alluvium, and a great deal of rubbish such as dead trees, plastic bags, etc. On the left river bed, there is mud, alluvium, and rubbish, including pesticide bottles. On the right river bed, there is sand and clay, and in midstream there is sand and alluvium. The human activities consist of agriculture, boat transportation, fishing and washing.

VVL (Mekong River, My Thuan, Vinh Long)

The VVL site is on the Mekong River near Vinh Long Town. On the left bank there are gardens, agricultural land, and houses. On the right bank, there are houses, orchards, and construction-material storage areas. There is a mixture of sand, dead fish, rubbish, plastic bags, and pesticide bottles in the littoral areas. On the right river bed, there is clay and sand. On the left bank, there is sand, and also dead fish, rubbish, plastic bags, and pesticide bottles. The midstream bed is sand. Since this site is near a bridge construction area there are many of ships, barges and boats. Many construction materials are stored on the right bank, and sand excavation, fishing, erosion, sewage and agricultural activities are evident.

Table 2.2 *Description of sites sampled in 2008*

Site code	River	Location	Date sampled	Coordinates (UTM)	Land cover of left bank	Land cover of right bank	Littoral substratum	Potential human impacts
CKT	Mekong	Kampi pool	19/3/08	48P N1393502 E0610914	Few houses; tourist area; moderate slope; some erosion	Steep, eroded bank; some trees on face; many on top; few houses	Sand; some stones	Tourism activities at dolphin tourist site
CMR	Mekong	Stung Treng Ramsar site	23/3/08	48P N1504098 E618663	Forest, few houses	Forest, few houses	Sand; pebbles; cobbles; bedrock; filamentous algae	Disposal of human and animal wastes
CSJ	Se San	downstream of Srepok River junction	20/3/08	48P N1498832 E621744	Forest; water buffalo	Forest; water buffalo	Sand; pebbles; cobbles; bushes	In significant impact from human activities
CKM	Se Kong	Kbal Koh village	21/3/08	48P N1539069 E606331	Forest; few houses; eroded banks	Forest; few houses; eroded banks	Sand-rocks, mud and little debris.	Disposal of animal wastes, navigation
CSP	Sre Pok	Phik village	23/3/08	48P N1525674 E765124	Forest, small scale agriculture; ferry crossing	Forest; small scale agriculture; ferry crossing	Bedrock and cobble, with many small channels	Disposal of human wastes
CSU	Se San	Dey It village	24/3/08	48P N1490553 E717794	Forest, bamboo, cashew nut trees outside riparian zone	Forest and bamboo; fruit trees outside riparian zone	Boulders on bedrock	River traffic
CKL	Bassac	Koh Khel	29/3/08	48P N1245255 E503786	Villages and gardens; bananas	Villages and gardens	Sand; mud; water hyacinth	Disposal of human and animal wastes
CSK	Stoeng Sangke	Battambang	28/3/08	48P N1461902 E357473	Open forest; fish pens; floating hut; floating village downstream	Open forest; fish pens	Silt; flooded bushes	Disposal of human waste; fishing; river traffic n
LDN	Mekong	Done Nguei	10/3/08	48P N1657517 E596193	Maize and tobacco gardens, bank erosion	Villages and vegetable gardens; shrub (Homonia riparia)	Sand; mud filamentous algae	Fishing and river traffic
LSD	Se Done	Ban Hae	11/3/08	48P N1671756 E587623	Villages and gardens; bananas	Maize, vegetable gardens	Bed rock; mud; sand; filamentous algae	Agricultural runoff; disposal of human, pumping, and animal wastes
LKL	Se Kong	Ban Xou Touat	13/3/08	48P N1623478 E670696	Gardens; bananas; bamboo; bank erosion	Villages and gardens; bank erosion	Cobbles; pebble; gravel; changes in water channel since 2007	Disposal of human waste; fishing; river traffic and animal wastes
LBH	Se Bang Hieng	Under the bridge	15/3/08	48Q N1887920 E498434	Houses; some trees on bank; washing place	Villages; washing place; boat parking; vegetation; gardens downstream	Boulders on bedrock; sand; mud; filamentous algae	Human wastes; rubbish disposal; and animal wastes

Site code	River	Location	Date sampled	Coordinates (UTM)	Land cover at left bank	Land cover at right bank	Littoral substratum	Potential human impacts
LBF	Se Bang Fai	Under the bridge	16/3/08	48Q N1959958 E454745	Houses; water pumping; some trees on bank; washing place	Houses; office; floating pump; washing place; vegetation gardens downstream	Little boulders on bedrock; sand; filamentous algae on bed rock	Waste and rubbish; disposal of human and animal wastes; bank erosion downstream
LVT	Mekong	Ban Huayhome	18/3/08	48Q N1988731 E239871	Lao villages; port; vegetable gardens, and grass on the bank	Thai villages; port and vegetable gardens, and grass on the bank	Cobbles, gravel, sand; debris, and clay	Agricultural run off; human wastes and rubbish disposal; fish farming and river traffic n
LMX	Mekong	Ban Xiengkok	20/3/08	47Q N2311778 E670860	Lao villages; port and; washing place	Burmese vegetable gardens, bamboo and cattle	Cobbles; gravel; filamentous algae; clay	Wakes from large boats; damage to banks; bank erosion; disposal of human and animal wastes; livestock
LPB	Mekong	Done Chor	22/3/08	48Q N2206957 E206113	Village; downstream of university; large sand and gravel excavation; road from left to the island	Steep, eroded bank; some trees on face; many on top; village downstream	Cobble; gravel; sand filamentous algae; clay	Sand and gravel excavation, river traffic, fishing
TNP	Mekong	Nakorn Panom	5/3/2008	48Q N1926454 E476094	Agriculture, a few houses.	Agriculture, some trees on bank, small scale fish farms	Clay and mud, bed rock, wood debris,	Rubbish disposal, agricultural runoff, fish farming, bank erosion
TSM	Songkhram	Mekong junction	6/3/2008	48Q N1951509 E443775	Forest , land slide, few houses, aquatic plants and algae	Small scale agriculture, docks, floating houses and fish cages	Sand and clay, firm mud and sand	Restaurant, fish cages, disposal of human and animal wastes, agricultural runoff, livestock damage to bank
TNK	Nam Kam	Mukdaharn	7/3/2008	48Q N1874332 E450496	Soil erosion, a few houses, wood and leaf debris,	Soil erosion and land slide	Sand and clay, gravel, sand and mud	Human waste and rubbish disposal form downstream, bank erosion
TMU	Nam Mun	Kong Chiam	8/3/2008	48P N1673182 E552465	Fields, agriculture, houses and floating houses, soil erosion, cattle grazing	Fish farm and floating house	Sand and gravel	Disposal of human and animal wastes, agricultural and urban runoffs, urban runoffs
TKC	Nam Mun and Mekong	Kong Chaim	9/3/2008	48P N1694552 E552099	Village, agriculture, cattle grazing, fish farm	Bed rock and cobbles, with many small channels and soil erosion	Sand and mud	Agricultural runoff, livestock damage to banks, urban runoff
TUN	Nam Mun	Ubon-rachathani	10/3/2008	48P N1685056 E494860	A few houses, small scale agriculture	Aquatic plants and a few houses	Sand and silt	River traffic, agriculture

Site codte	River	Location	Date sampled	Coordinates (UTM)	Land cover at left bank	Land cover at right bank	Littoral substratum	Potential human impacts
TCS	Mekong	Chiang San	11/3/2008	47Q N2240109 E614718	Water buffalo, soil erosion, algae, aquatic plants	Mud, aquatic plants, a few houses, market	Sand and clay, firm sand, gravel	River traffic, construction, domestic and human waste disposal, market rubbish
TKO	Nam Kok	Chiang Rai	12/3/2008	47Q N2201793 E582195	Gravel and sand	Riparian zone	Cobbles, gravel and sand	Agricultural runoff, river traffic, small village
VCT	Bassac	Phu An, Cai Rang, Can Tho	17/03/08	48P N1106685 E589048	Orchards, housing	Orchards, housing	Thin mud	Bridge construction, transport, navigation works, oil storage, washing, sewage treatment, port materials and fishing
VLX	Bassac	Long Xuyen, An Giang	18/03/08	48P N1143437 E551897	Agriculture, land erosion, strong flows	Housing, processing factory	Mudflats, organic matter, rubbish (plastic bags, wood, decaying bodies of dead animals)	Boats and ships, rice storage, grain processing factory, agriculture, bank erosion, washing, boat transportation, waste water,
VDP	Bassac	Da Phuoc, An Phu, An Giang	19/03/08	48P N1188035 E514690	Agriculture, housing, gardens, bushes, trees	Agriculture such as maize, beans, etc.,	Alluvium,	Boating fishing, washing, housing, gardens, soil erosion
VKB	Bassac	Khanh Binh, An Phu, An Giang	20/03/08	48P N1210872 E509482	Grain agriculture, natural land, grass cover	Market, shop	Sand, detritus, rubbish, clay	Market, waste water, rubbish, agriculture, river transportation, washing, sand excavation, fish farming and fishing
VTP	Mekong	Thuong Phuoc 1, Hong Ngu, Dong Thap	22/03/08	48P N1205766 E519830	Natural land, border guard post	Housing, gardens, border guard post	Sand, alluvium	Sand excavation, transportation activities
VTT	Mekong	Thuong Thoi, Hong Ngu, Dong Thap	23/03/08	48P N1194447 E528951	Grain agriculture, natural land	Soil erosion, natural land	Sediment, alluvium, organic fertilizer	Fishing, agriculture, farming, soil erosion, river transportation.
VCL	Mekong	Tan Hau, Tan Thuan Tay, Cao Lanh, Dong Thap	24/03/08	48P N1153777 E563798	Agricultural and natural land	Housing, gardens, river transportation	Mudflats, alluvium, a lot of rubbish like dead trees, plastic bags, etc.	Agricultural activities, river transportation, fishing, solid rubbish, decaying organic matter
VVL	Mekong	My Thuan, Vinh Long	25/03/08	48P N1134514 E603698	Gardens, agricultural land, housing	Housing, orchards, construction materials storage	Sediment, sand, dead fish, rubbish, plastic bags, pesticide bottles	Ships and boats, construction material storage on the right bank, sand excavation, fishing, erosion, sewage and agriculture

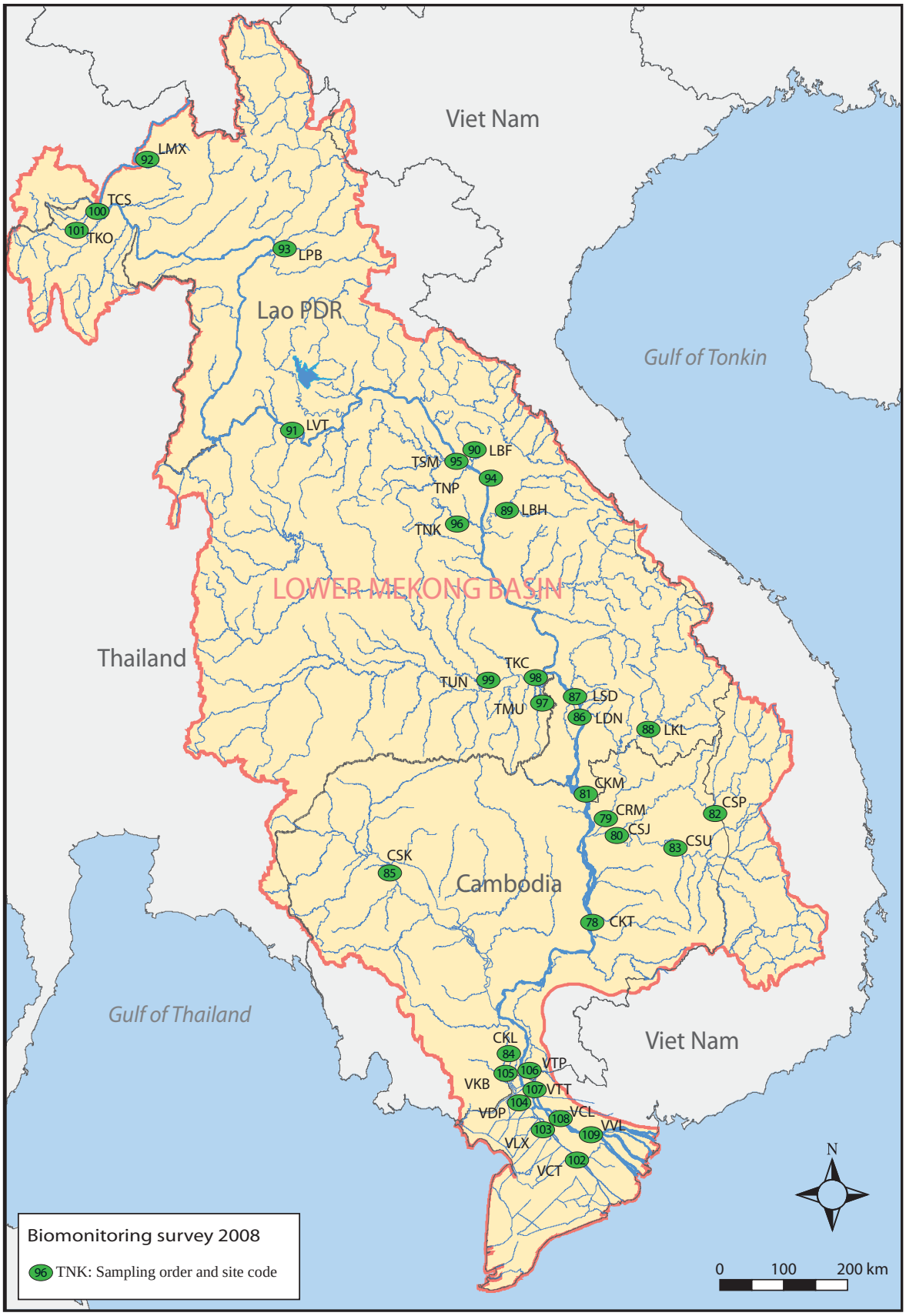

Figure 2.1 Map of sites surveyed in 2008

2.2 Data collection

Environmental variables

The objective in studying the physical and chemical factors related to the selected sites in the lower Mekong River is to describe certain environmental variables by collecting data on altitude, river width and depth, the Secchi depth (water transparency), water temperature, dissolved oxygen (DO), pH and electrical conductivity (EC) and to determine a Site Disturbance Score.

1. The map coordinates and altitude of the sampling sites are determined with a Garmin GPS 12XL.

2. Stream width is measured with a Newcon Optik LRB 7x50 laser rangefinder.

3. At each site, water-quality measurements are made in three sections of the river: near the left bank, near the right bank, and in the centre of the river.

    a. A Secchi disc is used to determine water transparency. The disc is slowly lowered into the water, and the depth at which it disappears is recorded. The disc is then lowered another metre and slowly pulled up until it reappears. If the difference between the depths of disappearance and reappearance is more than 0.05 m the procedure is repeated.

    b. Temperature, DO, EC, and pH are measured with a YSI 556MP5 meter, calibrated according to the manufacturer's instructions. Readings are taken at the surface and at a depth of 3.5 m, or at the maximum depth of the river, whichever is less.

    c. Elevation and river width are reported in m. Water transparency is expressed in m. Temperature is reported as degrees Celsius, and conductivity as mS/m.

4. In some situations, such as the determination of chemical variables such as DO, EC and pH, water samples can be collected from the water surface using of a water sampler. One litre per sample or three litres per site is collected. Bottles are labelled, kept in an ice box and transferred to the water quality laboratory within 24 – 36 hours for analysis.

    a. For DO, the water sample is stored in 250 mL glass bottles.

    b. The DO of each field sample is fixed immediately by pipetting 2 mL of manganous sulphate solution and 2 mL of alkali-iodide- azide solution into the water sample. The bottle is carefully stoppered to prevent air bubbles. The contents are mixed by inverting the bottle for at least 5 minutes and then letting it stand until the precipitate settles.

c. DO is reported as mg/L (the same as ppm).

4. All measurements of environmental variables are reported as average values.

5. A Site Disturbance Score is determined by a team of eight to ten ecologists/biologists who rate each site visited in terms of their individual observations of the combination of stressors generated by human activities. Light stress is rated 1, medium stress 2, and heavy stress 3. Sites are awarded initial independent scores which are later discussed by the group of assessors. A small percentage (-1% overall) of the scores are changed. The scores are averaged to obtain the overall Site Disturbance Score for each site.

Benthic diatoms

The objective in studying the benthic diatoms is to describe the characteristics of the diatom community in quantative terms. Diatoms respond rapidly to environmental changes.

Field methods

1. Benthic diatom sampling is performed at sites where the water depth is less than 1 m and suitable substrata extend over a distance of 100 m. The most appropriate substrata are cobbles and other grades of stones with a surface area greater than 10 cm^2, but that are still small enough to fit in a 20 – 30 cm diameter sampling bowl. At sites where the river bed is predominantly muddy or sandy and lacking suitably sized stones, samples can be taken from bamboo sticks, aquatic plants, and artificial materials.

2. At each site, ten samples are collected at about 10 m intervals. A sample is collected from a stone if this is coated with a thin brownish film or has a slippery feel. These characteristics are often indicative of the presence of abundant benthic diatoms. Where there were no suitable stones, the nearest hard substratum can be sampled instead.

3. To sample the diatoms, a plastic sheet with a 10 cm^2 square cut-out is placed on the upper surface of the stone or other substratum, and the benthic diatoms are brushed and washed off into a plastic bowl until the cut-out area is completely clear. Each sample is transferred to a plastic container and labelled with the site name, a location code, the sampling date, and sample-replicate number. The collector's name and substratum type are also noted. Samples are preserved with Lugol's solution.

Laboratory methods

1. In the laboratory, the samples are cleaned by digestion in concentrated acid, and then centrifuged at 3,500 rpm for 15 minutes. The diatom cells (which form the brown layer between the supernatant and solid particles) are siphoned into an 18-cm core tube.

2. Strong acid (H_2SO_4, HCl or HNO_3) is added and the tubes are heated in a boiler (70 – 80ºC) for 30-45 minutes. The samples are then rinsed 4 - 5 times with de-ionized water. Distilled water is added to give a final volume of 1 mL.

3. A drop (0.02 mL) of each sample is placed on a microscope slide and dried. A mounting agent such as Naphrax or Durax is added to make a permanent slide for diatom identification and counting.

4. Identifications are made using a compound microscope, and are based on frustule type, size, special characteristics, and structure, as described and illustrated in textbooks, monographs and other publications on tropical and temperate diatoms (see Foged, 1971, 1975, 1976; Krammer & Lange-Bertalot, 1986, 1988, 1991a, 1991b; Pfister, 1992). In many cases identification to species-level is not possible and presumptive species are designated by numbers (e.g. Navicula sp.1). This designation must be applied to that particular morphological type over all the years of the study.

5. The total count of cells on the slide (i.e. the number in the 0.02 mL drop) is used to estimate total number of individuals per sample. The number of cells counted, when multiplied by 5 gives the number per cm^2. The average richness is the number of taxa per 0.2 cm^2 sampled.

6. Richness, abundance and ATSPT scores are always reported per sample (0.02 cm^2).

Zooplankton

The objective in studying the zooplankton is to describe the characteristics of the zooplankton community in quantitative terms. Zooplankton provide a reflection of the biological environment and chemistry of the water column whereas the other indicators used tend to reflect the influences of water chemistry and substrate characteristics.

Field Methods

1. Three sets of samples are collected at each site. One sample is taken near the left river bank, at a distance of about 4 – 5 m from the water's edge. A second sample is taken at a similar distance from the right bank, and the third sample is taken in the middle of the river. The samples are taken at least 1 m from any potential contaminants such as debris and aquatic plants, and at least 2 m from vertical banks. At sites where the water current

is too fast to sample in the exact mid-stream, samples are collected closer to the left or the right bank, but not as close to the bank as where the sets of near-bank samples are taken.

2. Before sampling at each site, the sampling equipment (a net, bucket, and plastic jar) is washed to remove any organisms and other matter left from the previous site. Quantitative samples are collected at a depth of 0 - 0.5 m using a bucket with a volume of 10 L.

3. The 10 L of river water collected are slowly filtered through a plankton net (with a mesh size of 20 μm) in order to avoid any overflow. Water is splashed on the outside of the net to wash down any zooplankton adhering to the inner surfaces of the net.

4. When only about 150 mL of water remains in the net, the water (which contains the zooplankton) is transferred to a 250 mL plastic jar. The sample is immediately fixed by adding about 75 mL of 10% formaldehyde to give a final concentration of 4 - 5% formaldehyde. The sample jars are labelled with the site name, site code, sampling position (left bank, middle, right bank), sampling date, and the sample number.

Laboratory methods

1. In the laboratory, any large particles of debris are removed from the samples with forceps. The samples are shaken to remove any attached zooplankton, and each is filtered through a net with a mesh size of 10 μm, rinsed with distilled water, then allowed to settle to the bottom of a graduated cylinder and left for one hour. Any excess water is poured off until about 50 mL of water and the settled material (which contains the zooplankton) remain.

2. This 50 mL together with the settled material is transferred to a Petri dish and examined under a stereomicroscope at a magnification of 40x to identify the larger species of zooplankton (> 50 μm in diameter). The smaller species and details of larger species are examined using a compound microscope at a magnification of 100 – 400x. All individuals collected are counted and identified to the lowest level of taxonomy possible, generally species. Identification is based on morphology as described in various references (e.g. Dang *et al.*, 1980; Eiji, 1993). After analysis, samples are returned to the bottles and preserved.

3. Richness, abundance and ATSPT scores are always reported per sample (10 L).

Littoral macroinvertebrates

The objective of studying the littoral macroinvertebrates is to describe, in quantative terms, the characteristics of the macroinvertebrate community living in the shallow near-shore areas.

Field methods

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

2. At each site, sweep sampling methods are used. A D-frame net with 30 cm x 20 cm opening and mesh size of 475 μm is used. Sweep samples are taken along the shore at about 20 m intervals. To obtain each sweep sample, the collector stands in the river about 1.5 m from the water's edge and sweeps the net towards the bank, near the substrate surface. Ten sweeps make up a sample. Each sweep is done for about 1 m at right angles to the bank, in water no deeper 1.5 m and should not overlap the previous sweep. Ten sweep samples are taken per site.

3. After the sample collection, the net contents are washed to the bottom of the net by splashing the outside with water. The net is then inverted and its contents emptied into a metal sorting tray, with any material adhering to the net being washed off with clean water. Invertebrates are picked from the tray with forceps and placed in a jar of 70% ethanol. Samples with a small number of individuals are kept in 30 mL jars while large samples are kept in 150 mL jars. During the picking process, the tray is shaken from time to time to redistribute the contents, and tilted occasionally to look for animals adhering to it. Sorting proceeds by working back and forth across the tray until no more animals are found.

4. The sample jars are labelled with the site name, site location code, date, and sample replicate number. The collector's name, the sampling site, and replicate characteristics (including substrate types sampled) are recorded in a field notebook.

Laboratory methods

1. In the laboratory, the samples are identified using a stereomicroscope with a 2 – 4x objective lens and a 10x eyepiece. Identification is done to the lowest taxonomic level

that could be applied accurately, which is usually to the genus level. The references used for identification include Sangpradub and Boonsoong (2006), Nguyen *et al.* (2000), Morse *et al.* (1994) and Merritt and Cummins (1996).

2. Specimens are divided into orders, and kept in separate jars labelled by site.

3. Richness, abundance and ATSPT scores are always reported per sample (10 sweeps or approximately 3 m^2 of substrate surface).

Benthic macroinvertebrates

The objectives of the benthic macroinvertebrates study are to describe, in quantative terms, the characteristics of the macroinvertebrates in the substrata in deeper waters away from the littoral zone of the river.

Field methods

1. Five sample locations in the right, middle, and left parts of the river are selected at each site. At some sites, it is impossible to take samples from the middle of the river because of the presence of hard bed material (which the grab sampler cannot penetrate) or fast currents. Also, the middle portion of those sites where the river is narrower than 30 m cannot be sampled.

2. Prior to sampling, all the equipment to be used is thoroughly cleaned to remove any material left from the previous sampling site. At each sampling location, four sub-samples are taken with a Petersen grab sampler and composited into a single sample which covers a total area of 0.1 m^2. Grab contents are discarded if the grab does not close properly because material such as wood, bamboo, large water-plants, or stones jammed the grab's jaws. In these cases the sample is retaken.

3. Each sample is washed through a sieve (0.3 mm mesh) with care taken to ensure that any macroinvertebrates do not escape over the sides of the sieve.

4. The contents of the sieve are then placed on a white sorting tray and the materials (including the benthic macroinvertebrates) are dispersed in water. All the animals in the tray are picked out with forceps and pipettes, placed in jars, and fixed with 10% formaldehyde at a final concentration of 5%. Samples taken by less experienced sorters are checked by an experienced sorter.

5. The sample jar is labelled with the site name, location code, date, position within the river, and sample replicate number. The sampling location conditions, collector's name and sorter's name are recorded on a field sheet. Sometimes, samples can not be sorted at

a site because the boat is too unsteady, a very large number of animals are collected, there is insufficient time, or because the presence of lumps of clay cause continual clouding of the samples. In these cases, the entire sample is preserved and sorted in the laboratory.

Laboratory methods

1. All individuals collected are identified and counted using a compound microscope (with magnifications of 40 – 1200x) or a dissecting microscope (16 – 56x). Oligochaeta, Gastropoda, Bivalvia, and Crustacea are generally identified to species level. Insects are usually identified only to genus level. The references used for identification include Sangpradub and Boonsoong (2006), Nguyen *et al.* (2000), Morse *et al.* (1994), Merritt and Cummins (1996), Fernando and Cheng(1963), and Lehmkuhl (1979).

2. Richness, abundance and ATSPT scores are always reported per sample (0.1 m^2).

2.3 Calculation of biometric indicators

The biometric indicators calculated for all sites are: abundance (the number of individual organisms collected per sample or unit area or volume), average richness (the mean number of taxa counted in a sample), and the Average Tolerance Score per Taxon (ATSPT) for each site. 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.

Calculation of abundance

Abundance 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. Abundance can be measured as the number of individuals per unit area, volume or sample.

Calculation of average richness

Average richness refers to the mean number of taxa (types) of plants or animals belonging to a particular indicator group (e.g. diatoms, zooplankton) counted in a sample.

Calculation of ATSPT

A tolerance value was calculated for each taxon collected during the baseline studies conducted in 2004, 2005, 2006 and 2007. Tolerance values for any new taxa collected in 2008 are determined from the average Site Disturbance Scores (SDS) at the sites where these new taxa are found. Tolerance values are derived by assessing the relationship between the presence or absence of species in samples from each study site, and the value of an independently measured SDS for each site. The method for determining the SDS is described in the environmental variables section.

The tolerance of each species (or higher taxon where identification to species is not possible) is calculated as the average SDS for all sites at which that species occurs weighted by the number of samples per site in which the species is recorded. The tolerance values are then re-scaled so that they range from 0 to 100, where 0 represents low tolerance and 100 represents high tolerance to human-generated stress such as water pollution.

The Average Tolerance Score per Taxon (ATSPT) is then calculated for each sample collected. ATSPT is the average tolerance of all taxa recorded in a sample. It is calculated without regard to their abundances. An example of the calculation is shown on page 17 of the MRC Technical Paper No. 22 (Vongsombath et al., 2009a).

2.4 Evaluation of sites

Designation of reference sites

Reference sites provide a ‘baseline’ from which the other sites can be measured. Furthers details on the reference sites can be found on page 15 of the MRC Technical Paper No.20 (MRC, 2008). These were chosen from the 51 sites surveyed during 2004 - 2007 and defined by the following criteria:

1. The pH of the site at the time of biological sampling was between 6.5 and than 8.5.

2. The electrical conductivity at the time of biological sampling was less than 70 mS/m.

3. The dissolved oxygen concentration at the time of biological sampling was greater than 5 mg/L.

4. The average SDS was between 1 and 1.67 on a scale of 1 to 3, that is, in the lowest one-third of possible scores. A typical site with a score between 1 and 1.67 might have low-level rural development, such as low-density village activities, but not major urbanisation, intensive agriculture or waste disposal.

5. There was no major dam or city within 20 km upstream of the site, and flow at the site was not affected by inter-basin water transfers. Downstream development was also considered where a site had upstream flow because of tidal influences.

Using biological indicators to evaluate sites

Until recently, physical and chemical information were often the only basis for monitoring the environmental quality of rivers and lakes. Today, with the widespread implementation of biological monitoring programmes, physical and chemical data are complemented with biological information.

Three types of indicators of the health of the Mekong aquatic ecosystem are calculated for each of the four groups of organisms (benthic diatoms, zooplankton, littoral macroinvertebrates and benthic macroinvertebrates) included in the biomonitoring programme. The indicators are abundance, average richness, and ATSPT (the Average Tolerance Score per Taxon) for each of the four groups. A healthy ecosystem is indicated by high abundance, high average richness, or a low ATSPT (signifying the presence of pollution-sensitive species).

Each indicator is calculated for individual samples of each group of organisms collected during the site examination. The collection of multiple samples per site enables the assessment of the within-site variability of the indicators. It also allows for statistical testing of the significance of differences within and between the same sites over multiple years.

Guidelines for site-average values of each indicator are set according to the range of site-average values obtained at the reference sites. For indicators where low values indicate harm to the ecosystem (abundance and average richness) the guideline was set at the 10th percentile of reference site values (the value that is lower than 90% of all reference values). For the indicator where a high value indicates harm to the ecosystem (tolerance) the guideline was set at the 90th percentile of reference site values (the value that is higher than 90% of all reference values). These percentiles are commonly used in biomonitoring programmes in other parts of the world. Interim guidelines are listed in Table 2.3.

Table 2.3 *Guidelines for biological indicators of ecosystem health based on 2004 - 2007 baseline studies*

Biological metrics	Biological indicator groups	Reference site values		Guideline of healthy ecosystem
		10th percentile	90th percentile	
Abundance (mean number of individual organisms per sample).	Diatoms	136.22	376.34	Greater than 136.22
	Zooplankton	22.33	174.07	Greater than 22.33
	Littoral macroinvertebrates	46.68	328.56	Greater than 46.68
	Benthic macroinvertebrates	5.37	56.34	Greater than 5.37
Average richness (mean number of taxa per sample).	Diatoms	6.54	11.78	Greater than 6.54
	Zooplankton	9.80	20.20	Greater than 9.80
	Littoral macroinvertebrates	5.37	18.48	Greater than 5.37
	Benthic macroinvertebrates	1.87	7.88	Greater than 1.87
Average tolerance Score per Taxon (ATSPT).	Diatoms	30.85	38.38	Less than 38.38
	Zooplankton	34.83	41.80	Less than 41.80
	Littoral macroinvertebrates	27.80	33.58	Less than 33.58
	Benthic macroinvertebrates	31.57	37.74	Less than 37.74

Four biological groups: benthic diatoms, zooplankton, littoral macroinvertebrates and benthic macroinvertebrates were selected for the studies. Three biological metrics namely abundance, average richness and the Average Tolerance Score per Taxon (ATSPT) were measured for each of the biological groups. Thus a total of twelve biological indicators were used to evaluate sites. The sites were classified as one of four groupings:

- Class A (Excellent): 10 - 12 of the 12 indicators meet the guidelines. The biodiversity and ecological capacity to support fish and other freshwater functions are similar to those at the reference sites defined in the 2004 – 2007 surveys. These reference sites provide a 'baseline' against which other sites can be measured.

- Classes B (Good) 7 - 9 of the 12 indicators meet the guidelines. The biodiversity and ecological capacity are slightly less than that at the reference sites. Human activities may have caused some disturbance.

- Classes C (Moderate) 4 - 6 of the 12 indicators meet the guidelines. The biodiversity and ecological capacity are markedly less than that at the reference sites. Disturbance resulting from human activities is present.

- Class D (Poor) 0 - 3 of the 12 indicators meet the guidelines. The biodiversity and ecological capacity are significantly less than that at the reference sites. Various disturbances from human activities are likely to be present.

In 2008, poor sample preservation resulted in the loss of zooplankton data from Cambodia, so the rating criteria for the assessment of the Cambodian sites were: Class A where 7 – 9 of the nine indicators met the guidelines; Class Class B where 5 – 6 of the nine indicators met the guidelines; Class C where 3 – 4 of the nine indicators met the guidelines; and Class D where 0 – 2 of the nine indicators met the guidelines.

3. Results and discussion

3.1 Environmental variables

Cambodia

There was a broad range of the averages of the environmental variables across the eight study sites examined in Cambodia (Table 3.1). Altitude varied from 3 to 134 m above sea level. River width varied from 130 to 1,310 m. The site with largest river width is CKT on the Mekong mainstream, at Kampi Village, Sam Bok Commune, Kratie District, Kratie and the narrowest is CSK where the Sangke River enters the Tonle Sap Great Lake, Battabang Province.

Water temperature ranged from 22.3°C in one high-altitude site, CSP - Sre Pok River, to 30.7°C in lower-altitude sites such as CKT, with an average of 28.8°C. As expected, temperatures tended to be lower at the higher altitudes, although there was considerable variation.

Concentrations of dissolved oxygen were generally high, ranging from 4.9 to 8.14 mg/L with an average of 6.79 mg/L. A low DO concentration was found at CSK on the mouth of the Sangke River, which flows through many residential areas before flowing into the Tonle Sap Great Lake. At most sites, the water was slightly alkaline, with pH varying between 6.79 and 8.29, with an average of 7.45. EC was generally low, varying from 3.57 to 120.93 mS/m with an average of 24.32 mS/m. Water transparency (Secchi depth) was also variable, and ranged from 0.39 to 1.54 m with an average of 1.09 m.

The site disturbance score in Cambodia ranged from 1.1 to 2.0. The highest human disturbance score was assigned to CSK, where the lowest DO concentration and Secchi depth were also found.

Lao PDR

There was a broad range of values of the environmental variables across the eight widely dispersed study sites in Lao PDR (Table 4.1). For example, altitude varied from 72 m above sea level at LKL to 410 m at LMX. Channel width varied from being as narrow as 80 m at LBF to as wide as 1,240 m at LDN. Water transparency (Secchi depth) ranged from 0.19 m at LPB and 0.2 m at LMX to 1.4 m at LDN. The average water transparency of all sites was 0.77 m (with a standard deviation of ±0.46 m). Turbidity was generally higher at sites in the main channel than at sites in the tributaries, and downstream sites. Turbidity was especially high at LMX where the

site sampled was downstream from the Chinese border, and at LPB where the site sampled was affected by upstream gravel excavation.

Water temperature varied slightly from site to site, with an average of 26.74°C (±2.45°C). The lowest value of 23.0°C was recorded at LMX, and the highest value of 29.3°C at LKL. Dissolved oxygen (DO) concentrations were generally high compared to those typically reported for tropical waters, with an average of 7.85 mg/L (±0.57 mg/L).

Water was slightly alkaline at most of the sites, with pH varying between 7.2 and 8.5 and averaging 7.76 (±0.45). Electrical conductivity varied from 7.1 to 33.0 mS/m, with an average of 24.0 mS/m (±9.3). Higher conductivity was found at sites LBH; LMX and LBF with values of 33.0; 31.0 and 30.1 mS/m, respectively.

Thailand

There was a broad range of values of the environmental variables across the widely dispersed sites examined in Thailand (Table 3.1). The water temperature varied widely from site to site, ranging from 23.0°C to 26.3°C. Lower temperatures were recorded at the upstream sites with the lowest values of 23.0°C and 24.0°C being recorded at TCS and TKO respectively. Higher temperatures were recorded at TSM, with the highest value of 26.3°C being recorded in the Mekong River at Songkram Mountain. The dissolved oxygen (DO) concentrations were generally high compared to those typically reported for tropical waters, with an average of 7.3 – 8.3 mg/L. The highest DO value of 8.3 mg/L was recorded in the Mekong River at TSM. Lower DO values were found at sites where human activities were present, such as at TMU where the value was 7.3 mg/L. The water pH was in the neutral range at most of the sites, with pH varying between 6.6 and 7.4. The highest pH value of 7.41 was recorded in the Mekong River at TSM and the lowest of 6.6 at TNK. The electrical conductivity varied from 17.1 to 28.5 mS/m, with an average of 22.2 mS/m. The highest conductivity was found at TSM and the lowest was found at TUN in the Mun River.

The values of the environmental variables at the sampling sites were mostly within the normal ranges expected for surface waters in this region. However, at some sites where the surrounding land is saline such as TSM, conductivity was slightly outside the normal range. 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, in comparison to the Water Quality Standards of Thailand (MRC, 2005; PCD, 2004) could be classified as Category 2 - 3. The DO values were on the high side, even at those sites showing evidence of human disturbance from villages, agriculture, or dam construction; all sites had DO values higher than or very close to 6 mg/L, falling within Class 2 (very clean) of Thailand's Water Quality Standards. However, all measurements were made during the daytime, and some values may reflect the influence of factors such as photosynthesis that could affect pH and DO. The pH and DO in TSM was higher than those at other sites. This area may be more suitable for the growth of autotrophic organisms such as river weed and algae.

Viet Nam

There was a broad range of values of most of the environmental variables across the eight study sites in Viet Nam. Altitude varied from 5 m above sea level at VDP to 10 m above sea level VCT. The channel width varied from being as narrow as 250 m at VKB to as wide as 2,000 m at VCL, and the depth varied from 5 m at VCT to 20 m at VTR.

Water transparency (Secchi depth) ranged from 22 cm at the right hand river bank at VCT to 85 cm at the mid-river sampling area of VTP. It also varied from site to site, with an average of 54.6 cm (±18.4 cm).

Water temperature varied slightly from site to site, from 28.3°C to 30.2°C, with an average of 29.1°C (±0.4°C). Dissolved oxygen (DO) concentrations ranged from 5.00 mg/L to 8.25 mg/L and were generally high compared to those typically reported for tropical waters, with an average of 6.6 mg/L (±0.9 mg/L). The highest DO value of 8.25 mg/L was at the site on the left of the river at VTP, and lower values were found at sites with the presence of human activities, such as the left hand river site at VVL.

At most sites, the water was slightly alkaline with pH varying between 7.14 and 8.37 and averaging 7.96 (±0.27).

Electrical conductivity varied from 13.8 mS/m to 19.0 mS/m, with an average of 17.8 mS/m (±1.65 mS/m). The highest conductivity of 19.0 mS/m was found in the mid-river area of VCL with the lowest of 13.81 mS/m. being found at VKB,

Conductivity was within the normal range and yielded much the same results as those found in the previous studies. The pH, DO, and temperature data were also within the normal ranges for aquatic ecosystems according to the standards for surface water quality set by Viet Nam. Dissolved oxygen values were high, even at those sites showing evidence of human disturbance from villages, agriculture, or dam construction. Most of the sites had DO values higher than or very close to 6 mg/L, the concentration described as being necessary for biodiversity conservation.

The highest turbidity and lowest Secchi disk depths at all of sites were comparable those found in 2006. Most probably, turbidity was caused by the sediments released from the upstream by agriculture, bridge construction, transport activities, river traffic, oil storage, washing and bathing activities, sewage treatment, soil erosion, sand excavation, and other factors.

The environmental variables at the sampling sites were mostly within the normal ranges expected for surface waters in this region.

Table 3.1 *Environmental variables at the 32 sites sampled in 2008.*

Site Code	Altitude (m)	River width (m)	Depth (m)	Secchi depth (m)	Temperature (°C)	DO (mg/L)	pH	EC (mS/m)	SDS
CKT	12	1,310	8.0	1.20	30.7	8.14	7.21	15.05	1.1
CRM	58	430	8.0	1.54	27.9	6.82	7.76	5.57	1.4
CSJ	50	640	4.0	1.26	30.2	6.77	6.79	3.62	1.3
CKM	48	390	2.0	1.19	30.5	7.76	8.29	18.35	1.2
CSP	100	230	3.0	1.11	22.3	6.45	7.28	3.57	1.1
CSU	134	175	14.0	1.29	28.5	7.28	7.45	5.38	1.8
CKL	3	300	8.0	0.76	30.1	6.27	7.51	120.93	1.7
CSK	5	130	2.0	0.39	30.0	4.90	7.29	22.05	2.0
LDN	82	1,240	2.9	1.40	28.6	8.50	8.50	22.90	1.6
LSD	101	130	1.8	0.70	28.7	7.42	7.80	12.90	1.8
LKL	72	200	2.2	0.85	29.3	7.26	7.20	71.00	1.8
LBH	111	150	2.0	1.20	28.3	7.70	7.90	32.90	1.8
LBF	134	80	2.6	1.15	27.1	7.54	8.10	30.10	1.9
LVT	178	790	1.8	0.50	23.9	8.73	7.80	28.30	1.8
LMX	410	100	1.1	0.20	23.0	7.40	7.15	31.00	2.1
LPB	407	195	2.5	0.20	25.0	8.30	7.75	26.50	1.6
TNP	133	800	9.2	0.59	25.0	8.20	7.39	23.00	1.7
TSM	136	350	1.8	0.52	26.3	8.30	7.41	28.50	1.6
TNK	130	19	3.0	0.54	24.8	7.60	6.59	21.20	1.8
TMU	96	248	6.5	0.75	25.3	7.30	6.84	18.30	1.6
TKC	88	1,200	11.6	0.80	25.8	8.20	7.35	19.90	1.6
TUN	93	285	4.0	0.34	25.1	8.20	7.02	17.10	1.7
TCS	353	550	10.5	0.17	23.0	7.60	7.27	24.70	1.3
TKO	391	100	1.4	0.40	24.0	7.20	6.97	7.50	1.5
VCT	10	1,900	9.7	0.26	28.5	5.70	8.24	17.90	2.1
VLX	7	800	10.3	0.42	28.8	7.20	7.58	17.80	2.2
VDP	5	900	6.0	0.45	29.0	7.60		18.60	2.2
VKB	6	250	1.5	0.73	29.9	7.60	8.27	13.80	2.1
VTP	7	1,500	7.7	0.82	29.4	7.00	7.94	18.40	1.9
VTT	6	400	4.0	0.68	29.0	6.30	8.25	18.50	2.1
VCL	7	2,000	6.0	0.52	29.3	6.30	7.86	19.00	2.2
VVL	8	1,200	11.5	0.49	29.1	5.20	7.93	183.80	2.1

3.2 Benthic diatoms

Cambodia

In total, 36,435 diatoms comprising 64 species and varieties were identified from 80 algal samples collected at eight sites in Cambodia in 2008.

Abundance

The average number of diatoms ranged from 64 - 916 cells, with an average of 320 individuals per sample (0.2 cm^2). The greatest abundance was found at the Se San River site (CSJ) and the lowest the Bassac River site (CKL) where the water surface was completely covered by water hyacinths (Table 3.2).

Average richness

Average richness per site ranged from 3 - 10 taxa. The highest average richness of 10 and 9 taxa occurred at CKM and CSJ in the Se Kong and Se San Rivers respectively. The CKL site was covered by water hyacinths. This may explain the low abundance and average richness of this site.

ATSPT

The average ATSPT per site ranged from 33 - 41, with the highest value found at CSK and the lowest at both CMR and CSJ (Table 3.2). The ATSPT values in the 2008 survey were quite similar to those values found in previous years, except at CKL, where the ATSPT dropped from 44 in the 2006 survey to 34 in the 2008 survey.

Lao PDR

From a total of 18,025 diatoms collected in Lao PDR, 71 species were identified from 80 samples collected at the eight sites in 2008.

Abundance

The average number of diatoms per sample ranged from 25 - 568 cells (Table 3.2). A comparison of the previous years' samples with those of 2008 showed a high variability through the years. For example, in 2007 the abundance of 1,338 cells found at LVT decreased 3.6 fold to 373 cells found in the 2008 sample. There was also a decrease at LSD, where the abundance decreased by a factor of 2 from 108 cells found in 2007 to 58 individuals found in the 2008 sample. This decrease in abundance may have been the result of a lack of suitable substrata and/or difficulties in sample collections at LVT and, LSD.

Average richness

The total number of taxa per site ranged from 2 - 23 taxa. Average richness per sample ranged from 2 - 6 species (Table 3.2). The lowest average richness was found at both LSD and LBF, and highest at LVT. The average richness per site in 2008 samples showed a decrease of 2 - 8 taxa per site from the previous years. LMX suffered the greatest decrease with the loss of 8 taxa; LSD and LPB both decreased by 7 taxa; LSD and LBF decreased by 6 and 5 taxa respectively. Other sites decreased by 2 - 3 taxa.

ATSPT

The Average Tolerance Score per Taxon (ATSPT) of diatom samples taken in 2008 ranged from 35 - 44, with the highest value being found at LMX and the lowest at LDN (Table 3.2). ATSPT values within sites and through the years showed little change, showing consistently low values of between 35 and 44.

Thailand

The eight sites sampled in Thailand in 2008 yielded a total of 72 taxa of benthic diatoms out of the 20,502 individuals in the samples. Twenty two previously uncollected taxa were found. The most common taxa were in the order Naviculales (26 taxa) and order Cymbellales (15 taxa). Cymbella turgidula, Gomphonema lagenula, and Synedra ulna were present in the greatest abundance and had the widest distribution being found at all the sites sampled. In 2008, the total richness per site in Thailand ranged from 15 - 38 taxa.

Abundance

The average density of diatoms ranged from 45 - 366 cells (Table 3.2). The greatest abundance was found at the Mekong River site of TCS while the lowest was found at the Mun River site (TUN) where substratum of mud and sand was unsuitable and the turbidity was the highest.

Average richness

The highest average richness of 12 taxa was found at both TCS and TKC, while 11 taxa were found at TSM. The lowest richness was found at those Mekong River sites with sandy and muddy substrata, such as the sites of TNP (6 taxa) and TUN (7 taxa).

ATSPT

The Average Tolerance Score per Taxon (ATSPT) of benthic diatom samples taken in 2008 showed little variation, and ranged from 36 - 39 (Table 3.2). The highest value was found at TMU and the lowest at both TCS and TSM. The ATSPT values for sites in the 2008 study are only slightly different to those found in the previous investigations.

Viet Nam

In 2008, a total of 80 samples of algae containing 252,936 individuals were collected from the eight sampling sites. These samples yielded a total of 125 taxa of benthic diatoms. Nitzschia filiformisi, Cymbella affinis, and Navicula sp. were the most widely distributed with each occurring at all the sites.

Abundance

The average density of diatoms ranged from 213 - 14,940 cells per sample. The greatest abundance occurred at VVL, while the lowest was found at VLX.

Average richness

The average richness per site ranged from 11 - 16 taxa (Table 3.2). The highest average richness occurred at VTT, while the lowest was found in those lower Mekong River sites that had sandy and muddy substrata, such as VCT.

ATSPT

ATSPT ranged from 49 - 52, with the highest at VVL where the greatest abundance of 14,925 individuals/sample was also found. In comparison to other countries in the region, the ATSPT of benthic diatoms is the highest in Viet Nam. The average ATSPT in Viet Nam was 49, while those in Cambodia, Lao PDR and Thailand were 33, 35, and 36, respectively.

Table 3.2 *Abundance, average richness and ATSPT of benthic diatom recorded at sites sampled during 2004-2008*

Site code	Abundance					Average richness					ATSPT				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
CKT	318		134		307	12		8		6	34		39		36
CMR		206	217	58	439		6	10	7	6		33	36	37	33
CSJ		214	314	655	916		7	11	6	9		33	36	34	33
CKM		191	250	71	820		9	11	7	10		33	37	34	34
CSP	144	232	308	532	219	8	10	9	8	6	36	30	36	35	36
CSU		269	140	287	412		9	6	5	8		36	39	38	37
CKL			311		64			8		3			44		34
CSK			107		469			5		5			44		41
LDN				266	213				9	3				34	35
LSD				108	58				8	2				38	40
LKL		219		63	305		7		7	5		35		40	38
LBH				257	197				8	6				36	39
LBF				46	75				6	2				36	36
LVT	563			1,338	373	13			8	6	41			39	40
LMX		133			82		10			3		39			45
LPB	388	305			568	11	12			5	37	38			41
TNP					219					6					38
TSM				128	252				5	11				39	36
TNK				101	300				7	8				48	39
TMU	346				272	9				6	40				39
TKC					279					12					38
TUN					45					7					37
TCS					366					12					37
TKO	372	229			318	21	10			8	41	40			37
VCT			72		362			5		11			48		50
VLX			317		213			6		12			51		50
VDP					4,936					14					50
VKB					510					12					51
VTP					1,384					13					49
VTT					2,362					16					51
VCL			180		603			6		13			49		51
VVL					14,925					15					52

3.3 Zooplankton

Lao PDR

The eight sites in Lao PDR recorded a total of 9,080 individual specimens of zooplankton and larvae. These comprised 101 taxa within 28 families. The five main zooplankton groups were: Crustacea, Eurotatorea, Lobosea, Fiosea, Phytomastigophora and larvae. The most prolific were Eurotatorea of which there were 59 taxa in 15 families, while Filosea and the larvae were of only one family. The larval forms were present in the highest numbers.

Abundance

In 2008, abundance varied widely across the eight sites, with an average of 17 - 1,707 individuals per 10L sample (Table 3.3). The highest average abundance was found at LDN, while the lowest averages of 17 and 19 individuals/sample were found at LVT and LBH respectively. The dominant taxa were *Copepoda sp* (larval stages) and *Ceratium spp*. These characteristically occur in sites where the river is wide and deep with slow water currents. However in four sites, the average abundance in 2008 was 2 – 28 times less than that found in 2007. The decrease was even greater in comparison to that found in 2005, with 28, 10, 6 and 2 fold decreases found in LBH, LVT, LSD and LMX respectively. These may have been caused by stronger currents and shallower water than in earlier years. At the four other sites, abundance increased 2 – 10 fold. For example, in 2008 the greatest number of individuals/sample (219) were found at LKL while 2007 and 2005 only 17 and 22 individuals/sample had been found. At LDN, LPB, and LMX the numbers also increased 7, 7 and 2 fold respectively. These were increases in only a few common taxa and Copepoda larvae, which are widely distributed.

Average richness

The total number of taxa per site ranged from 11 - 61 taxa, with the lowest number found at LMX and the highest at LDN. The average richness per site ranged from 6 - 40 taxa. The lowest average richness was at LBH, and the highest at LDN. (Table 4.3). The taxa of the Copepod group and the Peridiniidae family predominated and were widely distributed.

In almost all of the 2008 sites, there was a decreasing trend in the average richness in comparison to samples taken in previous years. For example, at six sites richness per site decreased by 2 – 10 taxa. At LSD, LBH and LMX richness reduced by 10, 10 and 8 taxa, respectively, and at LPB, LVT and LKL by 4, 3 and 2 taxa respectively. In 2008, only the two sites of LDN and LBF showed any increase in average richness. These decreases in average richness probably resulted from the same causes as those given for the decreases in abundance.

ATSPT

The ATSPT for zooplankton ranged from 29 - 42 (Table 3.3). The lowest occurred at LMX. All the other seven sites showed a narrow range varying from 38 - 42.

Thailand

The eight sites sampled in 2008 yielded a total of 3,191 individual specimens of 24 taxa of zooplankton. Eighteen of which belonged to the order of Ploima and four to the order of Cladocera. In 2008, 12 taxa were found for the first time. Overall *Keratella cochlearis* and *Polyarthra vulgaris* were present in the greatest number and were the most widely distributed, occurring at all the sites sampled.

Abundance

In 2008, the average abundance of zooplankton ranged from 15 - 328 individuals at the sites examined. The greatest abundance occurred at TSM, while the lowest was found in the Mekong River at the Chiang San site (TCS). The abundances in the 2008 samples were lower than those found in previous samples at TMU and TKC.

Average richness

In 2008, average richness per site ranged from 3 - 11 taxa (Table 3.3). The highest average richness of 11 and 8 taxa occurred at TMU and TSM respectively, while the lowest of 3 taxa were found both in the north in the tributary at TKO and in the Mekong River at TCS. The average zooplankton richness was significantly lower than that found in the previous studies.

ATSPT

The Average Tolerance Score per Taxon (ATSPT) of zooplankton samples taken in 2008 ranged from 38 - 40 (Table 3.3). There was little variation in ATSPT values between the sites. This was similar to the previous years' ATSPT values in Thailand which had also shown little variation ranging from 40 - 43. In 2008, there was a decrease in ATSPT from the 2005 levels in some sites such as TKO and TNK.

Viet Nam

A total of 3,904 individual specimens of zooplankton was recorded at the eight sites in Viet Nam. These comprised 32 taxa belonging to 16 families and 5 larval stages. There were four main zooplankton groups: Protozoa, Eurotatorea, Crustaceae (which included Cladocera, Copepoda and Ostracoda) and larval stages. The predominant group with 15 taxa in 10 families was that of Crustaceae accounting for 46.9% of the total zooplankton collected. The second biggest group, accounting for 19.4% of the zooplankton, was Eurotatorea of which there were 12 taxa. The smallest group was that of Protozoa where there was only 1 taxa. This group accounted for 3.1% of the total zooplankton.

Abundance

The average abundance of zooplankton ranged from 7 - 1,115 individuals/sample (Table 3.3). The greatest abundance occurred at VKB. The dominant group was the Crustaceae (Bosminidae, Daphniidae, Moinidae, Cyclopidae and Larvae). The lowest abundance was found at VVL where the dominant groups were Eurotatorea and larvae, while Crustaceae were represented by only a few individuals.

Average richness

In 2008, the total richness per site ranged from 8 - 19 taxa while the average richness ranged from 5 - 13 taxa (Table 3.3). The highest average richness occurred at VKB. Two taxa, *Trichocerca longiseta* (Eurotatorea, Trichocercidae), and *Heterocypris anomala* (Crustaceae, Cyprididae), were present only at VKB. The lowest average richness of 5 taxa was found in all four of the sites of VDP, VTT, VCL, and VVL.

ATSPT

The ATSPT for zooplankton ranged from 47 - 54 (with an average of 50). The sites of VCT and VVL, which have experienced greater impacts had high values of 52 and 54 respectively, while those at VTT and VTP, which have experienced smaller impacts showed the lower value of 47.

Table 3.3 *Abundance, average richness and ATSPT of zooplankton recorded at sites sampled during 2004 - 2008*

Site code	Abundance					Average richness					ATSPT				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
CKT	36		27			15		12			44		37		
CMR		39	24	35			11	9	12			38	39	38	
CSJ		119	62	52			14	20	17			37	38	38	
CKM		78	21	35			14	11	14			39	37	39	
CSP	22	86	70	62		12	13	12	15		41	36	37	42	
CSU		14	176	113			11	32	28			37	40	39	
CKL			844					22					48		
CSK			1,431					34					46		
LDN				194	1,707				21	40				40	41
LSD				1,408	278				26	16				44	40
LKL		22		17	219		14		10	8		35		39	40
LBH				473	19				16	6				41	42
LBF				222	508				17	20				39	41
LVT	24			160	17	9			10	7	37			40	41
LMX		76			47		15			7		40			29
LPB	182	26			231	10	13			9	36	42			38
TNP					60					7					40
TSM				2,586	328				19	8				43	40
TNK				473	200				25	6				43	40
TMU	1,327				77	40				11	43				39
TKC					115					7					39
TUN					300					7					40
TCS					15					3					40
TKO	53	145			27	14	29			3	40	42			38
VCT			55		47			11		7			46		52
VLX			148		39			16		9			45		51
VDP					32					5					47
VKB					1,115					13					50
VTP					16					6					49
VTT					35					5					47
VCL			127		11			15		5			46		49
VVL					7					5					54

3.4 Littoral macroinvertebrates

Cambodia

In 2008, a total of 6,484 individual specimens of littoral macroinvertebrates were collected at the eight sites Cambodia. These specimens comrised 34 taxa.

Abundance

The average abundance per site ranged from 17 - 587 individuals/sample, with the greatest occurring at CMR on the Mekong River, and the lowest at CKL, on the Bassac River at Koh Khel village. With the exception of CKM and CKL where the average abundances were respectively reduced from 136 to 22 and from 163 to 17 individuals, average abundances at all the other sites were higher than those previously recorded.

Average richness

In 2008, the average richness per site ranged from 3 - 6 taxa (Table 3.4) with the greatest numbers of 6 taxa occurring at both CKT and CSJ, while the lowest of 3 taxa being found at both CSP and CKL. However, the average richness values of most of the sites were lower than those of the previous years.

ATSPT

In Cambodia, the ATSPT for littoral macroinvertebrates showed a wide variation from 13 - 38, with an average of 28. The lowest ATSPT was found at CSP and the highest at CKL. At the other sites of CKT, CMR, CSJ, and CSK, the ATSPT ranged from 27 to 31.

Lao PDR

The 13,111 individual specimens collected from the eight sites in Lao PDR contained 92 taxa of littoral macroinvertebrates. In terms of biodiversity, the highest number of taxa were in the insect orders of Ephemeroptera and Trichoptera, and the Molluscs, with 32, 21 and 20 taxa, respectively. Richness in the orders of Hemiptera, Coleoptera, and Diptera was moderate ranging from 13 - 15 taxa. All of these orders were widely distributed with, for

example, *Heterocloeon* sp. (Baetidae, Ephemeroptera) found at all sites, while *Micronecta* sp. (Hemiptera) and *Chironomus* sp. (Diptera) were found at seven sites, and taxa of Decapoda and *Corbicula* sp. (Bivalvia) being found at most sites. Eighty taxa occurred at only a few sites. Some of these widespread groups are characteristic of taxa that typically occur in nutrient-rich conditions.

Abundance

The average number of individuals per site was highly variable, ranging from 55 individuals at LKL to 7,948 at LBF, with an average abundance ranging from 11- 795 individuals/sample (Table 3.4). The greatest abundances occurred at sites with large macroalgae and submerged vegetation, such as LBF. The lowest abundance was at LKL. The high abundance groups were in the orders of Mesogastropoda, Hemiptera, and Ephemeroptera. There were 4,407 individuals of *Hubendickia* sp, 2,236 individuals of *Karelainia* sp (Mesogastropoda), and 2,786 of *Micronecta* sp (Hemiptera). However, the average abundance in five of the eight sites showed a 1 – 4 fold decrease in abundance in comparison to the 2007 samples. For example, there was a 3 - 4 fold decrease in the average abundance at LKL, and at a 4 fold decrease LVT in comparison to the 2007 and 2005 values. These decreases probably resulted from the same causes as those discussed below in terms of the average richness. At some sites (LDN, LSD and LBF) abundance increased. This resulted from increases in only a few groups such as snails and water bugs, probably because in both these groups there are a large number of species which are widely distributed, and are taxa with a moderate to high tolerance to water pollution.

Average richness

The number of taxa collected per site ranged from 11 - 47. The average richness per site ranged from 5 to 15 taxa (Table 3.4). The highest richness occurred at LBF and the lowest at both LKL and LMX.

In general, high values of richness were found at sites with cobbles, gravel, submerged vegetation, and low to moderate human levels of impact. Such sites are the six sites of LVT, LBF, LBH, LSD, LDN and LKL that are in the middle and south of Lao PDR and where the conditions are good in terms of the diversity of taxa. However, in the 2008 samples, the average richness of these sites decreased by 1 – 8 taxa when compared to the 2007 results. This was especially true for LKL, which lost eight taxa. (In 2007, there were 13 taxa but only 5 taxa in 2008.) This site was a 2005 reference site, and rated a B score in the 2007 survey, but in 2008 the average richness was poor. The change may have been caused by bank erosion during the rainy season and by other human activities. At this site, many areas were found to have changed. In particular, there were changes in the direction of the water-flows, and in the accumulation of sand and clay. These changes could have affected many types of organisms previously found in this area.

In the northern sites, such as LPB, the average richness increased from 5 taxa in 2004 and 2005 to 8 taxa in 2008. The environmental conditions appeared to be stable at this site, although on a nearby island there was some sand and gravel excavtion, this appeared to have only small effects on the site.

ATSPT

The ATSPT for littoral macroinvertebrates ranged from 26 - 34 (Table 3.4). The lowest was found at LDN since this site had probably experienced little human impact (the SDS was 1.6), and the conditions provided habitats suitable for littoral macroinvertebrates. Such conditions were the presence of large amounts of floating macroalgae and other aquatic plants. The highest value of 34 was at LMX. In general, in 2008 the range in the ATSPT values at the sites was narrow with values for all of the sites indicating very low levels of pollution tolerance (<35). However, the trend in the ATSPT values has been that of an annual increase, perhaps indicating a change in the environmental health of the water resources.

Thailand

The eight sites sampled in 2008 in Thailand yielded a total of 3,266 specimens of littoral macroinvertebrates belonging to 52 taxa. Ten of these were in the orders of Odonata and Ephemeroptera while 33 were taxa not found in the previous 2004 - 2007 studies. The dominant littoral macroinvertebrates were *Macrobrachium* sp in the order of Decapoda where 704 specimens were found. Oligochaeta, *Baetis* sp. and *Micronecta* sp. were common and found at all the sites sampled.

Abundance

In 2008 , the average abundance ranged from 8 - 107 individuals per site. The highest abundance occurred at TUN, while the lowest abundance was found in the Mekong River at TNP, the Nakornpanom site where the substratum is unsuitable for invertebrates.

Average richness

In 2008, the average richness per site ranged from 5 - 13 taxa (Table 3.4). The highest richness occurred at TKO, while the lowest was found at TCS. Some sites had richness values lower than those found in the previous studies, while, in contrast, richness values increased at other sites, such as TKO, where 13 taxa were found compared to only 5 found in 2004 and 7 in 2005.

ATSPT

The ATSPT of littoral macroinvertebrate samples taken in 2008 ranged from 29 - 34 (Table 3.4), with the highest values found at both TNP and TKN and the lowest of 29 at both TCS and TKO.

Viet Nam

In 2008, a total 9,714 specimens of littoral macrovertebrates belonging to125 taxa were collected at the eight sites (Table 3.4). Mesogastropoda, Decapoda, Oligochaeta, and Veneroida were the predominant orders with 24, 14, 13 and 12 taxa, respectively being found. Diptera, Hemiptera, Decapoda, Mesogastropoda, Oligochaeta, Mytinoida, and Veneroida had the widest distribution, being found at all sites. In contrast, taxa of some small groups (Coleoptera, Ephemeroptera, Hirudinea, and Tricoptera) were found at only two sites. A number of the widespread groups comprised some taxa that typically occur in nutrient-rich conditions. All of the eight sites examined in 2008 had more than 6 taxa and had high abundance values.

Abundance

The average abundance was highly variable, ranging from 7 taxa found in VTP to 546 in VTT. Both the numbers of taxa and the highest abundances occurred at sites with a range of sediment types, alluvium, debris, substrata, macroalgae, and aquatic vegetation, while the lowest abundances occurred at sites such as VTP and VDP with sand, alluvium, and muddy substrates (Table 4.4). In the sites with the highest abundance, such as VTT, VVL, and VCT, taxa of Hemiptera, Mesogastropoda, Diptera, and Veneroida were dominant. These common taxa occurred on sediment substrata, alluvium, debris, macroalgae and aquatic vegetation, and in the water column.

Average richness

The average number of taxa collected per site ranged from 3 - 14, with the highest average richness at sites (such as VLX with 14 taxa, VCL with 13, VVl with 12 and VCT with 11). Mudflats, organic matter, wood, alluvium, dead trees, sand, thin mud, and sediments were present at this sites. In contrast, the lowest richness was at sites (such as VTP with 3 taxa and VTT with 5) with sediment, alluvium, organic fertilizer, and sand (Table 4.4). Taxa of Hemiptera, Mesogastropoda, Diptera and Venenoida were abundant at the richest sites, occurring among sediment, alluvium, debris, sand, dead fish, rubbish, plastic bags, pesticide bottles and abundant aquatic plant growth.

ATSPT

The ATSPT of littoral macroinvertebrates of sweep samples taken in 2008 ranged from 50.2 to 58.1, with the highest value found at VLX and the lowest at VKB (Table 3.4). The average ATSPT value in Viet Nam was higher in 2008 than it had been in the 2006 survey, with an increase from 43 to 54 in 2006 and 2008, respectively.

Table 3.4 *Abundance, average richness and ATSPT of littoral macroinvertebrates recorded at sites sampled during 2004 - 2008*

Site code	Abundance					Average richness					ATSPT				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
CKT	165		97		105	12		11		6	32		30		27
CMR		112	311	311	587		5	10	8	4		34	30	34	27
CSJ		83	46	88	128		13	11	14	6		32	30	32	27
CKM		104	26	33	56		10	9	9	5		32	29	34	29
CSP	301	229	54	136	22	19	20	16	17	3	30	28	27	31	13
CSU		121	179	10	83		15	5	3	4		34	33	34	32
CKL			163		17			11		3			39		38
CSK			92		299			4		5			43		31
LDN				340	369				14	12				33	35
LSD				50	83				11	10				37	39
LKL		48		35	11		9		13	5		31		33	34
LBH				73	35				8	7				36	35
LBF				254	795				16	15				35	37
LVT	25			122	34	6			8	8	34			34	35
LMX		30			24		5			5		36			40
LPB	112	76			23	5	5			8	28	34			35
TNP					8					5					34
TSM				24	52				6	6				38	32
TNK				23	24				6	7				38	34
TMU	50				21	7				6	38				33
TKC					22					6					33
TUN					107					7					33
TCS					21					5					29
TKO	20	52			54	5	7			13	31	34			29
VCT			24		95			4		11			43		55
VLX			30		51			5		14			44		54
VDP					15					7					53
VKB					37					8					52
VTP					7					3					50
VTT					546					5					52
VCL			39		49			7		13			42		58
VVL					173					12					56

3.5 Benthic macroinvertebrates

Cambodia

In 2008, a total of 928 individual specimens belonging to 43 taxa of benthic macroinvertebrates were collected from the eight sites. The total number of taxa per site varied from 8 - 18. The highest value was found at CKT and the lowest at both CSP and CSU. The average richness ranged from 2 to 4 taxa.

Abundance

The average abundance of benthic macroinvertebrates ranged from 4 - 20 individuals/sample (Table 3.5). The highest abundance was found in the Sangke River at CSK. The river flows through residential areas before entering the Tonle Sap Great Lake. The lowest abundance was found in the Se San River at CSJ where the substratum is composed of bedrock and cobbles, clay and mud, sand, debris, and bamboo leaves.

Average richness

In 2008, the average richness per sample ranged from 2 - 4 taxa. The highest average richness occurred at CSK, while the lowest richness values of 2 taxa were found at CSJ, CKM, and CSP in tributaries of the Mekong River.

ATSPT

The ATSPT ranged from 23 - 39. The highest value was at CKL and the lowest at CSP. The ATSPT values in this year's study were lower compared to those of previous studies. The average ATSPT in the 2008 sites was 30 while that of the sites during the 2004 - 2007 survey was 37.

Lao PDR

In 2008, a total of 1,985 individual specimens of benthic macroinvertebrates belonging to 61 taxa were collected from the eight sites. In terms of diversity, the most diverse were snails of which there were 15 taxa, next came 12 taxa of mayflies. The insect orders of Diptera and

Oligochaeta were widely distributed, with individuals of the family Chironomidae being found at all sites, and individuals of the orders of Ephemeroptera, Mesogastropoda, Odonata, Trichoptera and Veneroida being found at most sites. Other groups occurred at only a few sites.

Abundance

The number of individuals per site was highly variable, ranging from 34 individuals at LKL to 747 at LDN. The average density at a site was also highly variable, ranging from 2 - 50 individuals/sample (a square metre). The highest abundances occurred at sites with mud, clay mixed with sand, submerged plants and debris, such as at LDN (with 50 individuals/ sample), while the lowest density occurred at sites with sandy and rocky substrata, such as at LKL with 2 individuals/sample (Table 3.5). The high abundance was the result of the presence of *Chironomus* sp (Diptera) and Oligochaeta. However, there was little change in average abundance between the 2008 samples and the 2007 and 2005 samples. At four sites (LDN, LSD, LKL and LBF) abundance decreased, at two sites (LVT and LP) there were no changes and at another two sites (LBH and LMX) abundance increased. Decreasing abundance may have been caused by changes in substrate types or increased difficulties in taking samples, for example those caused by the large amounts of sand present at LKL and LSD, and the rocky substrate at LDN.

Average richness

Taxon richness varied widely at the eight sites sampled in 2008. Richness ranged from 8 - 26 taxa, with an average richness from 1 to 7 taxa per sample (Table 3.5). The highest richness occurred at sites such as LDN with soft substrata of mud and debris, and some submerged plants, while the lowest richness occurred at sites such as LMX with sandy and rocky substrata. In the sites with the highest richness *Hubendickia* sp (snails) and *Chironomus* sp (Diptera) were dominant. These are common taxa occurring in mixed substrata containing mud, debris, and submerged plants. In general, there was little change in taxa richness in the sites sampled in 2004 – 2008; taxa richness decreased by 1 - 2 taxa in only three sites, in three sites there was no change, and in two sites richness increased by 1 - 2 taxa.

ATSPT

The ATSPT) of the benthic macroinvertebrate samples taken in 2008 showed narrow variation, similar to that of littoral macroinvertebrates, and ranged from 36 - 40 taxa (Table 3.5). The highest values were found at LMX, LBF, LKL and LSD, and the lowest at LDN. No sites ranked in the high or very high stress level. There was little or no change from year to year, except at LKL where ATSPT increased from 35 in 2005, to 37 in 2007, and to 40 in 2008, and

for both LMX and LPB where there was an increase from 33 and 36 in 2005, to 36 and 40 in 2008, respectively.

Thailand

The eight sites sampled in 2008 yielded a total of 3,790 individual specimens of 50 species of benthic macroinvertebrates. Twelve of these were in the order of Diptera and eight in the order of Ephemeroptera. The remaining 36 taxa had not been found in the previous studies of 2004 - 2007. The dominant taxa were *Cryptochironomus* sp. with 962 individuals present. The most commonly distributed species were Oligochaeta and *Bezzia* sp which were found at all the sites.

Abundance

The average abundance of benthic macroinvertebrates ranged from 7 - 79 individuals at the 2008 sites (Table 3.5). The greatest abundances of 79 and 68 individuals were found TNP and TKO respectively. These sites had hard and suitable substrata, composed of cobbles and gravel. The lowest abundances was found at sites such as TMU (7 indivduals) on tributaries of the Mekong River with muddy substrata. Benthic macroinvertebrates were more widely distributed than the previous studies had shown. This was especially true in TKO, a site on a tributary of Kok River, in the main channel site of TSM in the mouth of the Songkram River, and in the Nakornpanom site (TNP).

Average richness

In the 2008 survey, the average richness per sample ranged from 1 - 3 taxa (Table 3.5) with the highest average richness occurring at both TKC and TKO, and the lowest at the lower Mekong River sites with sandy and muddy substrata, such as the sites of TMU and TCS.

ATSPT

In 2008, the ATSPT) of benthic macroinvertebrate samples had a very narrow range, from 26 - 36 (Table 3.5). The highest value was found in TUN and the lowest at TCS. The ATSPT values were lower than those of the previous studies. In general, the ATSPTs in the Thai sites were between 30 and 45.

Viet Nam

In 2008, 13,805 individual specimens of 108 taxa of benthic macroinvertebrates were collected in the eight sites. The predominant taxa, in terms of both density and abundance, were those of the Mollusca phylum, and were found in all the sites. The two lowest richness values were found for the taxa of Arthropoda (including cruscateans) with only one taxon found at each site and the taxa of Annelida-Polychaeta with 3 taxa at each site.

The Oligochaeta was the richest group and were present at each of the sites. They were also the most widely distributed. Taxa of the Tubificidae family were also abundant. Molluscs were also widely distributed, occurring at all sites. The insect species collected at each site were high in richness and widely distributed. Diptera species were especially diverse, with species in the Chironomidae family having highest richness and occurrence. *Cricotopus* sp. and *Chironomus* sp. were found in many sites. Many widespread species, in particular those of the oligochaetes, and of the Tubificidae, are characteristic of nutrient-rich conditions, .

There was a large diversity of Mollusca (snails and mussels) in the lower Mekong River. Mollusca were also abundant and widely distributed. Twenty five species of gastropoda were identified. Species of the families Thiaridae, Stenothyridae, and Viviparidae had the highest richness values.

Abundance

The density of benthic macroinvertebrate at each site was high, with total counts ranging from 18 - 301 individuals/sample (Table 3.5). The densities in the sites VCL (301 individuals/ sample), VCT (115 individuals/sample), VKB (145 individuals/ sample) and VDP (108 individuals/sample) were the highest. At these sites, the substrata are clay, sand, alluvium, mudflats, and dead trees. In contrast, the sites with low abundance such as VTP (18 individuals/ sample), VTT (47 individuals/sample), VVL (60 individuals/sample), and VLX (74 individuals/ sample) had substrata of sand, sediment, clay, alluvium, organic fertilizer, dead fish, rubbish, plastic bags, soil, and mud. In the four sites of VCL, VCT, VKB and VDP with high abundances, the dominant groups were Naididae (Oligochaeta), Stenothyridae, Thiaridae, Viviparidae (Mollusca, Gastropoda); Corbiculidae, Amblemidae (Mollusca, Bivalvia), Palaemonidae (Decapoda), Chironomidae (Diptera) and Corophiidae (Amphipoda). The widespread species were present in the sites with substrata of sand, soil, and roots of vegetable and other organic plant matter. The benthic macroinvertebrates were not evenly distributed with abundances differing between the banks and the middle of the river, and even the different banks of the same river. This was the result of construction and building activities, agriculture, deposits of alluvia, and other factors. In the middle areas of the river, where the river bottom is affected by ship and boat traffic and sand excavation, or there are variations in the river depth, differences in the abundance of benthic macroinvertebrates can result.

The density of benthic macroinvertebrates across the river varied because of differences in deposits of alluvia and the river depth. The banks usually have a higher density of benthic macroinvertebrates than do sampling sites in the middle of the river. Moreover, there is a greater diversity of benthic macroinvertebrate and a greater abundance of aquatic insect taxa at river banks than in the middle of the river. In contrast, the abundance of the bivalve classes and gastropoda in the middle of the river is higher than at river banks.

The composition of benthic macroinvertebrates often differed along the banks as a result of erosion or landslides. If a river bank bottom was sand, soil, and clay then the taxa of mollusca and aquatic insects were abundant. In contrast, if the bank had accumulated alluvia and debris then taxa of the phylum Annelida and larvae of Diptera predominated.

Average Richness

In 2008. the average richness varied widely from 5 - 11 taxa per sample at the eight sites. The highest average richness of 11 taxa occurred at both VLX and VDP, and of 10 taxa at VCL. The lowest richness values were at VTP (5 taxa), VCT (7 taxa), and VKP (8 taxa). In VLX, VDP, and VCL, the sites with the highest richness, taxa in the families of Tubificidae (Oligochaeta), Stenothyiidae and Hydrobiidae (Mollusca, Gastropoda), Corbiculidae and Amblemidae (Mollusca, Bivalvia), and Gomphidae (Insecta, Odonata) and Chironomidae (Insecta, Diptera) were dominant. These common taxa occurred in mixed substrata containing mud, soil, tree roots, and aquatic vegetation.

ATSPT

In 2008, the ATSPT of benthic macroinvertebrates in each site was high, ranging from 50 - 56. At the VLX, VDP, VCL, and VVL sites, the ATSPT indices were the highest at 56, while VTP was the lowest at 50 (Table 3.5). In sites, with substrata of sand, soil, organic matter, and aquatic plants, the ATSPT was higher than at sites with bottoms of clay, stones, and dead trees.

Table 3.5 *Abundance, average richness and ATSPT of benthic macroinvertebrates recorded at sites sampled during 2004 - 2008*

Site code	Abundance					Average richness					ATSPT				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
CKT	7		8		11	2		2		3	35		31		31
CMR		20	24	11	10		4	3	3	3		37	43	37	26
CSJ		3	3	5	4		2	2	3	2		37	33	36	27
CKM		4	3	4	6		2	2	3	2		35	36	37	26
CSP	8	25	6	7	6	3	6	3	3	2	35	38	31	33	23
CSU		23	8	5	7		5	3	3	3		36	39	37	34
CKL			17		11			5		3			52		39
CSK			11		20			3		4			47		34
LDN				51	50				8	7				36	37
LSD				13	11				5	4				40	40
LKL		25		4	2		6		2	2		35		37	40
LBH				7	20				3	5				38	38
LBF				38	26				6	6				38	40
LVT	1			6	7	1			3	3	31			39	40
LMX		4			10		2			1		35			41
LPB	25	6			6	7	2			2	32	33			36
TNP					79					2					33
TSM				9	59				3	2				37	32
TNK				3	12				2	2				42	35
TMU	8				7	3				1	46				32
TKC					51					3					31
TUN					12					2					36
TCS					14					1					26
TKO	31	12			68	6	4			3	36	34			29
VCT			8		115			3		7			63		55
VLX			24		74			5		11			57		56
VDP					108					11					56
VKB					145					8					55
VTP					18					5					50
VTT					47					9					54
VCL			9		301			3		10			53		56
VVL					60					9					56

3.6 Evaluation of sites

The eight sites in each of the Member Countries were assessed following the guideline proposed in the 2004 - 2007 studies. Sites sampled were classified and grouped according to how many of the 12 indicators met the guidelines. Since, there were no Zooplankton data available from Cambodia, nine indicators were used as the criteria for the assessment of the Cambodian sites.

The total of 32 sites were assessed and classified into the four class groupings. Twenty four of the sites were in good or excellent ecological health, with only one site in a poor condition. In order to illustrate their status and trends over time, the 2008 results are summarised in Table 3.6 and Table 3.7 together with the previous years' results. A temporal change of ecological health indicators over the period of 2004 - 2008 was found in many locations with some showing improvement, and others degradation. The temporal trend of ecological health of the Mekong River sounds a warning of environmental impacts such as those from human disturbance and from degradation of habitats and water quality in some parts of the river. Further investigations into the causes and effects on biological components are needed to identify the necessary remedial and restorative actions.

Cambodia

In Cambodia, most site classifications were stable and some even showed a slight improvement. Four sites were assessed as Class A (excellent ecological health), three sites as Class B (good), and one site as Class C (moderate). No sites were identified as being in a poor condition.

Lao PDR

In the Lao PDR, one site was assessed as Class D, three as Class C, and three as Class B. Only one site was assessed as Class A. The LKL site, a 2005 reference site, was assessed as Class C in the 2007 and 2008 surveys. This decrease may have been caused by bank erosions during the rainy season and other human activities which had taken place after 2005. At this site, there had been many changes, especially in terms of water flows, and the amounts of accumulated sand and clay. These factors could have affected many organisms living in the area.

The LMX site was assessed in 2005 as Class C and in 2008 as Class D. This decrease in ranking may be because almost all the biometric indicators were lower, most probably resulting from water level fluctuations, increased disturbance, and large decreases in water quantity compared to those of 2005.

Thailand

In 2008, four sites were assessed as Class A, three as Class B and only one as Class C. This revealed that human activities had had only a light to moderate impact. The Site Disturbance Scores for the eight sites were also low. Although no reference sites were examined in 2008 the 2008 survey results showed slight differences in all the sites. The sites of TKO and TSM were assessed as Class A in 2008 but TKO had been assessed as Class B in 2004, and TSM as Class C in 2007. Impacts at these sites have been decreasing as a result of the more limited use of tourist boats at the TKO site, and the bank protection provided by the Thai Government at the TSM site.

Viet Nam

The site assessment in Viet Nam shows a slight improvement at some sites. As in the 2006 survey, several sites in the rivers of the Mekong Delta were assessed as Class C and showed signs of ecosystem stress. Two sites (VCT and VLX) improved from Class C in 2006 to class B in the 2008 survey.

Table 3.6 *Assessment of all sites following the suggested guidelines.*

Site code	Benthic diatom			Zooplankton			Littoral macroinvertebrate			Benthic macroinvertebrate			Number meeting guidelines	Class
	Abun-dance	Average richness	ATSPT	Abun-dance	Average richness	ATSPT	Abun-dance	Average richness	ATSPT	Abun-dance	Average richness	ATSPT		
CKT	Y	N	Y				Y	Y	Y	Y	Y	Y	8	A
CMR	Y	N	Y				Y	N	Y	Y	Y	Y	7	B
CSJ	Y	Y	Y				Y	Y	Y	N	Y	Y	8	A
CKM	Y	Y	Y				Y	N	Y	Y	Y	Y	8	A
CSP	Y	N	Y				N	N	Y	Y	Y	Y	6	B
CSU	Y	Y	Y				Y	N	Y	Y	Y	Y	8	A
CKL	N	N	Y				N	N	N	Y	Y	N	3	C
CSK	Y	N	N				Y	N	Y	Y	Y	Y	6	B
LDN	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	10	A
LSD	N	N	N	Y	Y	Y	Y	Y	N	Y	Y	N	7	B
LKL	Y	N	Y	Y	N	Y	N	N	N	N	Y	N	5	C
LBH	Y	N	N	N	N	N	N	Y	N	Y	Y	N	4	C
LBF	N	N	Y	Y	Y	Y	Y	Y	N	Y	Y	N	8	B
LVT	Y	N	N	N	N	Y	N	Y	N	Y	Y	N	5	C
LMX	N	N	N	Y	N	Y	N	N	N	Y	N	N	3	D
LPB	Y	N	N	Y	N	Y	N	Y	N	Y	Y	Y	7	B
TNP	Y	N	Y	Y	N	Y	N	N	N	Y	N	Y	6	C
TSM	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	11	A
TNK	Y	Y	N	Y	N	Y	N	Y	N	Y	Y	Y	8	B
TMU	Y	N	N	Y	Y	Y	N	Y	Y	Y	Y	Y	9	B
TKC	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	10	A
TUN	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	10	A
TCS	Y	Y	Y	N	N	Y	N	N	Y	Y	Y	Y	8	B
TKO	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	11	A
VCT	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	N	7	B
VLX	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	N	7	B
VDP	Y	Y	N	Y	N	N	N	Y	N	Y	Y	N	6	C
VKB	Y	Y	N	Y	Y	N	N	Y	N	Y	Y	N	7	B
VTP	Y	Y	N	N	N	N	N	N	N	Y	Y	N	4	C
VTT	Y	Y	N	Y	N	N	Y	N	N	Y	Y	N	6	C
VCL	Y	Y	N	N	N	N	Y	Y	N	Y	Y	N	6	C
VVL	Y	Y	N	N	N	N	Y	Y	N	Y	Y	N	6	C

Y = meets guidelines; N = does not meet guidelines

Table 3.7 *Site assessment during 2004-2008*

Site code and Location		Site assessment by year				
		2004	2005	2006	2007	2008
Cambodia						
CKT	Mekong river, Kampi	A		A		A
CMR	Mekong river, Stung Treng Ramsar site		B	A	B	B
CSJ	Se San river, Sesan		A	B	A	A
CKM	Se Kong river, Ramsar site		A	B	B	A
CSP	Se Kong river, Pum Pi	A	A	A	A	B
CSU	Se San river, Lum Phat		A	B	B	A
CKL	Bassac river, Koh khel			B		C
CSK	Stoeng Sangke river, Prek Toal			C		B
Lao PDR						
LDN	Mekong river, Done Nguei				A	A
LSD	Se Done river, Ban Hae				B	B
LKL	Se Kong river, Ban Xou		A		C	C
LBH	Se Bang Hieng river, under bridge				A	C
LBF	Se Bang Fai river, under bridge				B	B
LVT	Mekong river, Ban Huayhome	C			B	C
LMX	Mekong river, Ban Xiengkok		C			D
LPB	Mekong river, Done Chor	A	A			B
Thailand						
TNP	Mekong river, Nakorn Panom					C
TSM	Connection between Songkram & Mekong Rivers				C	A
TNK	Nam Kam river, Mukdaharn				C	B
TMU	Nam Mun river, Ubonrachathani	B				B
TKC	Connection between Nam Mun & Mekong Rivers					A
TUN	Nam Mun river, Ubonrachathani					A
TCS	Mekong river, Chiang San, Chiang Rai					B
TKO	Kok River, Chiang Rai	B	A			A
Viet Nam						
VCT	Bassac river, Phu An, Can Tho			C		B
VLX	Bassac river, Long Xuyen, An Giang			C		B
VDP	Bassac river, Da Phuoc, An Giang					C
VKB	Bassac river, Khanh Binh, An Giang					B
VTP	Mekong river, Thuong Phuoc, Dong Thap					C
VTT	Mekong river, Thuong Thoi, Dong Thap					C
VCL	Mekong river, Cao Lanh, Dong Thap			C		C
VVL	Mekong river, My Thuan, Vinh Long					C

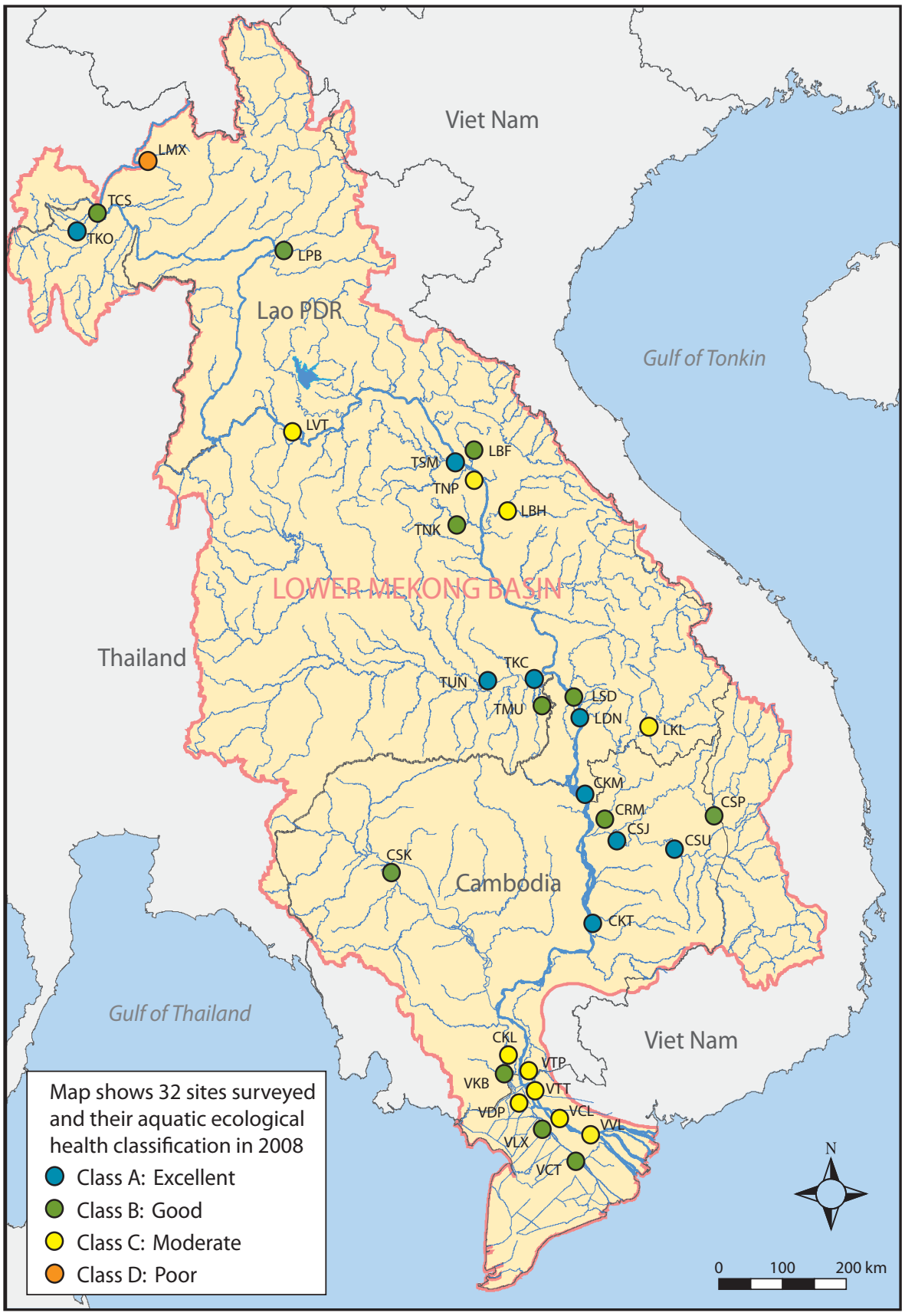

Figure 3.1 Rating of sites in the Lower Mekong Basin surveyed in 2008.

4. Conclusions

This report covers the ecological health monitoring activities that were transferred to the Member Countries in 2008. During the 2008 biomonitoring survey, eight sampling locations were examined in each country. Some of these were new sites where samples had not been collected during the 2004 – 2007 surveys. Four of these were in Thailand and five in Viet Nam.

The total of the 32 sites assessed were classified into four class groupings. Of the 2008 sites, nine were in Class A (excellent ecological health), 12 in Class B (good), 10 in Class C (moderate) and one in Class D (poor). Lower scores may have resulted from increased human activities, and reductions in both habitats and water quality.

In order to illustrate their status and trends, the 2008 results are summarised and compared to the previous years' results. Stability of site classifications in more than half of the sites and the improvement in some sites particularly in those in the Mekong Delta are positive signs for the health of the Mekong River. Some locations indicate improvement while others show degradation.

On-site observation suggests that the decline seen at some sites has probably been caused by bank erosion during the rainy season. Other sites have changed since 2005 in terms of water flows, water levels and amounts of sand and clay accumulation. These factors could have affected the organisms living in the area and caused the recorded changes.

The trends of degradations in isolated locations give a warning of increasing environmental impacts caused by human activities, and degradation of habitats in some parts of the Mekong River. Further investigations into the causes and effects on biological components are needed to identify the necessary remedial actions and possible restoration efforts.

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Appendix 1. List of participants on the sampling field trips in 2008

No.	Name	Position	Professional speciality
Participants on the sampling field trip in Cambodia, 19 – 28 March 2008			
1	Dr. Prum Somany	Team leader	Inland Fisheries Research and Development Institute (IFReDI)
2	Mr. Em Samy	Member	IFReDI
3	Dr. Chea Tharith	Member	IFReDI
4	Mr. Thach Phanara	Member	IFReDI
5	Mr. Touch Bunthang	Member	IFReDI
6	Ms. Kim Sopheap	Member	IFReDI
7	Mr. Chea Vanara	Member	Ministry of Water Resource and Meteorology (MoWRAM)
8	Mr. Mon Samoun	Member	MoWRAM
9	Mr. Phin Rady	Member	Ministry of Environment (MOE)
10	Mr. Chek Roth	Member	MOE
Participants on the sampling field trip in Lao PDR, 10 – 23 March 2008			
1	Mr. Chanda Vongsombath	Team leader	Macroinvertebrate specialist
2	Ms. Nian Sivong Say	Member	Zooplankton specialist
3	Ms. Chanthima Ponthalith	Member	Diatom specialist
4	Mr. Phoangsavat	Member	Lecturer at Suphanuvong University
5	Mr. Xoxiong	Member	Lecturer at Suphanuvong University
6	Mr. Orlavanh	Member	Lecturer at Champasak University
7	Ms. Odeth	Member	Lecturer at Champasak University
8	Mr. Vila	Member	Water quality specialist
Participants on the sampling field trip in Thailand, 05 – 12 March 2008			
1	Dr. Tartporn Kunpradid	Team leader	Benthic diatom specialist
2	Dr. Narumon Jangpradub	Member	Macroinvertebrate specialist
3	Ms. Kusuma Nuengchaknin	Member	Water quality specialist
4	Ms. Kesiree Kidsukum	Member	Water quality specialist
5	Ms. Jeeraporn Pekkoh	Member	Blue green algae specialist
6	Ms. Nopparut Sithiwong	Member	Algae specialist
7	Ms. Rungnapa Tagun	Member	Macroinvertebrate specialist
8	Dr. Nisarat Tungpairojwong	Member	Macroinvertebrate specialist
9	Ms. Prapatsorn Dabseepai	Member	Zooplankton specialist
10	Mr. Pragut Udonphimai	Member	Macroinvertebrate specialist
11	Dr. Pornsilp Pholpanthin	Member	Zooplankton specialist
Participants on the sampling field trip in Viet Nam, 16 – 26 March 2008			
1	Ms. Do Thi Bich Loc	Team leader	Benthic diatom specialist
2	Mr. Ngo Xuan Quang	Member	Benthic macroinvertebrate specialist
3	Mr. Duong Duc Hieu	Member	Benthic macroinvertebrate specialist
4	Mr. Phan Doan Dang	Member	Zooplankton specialist
5	Mr. Nguyen Xuan Dong	Member	Zooplankton specialist
6	Mr. Le Cong Nhat Phuong	Member	Water quality specialist
7	Mr. Tran Quang Vinh	Member	Water quality specialist
8	Mr. Nguyen Van Sinh	Member	Littoral macroinvertebrate specialist
9	Mr. Thai Ngoc Tri	Member	Littoral macroinvertebrate specialist
10	Mr. Pham Thanh Luu	Member	Benthic diatom specialist

Appendix 2. Detail site descriptions for 2008 Ecological Health Monitoring

Sampling event	Site Code	River	Location	Date Sampled	Coordinates			Land Use Cover		Substratum		Potential human impacts
					UTM	UTM (N)	UTM (E)	Left bank	Right bank	Littoral	Channel	
78	CKT	Mekong	Kampi	19/3/08	48P	1393502	610914	Few houses; tourist area; moderate slope; some erosion	Steep, eroded bank; some trees on face; many on top; few houses	Sand; some stones	R: Sand; rock; little debris M: Sand; rock; algae L: Sand; rock; algae	Tourism activities at dolphin tourist site
79	CRM	Mekong	at Ramsar site	23/3/08	48P	1504098	618663	Forest, few houses	Forest, few houses	Sand; pebbles; cobbles; bedrock; filamentous algae	R: Sand; rock; little debris M: Sand; little debris L: Sand; debris	Disposal of human and animal wastes
80	CSJ	Se San	downstream of Srepok River junction	20/3/08	48P	1498832	621744	Forest; water buffalo	Forest; water buffalo	Sand; pebbles; cobbles; bushes	R: Sand; rock M: Rock; cobbles; sand L: Sand; rock; little debris	In significant impact from human activities
81	CKM	Se Kong	Lower Se Kong River	21/3/08	48P	1539069	606331	Forest; few houses; eroded banks	Forest; few houses; eroded banks	Sand-rocks, mud and little debris.	R: Sand; little debris M: Rock L: Sand; mud; debris	Disposal of animal wastes, navigation
82	CSP	Sre Pok	Lumphat	23/3/08	48P	1525674	765124	Forest, small scale agriculture; ferry crossing	Forest; small scale agriculture; ferry crossing	Bedrock and cobbles, with many small channels	R: Clay and mud, bamboo leaves M: Sand L: Mud with few leaves	Disposal of human wastes
83	CSU	Se San	Phum Pi (Se San River at border)	24/3/08	48P	1490553	717794	Forest, bamboo bushes; cashew nut behind riparian	Forest and bamboo bushes; fruit trees behind riparian	Boulders on bedrock	R: Sand; debris M: Rock; sand L: Sand; mud; debris	Navigation
84	CKL	Bassac	Bassac River at Koh Khel	29/3/08	48P	1245255	503786	Villages and gardens; banana trees	Villages and gardens	Sand; mud; water hyacinth	R: Sand; mud M: Sand; a few granules L: Mud; fine sand; debris	Disposal of human and animal wastes
85	CSK	Stoeng Sangke	Stoeng Sangke River (Prek Toal)	28/3/08	48P	1461902	357473	Open forest; fish pens; floating hut; floating village downstream	Open forest; fish pens	Silt; flooded bushes	R: Mud; debris M: Mud; little debris L: Mud; debris	Disposal of human waste; fishing; navigation

Sampling event	Site Code	River	Location	Date Sampled	Coordinates			Land Use Cover		Substratum		Potential human impacts
					UTM	UTM (N)	UTM (E)	Left bank	Right bank	Littoral	Channel	
86	LDN	Mekong	Done Nguei	10/3/08	48P	1657517	596193	Maize and tobacco gardens, bank erosion	villages and vegetable gardens	Sand; mud filamentous algae; khai tree (Homonoia riparia)	R: Clay; Mud; sand M: Sand; little mud L: Sand; little mud	Fishing and navigation
87	LSD	Se Done	Ban Hae	11/3/08	48P	1671756	587623	Villages and gardens; banana trees	Maize, Vegetable gardens	Bed rock; mud; sand; filamentous algae	R: Sand; mud M: Sand; debris L: Mud; clay, fine sand	Agricultural runoff; disposal of human, pumping, and animal wastes
88	LKL	Se Kong	Ban Xou touat	13/3/08	48P	1623478	670696	Gardens; banana trees; bamboo; bank erosion	Villages and gardens; bank erosion	Cobbles; pebbles; gravel; Khai tree (Homonoia riparia). Water channel Changed from last year	R: Sand; mud M: Sand; a few granules L: Fine sand; little debris	Disposal of human; fishing; navigation and animal wastes
89	LBH	Se Bang Hieng	under the bridge	15/3/08	48Q	1887920	498434	Houses; some trees on bank; washing place	Villages; washing place; boat parking; vegetation gardens downstream	Boulders on bedrock; sand; mud; filamentous algae	R: Clay; mud; sand M: Mud; sand; L: Sand and little debris; little mud	Human wastes; rubbish disposal; and animal wastes
90	LBF	Se Bang Fai	under the bridge	16/3/08	48Q	1959958	454745	Houses; water pumping; some trees on bank; washing place	Houses; office; floating pump; washing place; vegetation gardens downstream	Little boulders on bedrock; sand; filamentous algae on bed rock	R: Mud and sand M: sand L: Mud	Waste and rubbish; disposal of human and animal wastes; bank erosion downstream
91	LVT	Mekong	Ban Huayhome	18/3/08	48Q	1988731	239871	Lao Villages; port and vegetable gardens;	Thai Villages; port and vegetable gardens	Cobbles, gravel, sand; debris, grass on the bank	L: upper- clay; little debris L: middle; little debris; little mud L: lower; little debris and sand	Agricultural run off; human wastes and rubbish disposal; fish farming and navigation
92	LMX	Mekong	Ban Xiengkok	20/3/08	47Q	2311778	670860	Lao Villages; port and; washing place	Burmese vegetable gardens, bamboo and cattle	Cobbles; gravel; filamentous algae; clay and grass on the bank	L: upper sand; little debris L: middle; little sand and mud L: lower; little debris and sand	Fluctuation from big boat; damage to banks; bank erosion; disposal of human and animal wastes; livestock
93	LPB	Mekong	Done Chor, upper Su-phanuvong University	22/3/08	48Q	2206957	206113	Village; downstream University; large sand and gravel collection; road from left to the island	Steep, eroded bank; some trees on face; many on top; Village in downstream	Cobbles; gravel; filamentous algae; clay and Khai tree on the bank	R: Sand; rock; little debris M: Sand L: mud and clay	Sand and gravel collection, Navigation, fishing

Sampling event	Site Code	River	Location	Date Sampled	Coordinates			Land Use Cover		Substratum		Potential human impacts
					UTM	UTM (N)	UTM (E)	Left bank	Right bank	Littoral	Channel	
94	TNP	Mekong	Nakorn Panom	5/3/2008	48Q	1926454	476094	Agriculture, few house, shoreline,	Agriculture, some trees on bank, small scale fish farms	Clay and mud, bed rock, wood debris,	R: mud and clay M: Bed rock and Cobble L: mud and clay	Rubbish disposal, Agriculture runoff, fish farming, bank erosion
95	TSM	Songkhram	Songkarm Mount	6/3/2008	48Q	1951509	443775	Forest , land slide, few houses, aquatic plants and algae	Small scale agriculture, docks, floating house and fish cages	Sand and clay, firm mud and firm sand	R: sand, mud M: sand, mud L: clay and sand	Restaurant, fish cage, disposal of human and animal wastes, agricultural runoff, livestock damage to bank
96	TNK	Nam Kam	Nam Kam	7/3/2008	48Q	1874332	450496	Soil erosion, few house, wood and leaf debris,	Soil erosion and land slide	Sand and clay, gravel, sand and mud	R: gravel and sand M: L: sand and mud	Human wastes and rubbish disposal form downstream, Bank erosion
97	TMU	Nam Mun	Kong Chaim	8/3/2008	48P	1673182	552465	Fields, agriculture, house and floating houses, soil erosion, cattle grazing	Fish farm and floating house	Sand and gravel	R: sand and gravel M: L:	disposal of human and animal wastes, agricultural runoff, urban runoff
98	TKC	Mekong	Kong Chaim	9/3/2008	48P	1694552	552099	Village, agriculture, cattle grazing, fish farm	Bed rock and cobble, with many small channels and soil erosion	Sand and mud	R: sand M: sand and clay L: sand and firm mud	Agricultural runoff, livestock damage to banks, urban runoff
99	TUN	Nam Mun	Ubon New	10/3/2008	48P	1685056	494860	Few house, small scale agricultural, aquatic and riparian	Aquatic plants and few house	Sand and silt	R: sand M: sand and clay L: sand and firm mud	Navigation, agriculture
100	TCS	Mekong	Chiang San	11/3/2008	47Q	2240109	614718	Water buffalo, soil erosion, algae and aquatic plants	Mud, aquatic plants and few house, market	Sand and clay, Firm sand, gravel	L: sand and gravel M: firm sand R: bed rock and cobble	Navigation, construction, domestic waste, disposal form human and market
101	TKO	Kok	Chiang Rai	12/3/2008	47Q	2201793	582195	Gravel and sand. Some algae on stone	Riparian zone	Cobble and gravel sand	L: gravel and sand M: sand R: mud and clay	Agriculture runoff, navigation, small village

Sampling event	Site Code	River	Location	Date Sampled	Coordinates			Land Use Cover		Substratum		Potential human impacts
					UTM	UTM (N)	UTM (E)	Left bank	Right bank	Littoral	Channel	
102	VCT	Bassac	Phu An, Cai Rang, Can Tho	17/03/08	48P	1106685	589048	Fruit gardens, house	Fruit gardens, housing	Thin mud	R: sand, mud, organic matter M: Sand, little mud L: Clay, organic matter, mud	Bridge construction, transport activities, navigation, oil restoration, human washing, sewage treatment, material port and fishing
103	VLX	Bassac	Long Xuyen, An Giang	18/03/08	48P	1143437	551897	Agriculture, land erosion, strong flow	housing, processing factory	Mudflat, organic matter, rubbish as plastic bag, wood, decay dead animal bodies.	R: Sand, sediment M: sand L: soil, mud, clay	High densities of boats, ships, rice storage, grain processing factory, agriculture, bank erosion, human washing, boat transportation, waste water,
104	VDP	Bassac	Da Phuoc, An Phu, An Giang	19/03/08	48P	1188035	514690	Agriculture, housing, gardens, bushes trees	Grain agriculture as maize, bean, etc.,	Alluvium, sediment	R: alluvium M: sand L: clay	Boat activities, fishing, human washing, housing, gardens, soil erosion
105	VKB	Bassac	Khanh Binh, An Phu, An Giang	20/03/08	48P	1210872	509482	Grain agriculture, natural land, grass cover	Market, shop	Sand, detritus, sediment	R: rubbish, sand, sewage M: Sand, silt L: Clay, sand	Market, waste water, rubbish, agriculture and boat transportation, human washing, sand exploitation, fishing farms and fishing
106	VTP	Mekong	Thuong Phuoc 1, Hong Ngu, Dong Thap	22/03/08	48P	1205766	519830	Natural land, border guard office	Housing, gardens, border guard office	Sand, sediment, alluvium	R: Sand, clay M: Sand L: Sand, sediment	Sand exploitation, transporting activities
107	VTT	Mekong	Thuong Thoi, Hong Ngu, Dong Thap	23/03/08	48P	1194447	528951	Grain agriculture, natural land	Soil erosion, natural land	sediment, alluvium, organic fertilizer	R: clay, sediment M: sand, sediment L: sediment, alluvium, organic fertilizer	Fishing, agricultural farm, soil erosion, boat transportation.
108	VCL	Mekong	Tan Hau, Tan Thuan Tay, Cao Lanh	24/03/08	48P	1153777	563798	Agricultural land, natural land	Housing, gardens, boat transportation	Mudflat, alluvium, a lot of rubbish like dead tree, plastic bag, etc.	R: clay, sand M: Sand, alluvium, L: Mudflat, alluvium, a lot of rubbish like dead tree, plastic bag, pesticide bottle, etc.	Agricultural activities, boat transportation, fishing, solid rubbishes, organic matter decay
109	VVL	Mekong	My Thuan, Vinh Long	25/03/08	48P	1134514	603698	Gardens, agricultural land, houses	Housing, fruit gardens, construction material storage	Sediment, sand, dead fishes, rubbish, plastic bag, pesticide bottle	R: clay, sand, M: sand L: Sediment, sand, dead fish, rubbish, plastic bag, pesticide bottle	High densities of ships and boats, construction material storage on the right bank, sand exploitation, fishing, erosion, sewage and agriculture

Appendix 3. Detail environmental variables measurement at 32 sites sampled in 2008

Site Code	Altitude (m)	River width (m)	Depth (m)			Secchi depth (m)			Temperature (°C)			DO (mg/L)			pH			EC (mS/m)			SDS
			L	M	R	L	M	R	L	M	R	L	M	R	L	M	R	L	M	R	
CKT	12	1,310	1.8	8	1.7	1.15	1.25	1.20	29.8	32.7	29.6	8.06	8.17	8.18	7.28	7.18	7.18	14.98	15.16	15.01	1.1
CRM	58	430	1.5	7.5	1.25	1.55	1.50	1.58	27.8	28.0	27.9	6.88	6.74	6.84	7.74	7.75	7.78	5.58	5.56	5.58	1.4
CSJ	50	640	1.3	35	1	1.20	1.10	1.47	29.7	30.6	30.3	6.76	6.76	6.80	6.78	6.77	6.81	3.61	3.65	3.59	1.3
CKM	48	390	0.7	1.5	0.5	1.25	1.18	1.13	29.7	30.6	31.2	7.76	7.74	7.79	8.26	8.25	8.36	18.63	18.26	18.17	1.2
CSP	100	230	2	2.5	1.5	1.10	1.07	1.15	22.3	22.1	22.4	6.45	6.43	6.47	7.29	7.28	7.28	3.58	3.58	3.56	1.1
CSU	134	175	1.25	13.5	1.5	1.30	1.17	1.40	28.8	28.3	28.4	7.34	7.29	7.22	7.47	7.46	7.42	5.38	5.37	5.38	1.8
CKL	3	300	4	8	6.5	0.75	0.72	0.80	30.5	30.3	29.5	6.25	6.28	6.28	7.52	7.51	7.50	121.00	120.90	120.90	1.7
CSK	5	130	0.75	1.75	1	0.40	0.33	0.45	30.3	30.3	29.5	4.88	4.95	4.87	7.29	7.29	7.30	22.13	22.01	22.02	2.0
LDN	82	1240	2.3	4.0	2.5	1.6	1.53	1.10	28.50	28.44	29	8.5	8.4	8.7	8.60	8.40	8.50	22.70	22.70	23.30	1.6
LSD	101	130	2.0	2.4	1.0	0.8	0.70	0.70	28.85	28.66	28.53	7.5	7.53	7.22	7.73	7.65	8.00	13.10	12.90	12.72	1.8
LKL	72	200	2.2	3.0	1.5	0.8	0.80	0.80	29.20	29.4	29.4	7.24	7.26	7.25	7.30	7.10	7.10	7.10	7.10	7.10	1.8
LBH	111	150	1.8	3.0	1.2	1.1	1.30	1.20	28.17	28.4	28.35	8	7.5	7.5	7.98	7.90	7.70	33.00	33.00	33.02	1.8
LBF	134	80	1.8	2.6	3.5	1.2	1.15	1.20	27.20	27.15	27	7.5	7.7	7.43	8.10	8.20	8.00	30.00	29.90	30.37	1.9
LVT	178	790	1.5	2.0	1.8	0.4	0.60	0.40	23.60	23.8	24.2	8.75	8.9	8.55	7.88	7.90	7.50	28.40	28.30	28.21	1.8
LMX	410	100	0.5	1.7	1.1	0.2	0.20	0.20	22.80	23.2	23	7.5	7.3	7.4	7.15	7.15	7.15	31.10	30.90	31.00	2.1
LPB	407	195	1.7	4.5	2.5	0.2	0.20	0.20	25.00	25	25	8.3	8.3	8.2	7.74	7.73	7.77	26.40	26.20	26.60	1.6
TNP	133	800	-	9.2	2.8	-	0.62	0.55	-	24.4	25.5	-	8.30	8.10	-	7.51	7.27	-	22.90	23.10	1.7
TSM	136	350	0.4	1.8	0.6	0.5	0.63	0.50	27.00	25.2	26.6	9.00	8.00	7.00	7.62	7.16	7.45	24.70	30.80	30.10	1.6
TNK	130	19	1.1	1.3	1.1	0.6	0.52	0.53	24.60	27.0	25.5	7.60	7.25	7.80	6.44	6.56	6.58	20.60	21.60	21.50	1.8
TMU	94	248	2.8	6.5	3.5	0.7	0.87	0.73	25.80	24.8	25.3	7.40	24.80	25.30	6.85	6.87	6.81	17.72	17.43	19.80	1.6
TKC	85	-	-	11.6	4.8	-	1.25	1.00	-	26.1	25.2	-	8.00	7.80	-	7.43	7.70	-	22.60	23.40	1.6
TUN	93	285	2.1	4.0	2.5	0.3	0.34	0.34	24.20	25.6	25.5	8.20	8.00	8.40	6.84	6.96	7.26	16.19	17.83	17.20	1.7
TCS	353	550	-	-	-	0.2	0.15	0.18	23.00	22.2	23.7	7.60	7.80	7.40	7.52	7.12	7.17	25.30	24.60	24.10	1.3
TKO	391	100	1.2	2.3	1.3	0.4	0.43	0.33	24.80	22.6	24.5	7.00	7.40	7.20	7.00	6.96	6.94	7.00	67.30	8.55	1.5
VCT	10	1900	7.0	15.0	7.0	0.3	0.30	0.22	28.70	28.5	28.3	6.42	5.50	5.24	7.82	8.52	8.37	17.81	17.53	18.47	2.1
VLX	7	800	8.0	18.0	5.0	0.4	0.40	0.50	28.80	28.9	28.8	7.80	7.67	6.14	7.69	7.92	7.14	18.05	17.43	17.92	2.2
VDP	5	900	7.0	10.0	1.0	0.5	0.45	0.45	29.20	28.9	29.0	7.97	7.90	6.81	7.55	7.65	7.67	18.69	18.62	18.43	2.2
VKB	6	250	2.0	7.5	1.0	0.6	0.80	0.80	29.40	30.2	30.0	7.57	8.03	7.29	8.16	8.27	8.37	13.84	13.82	13.81	2.1
VTP	7	1500	3.0	12.0	8.0	0.8	0.85	0.80	29.30	29.4	29.4	8.25	6.19	6.41	8.08	7.90	7.84	18.59	18.40	18.18	1.9
VTT	6	400	1.5	5.0	3.0	0.7	0.63	0.70	28.70	29.1	29.2	6.94	6.23	5.82	7.88	8.33	8.55	18.45	18.49	18.52	2.1
VCL	7	2000	2.5	8.0	4.0	0.6	0.50	0.50	29.30	29.3	29.3	6.75	5.29	6.75	8.12	8.02	7.45	18.94	19.00	18.94	2.2
VVL	8	1200	3.5	20.0	3.0	0.4	0.55	0.50	28.90	29.1	29.2	5.00	5.08	5.58	7.92	8.08	7.80	18.18	18.32	18.64	2.1

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