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# Report on the 2011 Biomonitoring Survey of the Lower Mekong River and selected tributaries

Report prepared by
**Mekong River Commision**
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# Acknowledgements

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# Acronyms

| | |
|---|---|
| **ATSPT** | Average Tolerance Score Per Taxon |
| **BDP** | Basin Development Programme of the MRCS |
| **EHM** | Environmental Health Monitoring |
| **LMB** | Lower Mekong Basin |
| **MRC** | Mekong River Commission |
| **MRCS** | Mekong River Commission Secretariat |
| **NMC** | National  Mekong Committee |
| **SDS** | Site Disturbance Score |

# Glossary

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|---|---|
| **Abundance** | 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** | The average number of taxa (types) of plants or animals belonging to a particular biological indicator group (e.g. diatoms, zooplankton) counted in the samples from a site. |
| **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, 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** | 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 rapid ecosystem health assessment in the Mekong. |
| **Diatoms** | Single-celled microscopic algae (plants) with cell walls made of silica. They drift in river water (benthic/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 invertebrates and fish. 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** | 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** | 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** | Organisms at the bottom of the food chain, such as most plants and some bacteria (including blue-green algae), which can produce organic material from inorganic matter. |
| **Primary production** | The organic material made by primary producers. Planktonic primary production is the amount of organic matter 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** | Total organic material made by primary producers over a given period of time. |
| **Reference sites** | 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 site disturbance score (SDS) (between 1 and 1.67). Reference sites provide a baseline from which to measure environmental changes. |

# Glossary

| | |
|---|---|
| **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)** | 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)** | A group or groups of animals or plants that are related through evolution. Examples include species, genera, families up to phylum or even kingdom. |
| **Total richness** | 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 in the water columns 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

# SUMMARY

This report describes the biomonitoring survey conducted in 2011 in the Lower Mekong Basin which contributes to the evaluation of the overall ecological health of the river.

The survey builds 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. During 2005–2007, the biomonitoring programme was managed by the Mekong River Commission (MRC). From 2008 onward the Member Countries, with support from the MRC Secretariat (MRCS), performed the monitoring themselves. Each country examined eight to seventeen sites, based on an agreed and standardised methodology (MRC, 2010a). Three types of biometric indicators of the health of the Mekong aquatic ecosystem were calculated for each of four groups of organisms included in the biomonitoring programme: benthic diatoms, zooplankton, littoral macroinvertebrates and benthic macroinvertebrates. The indicators used were abundance, average richness, and the Average Tolerance Score per Taxon (ATSPT). A healthy ecosystem is indicated by high abundance, high average richness, and a low ATSPT (signifying low presence of pollution/disturbance-tolerant 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 2011; (ii) use this information to derive biological indicators for the sites examined in 2011; and (iii) use biometric indicators to evaluate these sites.

A total of 41 sites were assessed, ranging from rocky rapids, sandy-alluvial areas of tributaries and the mainstream, Tonle Sap Lake and adjacent rivers including estuaries of the delta areas. The assessed sites are classed into four groups according to ecological status. Of the 2011 sites, seven were in Class A ('excellent ecological health'), 22 in Class B ('Good'), 11 in Class C ('Moderate') and 1 in Class D ('Poor').

No systematic geographical trend in ecological health was observed for the Lower Mekong Basin. The Mekong mainstream has sites in all four classes and not in descending quality from upstream to downstream as could be intuitively expected. The ecological quality at the mainstream sites varies between class A and D without any clear pattern. A temporal change in ecological health over the period 2005 to 2011 was found in many locations. When looking only

at the 10 sites that have been monitored since 2005, a somewhat gloomy picture appears: six sites have deteriorated (three of them by two class levels), three remain unchanged and one has improved by one class level. Lower scores may be the result of an increase in human disturbance and declines in habitat and water quality. Some locations indicate improvement, while others indicate degradation. This temporal trend in the river's ecological health sounds a warning that environmental impacts, such as human disturbance and degradation of habitats and water quality, are occurring in areas of dense urbanisation, i.e. Xiang Kok and Vientiane in Lao PDR; Nakon Panom and Khongchiam in Thailand; the upper tip of the Tonle Sap Lake in Cambodia, and the lower reaches of the delta in Viet Nam. Between 2008 and 2011 within 32 recurring sites; three sites show degradation from Good to Moderate, two have degraded from Excellent to Good and three sites degraded from Excellent to Moderate (Mekong-Songkram river/TSM, Mekong-Mun at Kongchiam/TKC of Thailand and Dey It Village, Se San river/CUS of Cambodia). Over the same period, seven sites improved from Moderate to Good and four sites from Good to Excellent (Luang Prabang/LPB and Don Ngiew/LDN in Lao PDR, a Ramsar site/CMR and the Srepok River/CSP in Cambodia). Thirteen sites have maintained a stable condition since 2008 (three Excellent, six Good, three Moderate and one Poor). Further investigations to identify the causes and effects on biological components are needed to suggest awareness raising and remedial actions. Overall, the ecological health of the Lower Mekong Basin remains similar in 2011 compared with 2008. About one-third of the monitoring sites show degraded scores, one-third show improved scores and similarly one-third show stable scores. From 2005 to 2011 two-thirds of the sites show degraded scores, one-third show improved scores.

# INTRODUCTION

# INTRODUCTION

The Mekong River is a very important river in terms of human dependence on its aquatic resources for sustenance and survival. More than 60 million people live in the Lower Mekong Basin (LMB), which covers the area from northern Lao PDR to the Delta of southern Viet Nam, and for many, particularly those living close to the river, their quality of life depends on both the economic resources and the ecological health of the river.

This report describes a biomonitoring survey of the lower Mekong River conducted in 2011, which contributes to evaluation of the river's overall ecological health. This type of monitoring activity was 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 biological variability within and between individual sites. This analysis confirmed that within-site variability is comparatively low, and that the sampling effort used in the pilot studies were sufficient to characterise each site adequately. In 2005, the study focused on testing the performance of assessment metrics developed and widely used elsewhere to describe community structure (species richness, abundance, a species diversity index, and a dominance index) when these assessment metrics are applied to data from the Mekong River system (MRC, 2005b; MRC 2006 and Campbell, 2007). 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 Average Tolerance Score Per Taxon). 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 (MRC, 2005a; MRC, 2005b; MRC, 2006; MRC, 2008; MRC, 2009a; MRC, 2009b and MRC, 2010b). 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 8–17 sites in 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 illustrates the development of monitoring activities over time. Currently, the approach is to conduct EHM every two years.

The objectives of this report are to (i) describe the biological indicator groups sam-

pled during 2011; (ii) use this information to calculate biological indicators for the sites examined in 2011; 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. 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, and a low ATSPT. 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 (from 2005 to 2011).

In this report, the sampling sites are rearranged into an upstream to downstream sequence and, in the case of the same latitude, from west to east. So, the order of sampling sites is Lao PDR, Thailand, Cambodia and Viet Nam.

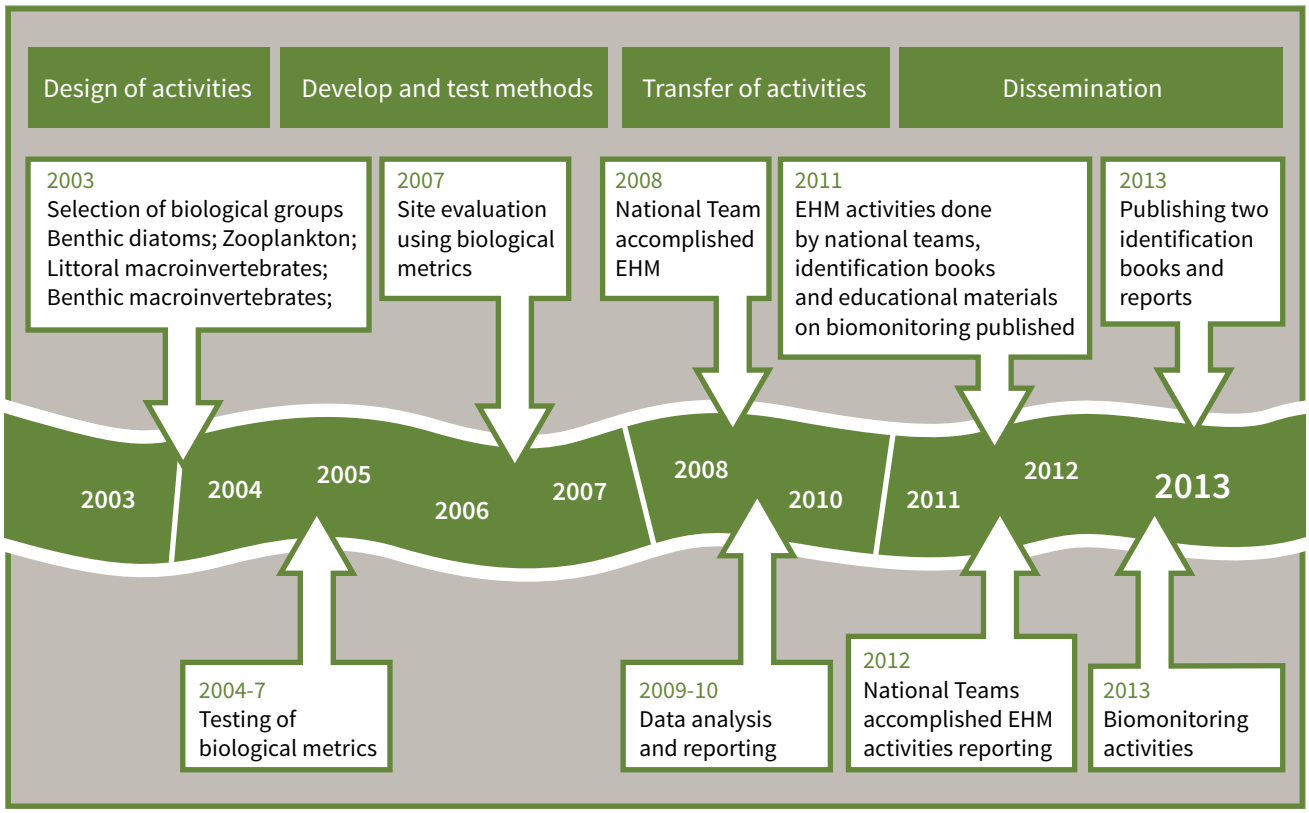



**Figure 1.1** Timeline for biomonitoring in the Mekong River and its tributaries 2003 to 2013

# MATERIALS & METHODS

# MATERIALS & METHODS

## SAMPLING SITES

In the EHM 2011 biomonitoring survey, a team of national experts, in consultation with the MRCS and National Mekong Committees (NMCs), sampled a total of 41 sites during March–April, 2011. Eight sampling locations were surveyed in Lao PDR, Thailand and Viet Nam and 17 sites in Cambodia. Two of the sites were new compared to the 2004–2008 surveys. This report compares data from 2005 onward. Site details are based on maps which are determined with a Garmin GPS 12XL, their data on coordinates and altitudes of the sampling sites and survey activities are given below, and summarised in Tables 1.1-1.4, Appendix 2 and Figures 2 and 3.

**Table 1.1.** Lao PDR sites sampled in 2011 and earlier biomonitoring surveys

| Site | Location | 2005 | 2006 | 2007 | 2008 | 2011 |
|---|---|---|---|---|---|---|
| LMX | Mekong River, Ban Xiengkok, Luangnamtha | x | | | x | x |
| LPB | Mekong River, Done Chor, Luang Prabang | x | | | x | x |
| LVT | Mekong River, Ban Huayhome, Vientiane | | | x | x | x |
| LBF | Se Bang Fai River, Se Bang Fai, Khammouan | | | x | x | x |
| LBH | Se Bang Hieng River, Songkhone, Savannakhet | | | x | x | x |
| LSD | Se Done River, Ban Hae, Pakse | | | x | x | x |
| LKL | Se Kong River, Ban Somsanouk, Attapeu | x | | x | x | x |
| LDN | Mekong River, Done Ngiew, Pathumphone | | | x | x | x |

### SITES IN LAO PDR

Sampling sites in Lao PDR include localities on the Mekong mainstream 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 farmlands, others are upstream of dams. At some sites, bank erosion, sand or gravel excavation, fishing and river transport occur.

#### LMX

(Mekong River, Ban Xiengkok, Luangnamtha)

The sampling site is on the Mekong River, about 200 m upstream from Ban Xiengkok, Long District, Luangnamtha Province. Myanmar is on the right-hand side of the river at Lao PDR side with villages, guesthouses, a migration office, port and boat gasoline station. Sampling could be done only along the left bank. In general, this site experiences strong currents and is highly disturbed by human activities as well as influenced by frequent tidal surges resulting from navigation. The substrata close to the bank is clay and sand with cobbles and pebbles about 5 m from the bank.

#### LPB

(Mekong River, Done Chor Luang Prabang)

This island in the middle of the Mekong River, about 1.5 km above Souphanouvong

University, features secondary forest on the right side of the island with some grass, minor shrubs and sandy areas. Villages, roads, and sand and gravel excavation are found on the left side of the island. The substrata of running water areas are a mix of bedrock, boulder and gravel with algae. A pool below the island has standing water habitat with a substratum composed of clay, mud and sand. In general, this site experiences a high level of disturbance from activities such as sand and gravel exploitation, water extraction, fishing and river traffic.

### LVT
(Mekong River, Ban Huayhome, Vientiane)

The sampling site is in Ban Huayhome, Sikhottabong District, about 5 km upstream from Vientiane capital. Thailand is on the right bank and Lao PDR on the left, with large vegetable gardens and a boat dock. The sampling problem here was related to national boundaries, making sampling impossible on the right side of the river, so samples were taken only from the left side. Other problems are the presence of bedrock substratum and a strong current in the middle section of the river. This site is frequently disturbed by human activities.

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

The sampling site in Ban Se Bang Fai, Se Bang Fai District, Khammouan Province, is at the bridge on National Route 13 over the Se Bang Fai River, a tributary of the Mekong. Vegetable gardens and houses occur on both banks. The substratum is comprised of mixed boulders, concrete, sand, mud and debris. This location is frequently disturbed by village activities.

### LBH
(Se Bang Hieng River, Songkhone, Savannakhet)

This sampling site in Ban Se Bang Hieng, Songkhone District, Savannaket Province, is at the bridge over the Se Bang Hieng River, a tributary of the Mekong. Vegetable gardens and houses occur on both banks. The substratum comprises mixed boulders, concrete, sand, mud and debris. This location is moderately disturbed by village activities.

### LSD
(Se Done River, Ban Hae, Pakse)

This site on the Se Done River, a tributary of the Mekong in Ban Hae, Pakse Town, is about 4 km upstream from the confluence of Se Done River with the Mekong. The right bank has a vegetable garden and on the left are houses, a school and gardens. 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 Somsanouk, Attapeu)

This site is on the lower Se Kong River, a tributary of the Mekong River, in Ban Somsanouk, Sanamxay District, Attapeu Province. The right bank has a town, fruit gardens and a boat pier, with many eroded stretches of river bank. On the left bank are banana orchards, bamboo and also some bank erosion. The area was flooded in 2010 and the channel has now changed its shape around an island in the middle of the river. This site is moderately disturbed by domestic waste

and fishing activities. Substrata present in the faster-flowing current are pebbles and gravel, with sand and debris accumulating in the pool where the current is slower.

### LDN

(Mekong River, Done Ngiew, Pathumphone )

This sampling site is on the Mekong River at Done Ngiew in Ban Muang, Pathumphone District, Champasak Province. The sampling point is about 800 m upstream of the ferry crossing to Wat Phu. The environment of both banks has changed slightly since 2008. A steep slope along with bank erosion appears on the right bank where maize gardens, vegetables and riparian shrubs (dominated by *Homonoia riparia)* are also found. Plantations and ricefields and scattered households about 100-200 m from the bank. Substrata are bedrock, sand and some small islands in the channel. This location is slightly disturbed by fishing and navigation activities.

**Table 1.2.** Thailand sites sampled in 2011 and earlier biomonitoring surveys

| Site | Location | 2005 | 2006 | 2007 | 2008 | 2011 |
|---|---|---|---|---|---|---|
| TCS | Mekong River, Chiang San, Chiang Rai | | | | x | x |
| TKO | Kok River, Chiang Rai City | x | | | x | x |
| TSM | Songkram River and Mekong River junction, Nakorn Phanom | | | x | x | x |
| TNP | Mekong River, Nakorn Phanom City | | | | x | x |
| TNK | Nam Kham River, Na Kae, Mukdaharn | | | x | x | x |
| TUN | Mun River, Ubon Rachathani City | | | | x | x |
| TMU | Mun River, Kong Chiam, Ubon Rachathani | | | | x | x |
| TKC | Mun River and Mekong River junction, Ubon Rachathani | x | | | x | x |

## SITES IN THAILAND

Sampling sites in Thailand include localities on the Mekong and its major tributaries and are mostly in the northern and north-eastern parts, 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 farmlands and ranches; some are upstream or downstream of dams or weirs, and some are exposed to moderate to heavy river traffic.

### TCS

(Mekong River, Chiang San, Chiang Rai)

This site on the border between Thailand and Lao PDR is located in Chiang San District, the most important dock for navigation, import and export transport between Thailand and the upper Mekong countries. There is a flat sand bar on the left (Lao) side and on the right is an artificial bank comprising a concrete wall and stairs. The site is surrounded by large communities, with about 10,000 inhabitants, mainly on the Thai side. The riparian zone consists of some forest, cattle grazing areas, eroded banks, the presence of algae and aquatic plants and a local market. The substrate is sand, clay, mud and gravel. The human impact at this site is heavy due to road construction (Lao PDR), boat navigation, construction, domestic waste, and disposal from transport and other activities.

### TKO
(Kok River, Chiang Rai City)

This site is on the Kok River at Chiang Rai. The left bank has a 30 degree slope, while the right bank is flat. Both banks are eroded and riparian areas are cleared of forest, with agricultural development on the left bank and a village on the right. A cobble and gravel island lies in the centre of the river. Human influences include agricultural runoff and navigation as tourist boats create bank erosion by waves from large ships.

### TSM
(Songkram River and Mekong River junction, Nakorn Phanom )

This site is on the border between Thailand and Lao PDR. The left bank is a flat sand bar, while the right bank has a 40 degree slope. The riparian vegetation is bamboo forest. The site is surrounded by medium-size villages, with a total of about 250 households. The riparian zone consists of some forest, landslides, aquatic plants and algae such as river weed ('Kai' or Cladophora glomerata), a few houses, small-scale agricultural plots, piers and floating houses and fish cages. Most of the substrate at the site is sand and clay, firm mud and firm sand. Human impacts are heavy, due to a restaurant, fish cages, solid and farm wastes, agricultural runoff and livestock damage to the banks.

### TNP
(Mekong River, Nakorn Phanom City)

This site on the border between Thailand and Lao PDR is located about 1.5 km upstream of Nakorn Phanom City. It is surrounded by small villages, totaling about 200 households. The left bank, on the Lao side, is steep (30 degree slope) and the right bank (Thai side) has a 45 degree slope. The riparian zone consists of a few agricultural plots, floating houses, a shoreline, some trees on the bank and small-scale fish farms. Disturbances are moderate due to rubbish disposal, agricultural runoff, fish farming and bank erosion.

### TNK
(Nam Kham River, Na Kae Mukdaharn)

This site is located about 20 km downstream of a water supply station. The river here is shallow (<0.5–1.5 m depth) and both banks have a slope of 20–30 degrees. The vegetation on the right bank is bamboo and grasses. The substrate is comprised of wood and leaf debris, sand, clay, gravel, and mud. The site shows severe bank erosion and landslides. Disturbances are moderate due to disposal of human wastes and rubbish from upstream.

### TUN
(Mun River, Ubon Rachathani City)

This site is located about 10 km from Ubon Rachathani City and is surrounded by a few fishermen's houses. Both banks have a 15 degree slope. The riparian zone consists of a cattle grazing area, soil erosion, algae and aquatic plants. The substrate is mud and aquatic plants, sand, clay and firm sandy gravel. Disturbances are moderate due to disposal of human and animal wastes, navigation and agriculture.

## TMU

(Mun River, Kong Chiam, Ubon Rachathani)

This site which is located downstream from the Pak Mun Dam, and about 2 km above the confluence of the Mun and Mekong Rivers, Ubon Rachathani Province. It is surrounded by a small community of about 180 inhabitants. The banks have a 30 degree slope and the riparian zone consists of vegetable orchards, farmland, houses and floating houses and soil erosion. Human activities are cattle herding and fish farms with floating cages. The substrate is mostly sand and gravel. This site is highly disturbed from disposal of human and animal wastes, including agricultural and urban runoff.

## TKC

(Mun River and Mekong River junction, Ubon Rachathani)

This site, on the border between Thailand and Lao PDR, is located at the confluence of the Mun and Mekong Rivers. The banks are formed by sand bars. The left (Lao PDR) bank of the Mekong River is steep, with a 40 degree slope while the right bank (Thai side) has a 45 degree slope. The riparian vegetation is bamboo woodlands and the site is surrounded by fishing villages, with a population of about 800 inhabitants. Banks are eroded and human activities include tourism facilities, a pier, a floating house and floating fish cages. The substrate of the site is bedrock, sand and clay, firm mud and firm sand. This site is moderately disturbed by rubbish disposal and animal/fish farm wastes.

## SITES IN CAMBODIA

Nine more sampling sites in Cambodia's Mekong Basin were added, including the Mekong mainstream and its tributaries; the Tonle Sap and Bassac Rivers; and in the Tonle Sap Great Lake, reaching a total of 17 sites. The sites were selected in an attempt to include a diversity of habitats in the Cambodian Mekong.

## CMR

(Mekong River, Ramsar Site, Stung Treng)

This site on the upper Mekong River is in a Ramsar site. It is located at Ouchheatheal Village in Stung Treng Province. The sampling point is on the right bank, some 300 m below the Ouchheatheal dolphin deep pool. The right bank is a steep slope covered with flooded forest and farmland and the left bank has a tourist boat landing, fishing boats and a market. Human disturbance in this area is slight. The river is characterised by strong currents and the presence of algae. The substrata are grasses, sand, pebbles, and boulders.

## CKM

(Se Kong River, Kbal Koh, Stung Treng)

This site is at Phdao village on the Se Kong River in Stung Treng Province. The sampling point is on the left bank, a short distance from a house which has only one inhabitant. Human disturbance is minimal. The left bank is covered with forest, bamboo and farmland, while the right is covered with sand, riverine shrubs, trees and bamboo. The river flows slowly and the substrata are sand and pebbles.

## CUS
(Se San River, Dey It, Rattanakiri)

This site is on the Se San River in Rattanakiri province. The sampling point is on the left bank, 500 m from Phumpi village and 200 m from Phumbinh village, about 50 m below the ferry dock and 1-1.5 km downstream from the Se San hydropower dam. Trees grow on the left bank and a cassava farm is located about 50 m from the river bank. On the right bank there is a 100 m long sand bar, trees and farmland and the site is slightly disturbed from the ferry and dam. The substrata are boulders, cobbles and sand. In the middle of the river are boulders with clear water and strong currents.

## CSS
(Se San River, Veunsai, Rattanakiri)

This site on the Se San River is downstream of Banhang Village, in Rattanakiri Province. The sampling point is on the left bank, about 1 km from the upper ferry dock and houses. The left bank slopes for about 30 m to a house and trail, planted trees and a woodland. On the right bank is woodland mixed with bamboo. The substrata are pebbles and sand. Disturbance from the ferry and houses is low. The water is clear and shallow with strong currents. In the middle of the river are sandy pebbles.

## CSP
(Srepok River, Phik, Rattanakiri)

This site on the Srepok River is located in Phik Village, Lomphat District Rattanakiri Province. The sampling point is on the right bank, 200 m above the ferry dock and 300 m from houses, and human disturbance is low. Both banks were slopes covered with bamboo and forest. The substrata are sandy soil, sand and boulders with strong currents.

## CSJ
(Se San River, downstream from junction with the Srepok River)

The sampling site is on the Se San River (lower part of Srepok River) in Kompun Village, Stung Treng Province. The sampling

**Table 1.3.** Cambodia sites sampled in 2011 and earlier biomonitoring surveys

| Site | Location | 2005 | 2006 | 2007 | 2008 | 2011 |
|---|---|---|---|---|---|---|
| CMR | Mekong River, Ramsar Site, Stung Treng | x | x | x | x | x |
| CKM | Se Kong River, Kbal Koh, Stung Treng | x | x | x | x | x |
| CUS | Se San River, Dey It, Rattanakiri | x | x | x | x | x |
| CSS | Se San River, Veunsai, Ratanakiri | | | | | x |
| CSP | Srepok River, Phik, Rattanakiri | x | x | x | x | x |
| CSJ | Se San River, downstream from the junction with the Srepok River | x | x | x | x | x |
| CKT | Mekong River, Kampi Pool, Kratie | | x | | x | x |
| CPT | Prek Te River, Preh Kanlong, Kratie | | | | | x |
| CCK | Tonle Sap Lake, Chong Khnease, Siem Reap | | | | | x |
| CSN | Stung Sen River, Kampong Thom | | | | | x |
| CSK | Stoeng Sangke River, Battambang | | x | | x | x |
| CTU | Tonle Sap River, Prek Kdam Ferry, Kandal | | | | | x |
| CPP | Tonle Sap River, Phnom Penh Port | | | | | x |
| CPS | Pursat River, Damnak Ampil, Pursat | | | | | x |
| CKL | Tonle Sap Lake, Kampong Luong | | | | | x |
| CNL | Mekong River, Neak Loeung, Prey Veng | | | | | x |
| CKK | Bassac River, Khos Khel, Kandal | | x | | x | x |

point is on the left bank between Kompun and Chardoeum Villages, downstream of the Se San hydropower dam. Both banks have woodlands and farmlands, while bamboo also grows on the right bank. The site is moderately disturbed by farms and the dam. The water is clear with strong currents. Substrata consist of sand, pebbles, boulders and flooded forest. The upper part of the site has islands with farmland, and two channels, while in the lower part there is just one channel.

## CKT

(Mekong River, Kampi Pool, Kratie)

The sampling site is on the upper Mekong River in Kbalchour Village, Kratie Province. The sampling point is on the right bank, 200 m from the Kampi dolphin conservation area, with no fishing activity allowed. The right bank slopes slightly and is covered with flooded forest, boulders and sand. This bank also has a few houses, trees, bamboo, rice fields and farmland. On the left bank is a tourist-boat pier, national road, houses, crops, vegetables and rice fields. Human disturbance is low, due to the fact that it is in a protected area. The substrata are sand, boulders and cobble. Islands with flooded forest also occur in this part of the river, with sand on the lower islands. The water is clear with strong currents.

## CPT

(Prek Te River, Preh Kanlong, Kratie)

This site is on Prek Te River, in Preh Kanlong Village, Kratie Province. The sampling point is on the right bank, about 200 m from houses, where the river is 12 m wide. The site has been highly disturbed by fishing activity such as gillnets. The slightly sloping bank is covered with grasses, riparian shrubs, a corn farm and a rice field. The left bank features grasses, riparian shrubs (dominated by *Homonoia riparia*), trees, bamboo, crops, and houses.

## CCK

(Tonle Sap Lake, Chong Khnease, Siem Reap)

The sampling site is on Tonle Sap Lake near Chong Knease Village, Siem Reap Province. The sampling point is about 1 km from the shore and about 500 m from the boat waterway, disturbance is high from fishing and tourist boats. The lake shores are covered with flooded forests and is dominated by *Barringtonia asiatica* trees. The substrata are muddy soil, dead shells, and some solid waste. The water is turbid and algal blooms are present.

## CSN

(Stung Sen River, Kampong Thom)

The sampling site is located on the Stung Sen River, near Somrong Village in Kampong Thom Province. The sampling point is on the right bank about 300 m from houses. About 700 m further down, the river is highly disturbed by sand exploitation activities but above the sampling site it is undisturbed. Slopes on the right bank are covered with agricultural crops, tree plantations, rice fields, riparian grasses and shrubs. On the left bank, there is some erosion, shrubs and rice fields. The substrata are sandy soil and sand. The water is turbid with slow currents.

## CSK

(Stoeng Sangke River, Battambang)

The sampling site is on the Stoeng Sangke River, in Muthbangkang Village, Battam-

bang Province. The sampling point is on the right bank, about 800–900 m from the village, about 1–2 km upstream from Tonle Sap Lake. This site is moderately disturbed by trading boats traveling between Siem Reap and Battambang Province, and fishing boats. Both banks are sloping and covered with water hyacinth (*Eichhornia crassipes*), riparian grasses (*Cyperus elatus*), riparian shrubs and flooded forest. The turbid water of the river flows into the Tonle Sap Lake. The substrata of the area are muddy soil, bricks, wooden twigs and debris.

### CTU

(Tonle Sap River, Prek Kdam Ferry, Kandal)

The sampling site is on the Tonle Sap River, in Koeu Chhin, Kandal Province. The sampling point is on the right, 2 km from the Cambodia-China Bridge and 300 m from the village. About 20 m from the slightly sloping left bank are water hyacinth, riparian grasses and shrubs, and rice fields. Houses and National Road No. 5 are on the right bank. Human disturbance from housing is minimal. The turbid water flows from the Tonle Sap Lake. The substrata are muddy soil and clay.

### CPP

(Tonle Sap River, Phnom Penh Port)

The sampling site is located in Chroy Changwa Village, Phnom Penh. The sampling point is on the right bank about 350 m from Chroy Changwa Bridge. Disturbance is low, from a few boats that navigate this stretch of the river and only two or three fishing boats. The right bank features water hyacinth, riparian shrubs, some large trees, the National Road and houses. On the left bank is Phnom Penh Ferry Port and the National Road. The substrata are pebbles and muddy soil. The turbid water flows slowly here.

### CPS

(Pursat River, Damnak Ampil, Pursat)

This site is on the Pursat River, in Damnak Ampil Village, Pursat Province. The sampling point is Koh Thas, about 2–3 km from Damnak Ampil II Inlet. The right bank is a sandy slope with a community space, boulders, riparian grasses, and houses about 300 m from the river. A marsh/small lake with lotus (*Nelumbo nucifera*) is about 100 m from the river. On the left bank is some erosion, riparian grasses and trees. About 100 m from the river are houses, agricultural crops and rice fields. The substrata are sand, sandy soil, boulders and cobbles. The water is clear with slow currents and is slightly disturbed by gillnet fishing activities.

### CKL

(Tonle Sap Lake, Kampong Luong)

The sampling site is on the left bank of Tonle Sap Lake in Kampong Luong Village. The sampling point is about 800 m from houses, 500 m from the boat waterway and 1 km from the fishing lot margin. Between the rice fields and the lake is a flooded forest area with *Barringtonia asiatica*, grasses and waterplants. The site is moderately disturbed by floating houses and fishing activities. The substratum is mud, water is turbid and algal blooms are present. The waterway is used as a passage from the upper land (houses) to the lake shore.

**Table 1.4.** Viet Nam sites sampled in 2011 and earlier biomonitoring surveys

| Site | Location | 2005 | 2006 | 2007 | 2008 | 2011 |
|---|---|---|---|---|---|---|
| VTP | Mekong River, Thuong Phuoc, Dong Thap | | | | x | x |
| VTT | Mekong River, Thuong Thoi, Dong Thap | | | | x | x |
| VKB | Bassac River, Khanh Binh, An Giang | | | | x | x |
| VDP | Bassac River, Da Phuoc, An Giang | | | | x | x |
| VCL | Mekong River, Cao Lanh, Dong Thap, | | x | | x | x |
| VLX | Bassac River, Long Xuyen, An Giang, | | x | | x | x |
| VVL | Mekong River, My Thuan, Vinh Long | | | | x | x |
| VCT | Bassac River, Phu An, Can Tho | | x | | x | x |

## CNL

(Mekong River, Neak Loeung, Prey Veng)

The sampling site is located on the lower eastern Mekong River in Prek Svay Village, Prey Veng Province. The sampling point is on the left bank, about 500 m above a sand pumping site and about 1 km from Neak Loeung Ferry Port. The site has been greatly disturbed by sand dredging and fishing. Riparian grasses and shrubs grow on the sloping left bank. Water hyacinth, rice fields and a small lake are also found there. Riparian grasses and shrubs and farmland are found on the right bank.

## CKK

(Bassac River, Khos Khel, Kandal)

The site is located in Khpouk Village, Kandal Province on the Bassac River. The sampling point was on the left, 300 m upstream of the Khos Khel ferry dock. On the left bank is a slope covered with riparian grasses and shrubs, water hyacinth, maize, a vegetable plantation and a rice field. The right bank has riparian grasses and shrubs. The site is moderately disturbed by houses, a national road and some farmland.

## SITES IN 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. The substratum of these sites consists of fine sand, alluvia, and hard clay. The six sites are affected by tides. All sites are moderately to heavily impacted by human disturbances.

## VTP

(Mekong River, Thuong Phuoc, Dong Thap)

The site is located in Thuong Phuoc District, Dong Thap Province. Consist of housing, grasslands and fruit orchards are found at this site. The river bank is littered with solid wastes from domestic sources, such as plastic bags and bottles, clothes, sand bags, etc. The right bank has a substratum of sandy clay and wastes; the middle of the river is sandy and the left bank is clay. The main activities having an impact at the site are navigation and sand pumping. Dumping of construction material, fish farming and fishing also have an impact. Potential impacts are bank erosion and pollution from domestic waste.

## VTT

(Mekong River, Thuong Thoi, Dong Thap)

The site is located in Thuong Thoi District, Dong Thap Province, consists of crops

including legumes, chili peppers and maize, fruit orchards, grassland and housing. The right bank had a substratum of sandy clay and detritus; the middle and left bank of the river is sand and silt detritus. The main human activities are agriculture, navigation, cattle ranching, washing and capture fisheries. Potential impacts are bank erosion and pollution from domestic waste.

### VKB

(Bassac River, Khanh Binh, An Giang)

This site is at Khanh Binh District, An Giang Province on Bassac River, consists of farm and maize, legumes plantations, grasslands and housing. Water hyacinth grows in the river and there is evidence of bank erosion. Mud and sandflats, detritus, sediment, litter falls, twigs and domestic solid waste, i.e. plastic materials and cans, are also present. The substratum on both banks are silty detritus with solid waste and the middle of the river is sandy detritus. The main human activities affecting water quality are markets and commercial areas, grain storage and milling, cattle ranching, navigation, sand pumping, capture fisheries and fish farms, and washing.

### VDP

(Bassac River, Da Phuoc, An Giang)

The site is at Da Phuoc District, An Giang Province, consists of farmlands and housing. Bank erosion is present and the river contains water hyacinth, sunken bushes and trees. The substratum on the right bank is clay and sandy detritus, the middle of the river is sandy clay; and the left bank is clay with solid waste. Major activities affecting water quality are navigation, grain cultivation and fruit orchards, high intensive fish farming and capture fisheries, a grain processing factory and washing. Domestic solid waste, sewage and further bank erosion cause high disturbances.

### VCL

(Mekong River, Cao Lanh, Dong Thap)

The site is at Cao Lanh District, Dong Thap Province, dominated by farmlands and housing, with scattered grasslands, and water hyacinth growing in the river. Domestic solid waste and dead trees are found in the riverbed. The main activities are grain cultivation, fruit orchards and fishing. The right bank and the middle of the river are lined with sandy clay and detritus, while the left bank is mudflat and sandy detritus. This site is highly disturbed by pollution, organic and solid wastes, including domestic sewage and sand exploitation.

### VLX

(Bassac River, Long Xuyen, An Giang)

The site is at Long Xuyen District, An Giang Province, covered largely by houses and farmland, with some grasslands. Navigation on the river is intense. Domestic solid waste and dead trees are found in the riverbed. The main activities are fish farming and small industries. The right bank has a substratum of sulfide mud, the middle is sandy silt and the left bank is muddy detritus. This site is highly disturbed by pollution from organic and solid wastes, including domestic sewage and bank erosion.

### VVL

(Mekong River, My Thuan, Vinh Long)

The site is at My Thuan District, Vinh Long Province, covered largely by housing, orchards and cattle grazing. The main activities are a warehouse for construction material and sand pumping. Activities on the river are intense transportation, fish farming and capture fisheries. The riverbed is littered with domestic and agricultural solid wastes. The substratum of the right and the left banks are silty mud and the middle is sandy. Disturbances are high due to pollution from solid wastes including farm and domestic sewage, and bank erosion.

### VCT

(Bassac River, Phu An, Can Tho)

The site is at Phu An District, Can Tho City, consists of housing, small factories and farmland, including fruit orchards, cover this site. Water hyacinth grows in the river, which is also polluted with domestic solid wastes. Main activities are water transportation, landing and storage of goods, a small factory and capture fishery. The right bank is lined with sandy mud; while the middle of the river and the left bank both have silty sand as a substratum. This site is highly disturbed by pollution such as domestic solid wastes, spill from oil storages, and sewage from factories.

## DATA COLLECTION AND IDENTIFICATION

Data collection and identification of biota (benthic diatoms, zooplankton, littoral and benthic macroinvertebrates) follow the methodology described in MRC (2010a) for field, laboratory, and analytical methods for environmental variables and the four biological indicators.

### Environmental variables and status identification

The objective of studying the physical and chemical factors is to describe selected characteristics of the study sites in the lower Mekong River by collecting data on altitude, river width, depth, Secchi depth (water transparency), water temperature, dissolved oxygen (DO), pH and electrical conductivity (EC).

A field data sheet for environmental variables was provided for recording the following site information:

1. The map coordinates and altitudes of the sampling sites are determined with a Garmin GPS 12XL.
2. The stream or river width is measured, with a Newcon Optik LRB 7x50 laser rangefinder, by its wetted width at the current sampling time. Some sites are measured by Google Earth maps or GPS measurements at both banks.
3. At each site, environmental measurements in the water are made in three sections of the river: (i) near the left bank; (ii) near the right bank; and (iii) in the centre, making sure that the three sampling sections are within that Member Country's border, except at some mainstream border sites (Thai-Lao) and at Tonle Sap Grand Lake.

- Transparency is determined by measurement of Secchi disc depth.
- Temperature, DO, EC, and pH are mea-

sured with an electronic meter. Three readings are taken at each location at a depth of 0.5 m.

- Water depth is determined by dropping a weighted rope directly to the river bottom and is reported in metres.

4. In some situations, for determination of physical variables such as DO, pH and Conductivity (EC), water samples can be collected 0.5 m below the water's surface and examined later, details of the method can be found in 'Standard Methods for the Examination of Water and Wastewater' (APHA 1998).
5. All measured environmental variables are reported as average values. DO is reported as mg/L (ppm); electrical conductivity as mS/m and temperature in degrees Celsius. Water transparency, depth, elevation and river width are measured in metres. In Cambodia case, reported turbidity in NTU (Nephelometric Turbidity Units), instead of water transparency.

## Benthic diatoms

The objective of studying benthic diatoms is to quantitatively describe the characteristics of the diatom community as diatoms provide a rapid response to environmental changes.

*Field methods*

A field data sheet for benthic diatoms was provided to record the following site information:

1. The sampling of benthic diatoms within a site is performed close to the river bank, where the water is less than 1m deep and suitable substrata extends over a 100 m distance. At sites where the river bed is predominately muddy or sandy and lacks suitably sized stones, samples can be taken from branch litters or other hard substrates, and artificial materials.
2. At each site, ten samples are collected, one at a time, at about 10 m intervals. Where there are no suitable stones, the nearest hard substratum can be sampled.
3. To sample the diatoms, a plastic sheet with a 10 $cm^2$ cut-out is placed on the upper surface of the substratum, the surface is then brushed and the dislodged surface material is then washed into to a plastic container. Samples are preserved with Lugol's Solution.
4. The name of the site, the location code, the date of sampling, the sample-replicate number, the collector's name and substratum type are also noted in the field notebook, as is any information about the site that could be influencing the presence or abundance of different types of diatoms.

*Laboratory methods*

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

1. Sample is cleaned with strong acid ($H_2SO_4$, HCl, or $HNO_3$) and rinsed, distilled water is then added into 1 ml sample volume.
2. A drop of each sample (0.02 ml) is placed

on a microscope slide and dried to make a permanent slide for diatom identification and counting.

3. Identifications are made under a compound microscope and are based on the frustule type, size, special characteristics, and structure, as described and illustrated is various textbooks, monographs and other publications on tropical and temperate diatoms (see the list of identification aids).

*Analytical methods*

1. The richness, abundance, and ATSTP value are determined for each sample collected at a site. An average value is then calculated for each site.
2. Average richness is the number of taxa per 0.2 $cm^2$ sampled from each 1 ml sample. Calculated as the average of samples from the same site.
3. The total count of cells on the slide (0.02 ml) is used to estimate total number of individuals per sample, which is the abundance. The number of cells counted, when multiplied by 5, is the number per $cm^2$
4. The ATSPT for that site is calculated
5. Richness, abundance and ATSPT scores are always reported per sample (which is 0.2 $cm^2$)

*Identification aids*

The following references were used to identify benthic diatoms: Patrick (1939), Foged (1971, 1975, 1976), Krammer & Lange-Bertalot (1986, 1988, 1991a, 1991b), Pfister (1992) and Peerapornpisal, *et al*. (2000). A book on diatoms of the Lower Mekong is in preparation (Kunpradit *et al*. in prep.).

## Zooplankton

Zooplanktons were studied in order to quantitatively describe the characteristics of the zooplankton community. Zooplankton reflect the condition of the environment and water quality of the water column.

*Field methods*

1. Three samples are collected at each site. One sample is taken near the left bank of the river, at a distance of about 4-5 m from the water's edge. A second sample is taken in the middle of the river. And a third sample from the right bank , if a site is on a national border, the three samples should be taken within that Member Country's border.
2. Samples are taken at least 1 m from potential contaminants such as debris and aquatic plants, and at least 2 m from vertical banks.
3. The 10 l samples of river water are filled slowly through a plankton net (with a mesh size of 20 µm) to avoid any overflow from the net. The plankton is then transferred to a 250 ml sampling jar.
4. The sample is immediately fixed in the field by adding ~ 75 ml of 10% formalin to achieve a final concentration of 4-5% formalin in the sample jar. The sample jars are labeled with the site name, the site code, the sampling position and date.

The site name, the site code, the sampling position (left bank, middle, right bank), the sampling date, the sample number and the collector's name are also noted in the field notebook, as is any information about the

site that could be influencing the presence or abundance of different types of zooplankton.

*Laboratory methods*

1. In the laboratory, each sample is filtered through a net with a mesh size of 10 µm, rinsed with distilled water, and then allowed to settle to the bottom of a graduated cylinder and left for 1 hour.
2. All individuals collected are counted and identified to the lowest taxonomic level possible, generally that of species. After analysis, samples are returned to the bottles and preserved as reference materials.

*Analytical methods*

The average richness, abundance and ATSPT values are determined and reported for each sample (which is 10 L) and averaged for the site.

*Identification aids*

The following references were used to identify zooplankton: Kudo (1963), Dang *et al*. (1980) and Eiji (1993). A book on the identification of zooplankton for the Lower Mekong is in preparation (Dang *et al*. in prep.).

## Littoral macro-invertebrates

Littoral macro-invertebrates are monitored as their characteristics reflect the quality of areas near the riparian zone and the influence of many human activities that occur there.

*Field methods*

Littoral macro-invertebrate samples are usually taken on only one side of the river at each site. In most instances this is done on the depositional, rather than the erosion side. The depositional side tends to support more habitats 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 were selected at each site to facilitate comparisons between sites.

The sampling method follows these steps :

1. 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 see detailed methods in MRC, 2010a .
2. Ten samples are taken per site, and 10 sweeps make up a sample. Therefore, 100 sweeps are made when taking 10 individual samples at each site.
3. The 10 cleaned invertebrates samples of each site are preserved in 70-90% ethanol for identification in the laboratory and marked with label of the site name, the site code, the date, and the sample replicate number.
4. Information about collector's name, substrate types sampled as well as any information or characteristics about the site is filled in on the field data sheet.
5. In the laboratory, the samples are identified under a stereo dissection microscope with a 2x – 4x objective lens and a 10x eyepiece. Identification is done to the lowest taxo-

nomic level that could be applied accurately, which is usually to genus.

6. Identified specimens from each site are grouped into Phylum and then Orders, before being kept in separate jars for each taxon along with 70% ethanol, before being labeled.

*Analytical methods*

Richness, abundance and ATSPT scores are calculated per sample area (which is 10 sweeps or approximately 3 $m^2$ of substrate surface area), and the average result is then calculated for each site.

*Identification aids*

The following references were used to identify littoral macro-invertebrates: Dudgeon (1999), Morse *et al*. (1994), Merritt & Cummins (1996) and Merritt *et al*. (2008); and specifically for the Lower Mekong macro-invertebrate fauna (Sangpradub and Boonsoong 2006).

## Benthic macro-invertebrates

Benthic macro-invertebrates were monitored in order to quantitatively describe the characteristics of the macro-invertebrates that occur in the bottom substratum in deeper waters away from the littoral zone of the river.

*Field methods*

1. Sampling locations at each site are selected in the right, middle, and left parts of the river. If a site is on a national border, the three sections to be sampled should be within that Member Country's border.
2. Samples are taken at a minimum of three to a maximum of five plots at each location. More samples are required at sites with higher inter-sample variability (assessed on the basis of monitoring results from previous years), than in sites with lower variability.
3. At each sampling plot, four sub-samples are taken with a Petersen grab sampler and composited into a single sample, covering a total area of 0.1 $m^2$
4. Each sample is washed through a sieve (0.3 mm mesh) with care taken to ensure that macro-invertebrates do not escape over the sides of the sieve.
5. The content of the sieve is then placed in a white sorting tray and the material (including the benthic macro-invertebrates) is dispersed in water. All the animals are fixed with 10% formaldehyde to a final concentration of 5%. Alternatively, 95% ethanol can be used. It is crucial that the final alcohol concentration after specimens are added never falls below 70% .
6. The collector's name, the sampling site name, the location code and the replicated sample number are recorded in a field datasheet. Information about substrate types sampled as well as any information or characteristics about the site that could be influencing the presence or abundance of different types of benthic macro-invertebrates are included.

*Laboratory methods*

All individuals collected are identified and counted under a compound microscope (with a magnification of 40 – 1,200x) or a

dissecting microscope (16-56x). Oligochaeta worms, mollusc, and crustacea are generally identified to species level. Insects are usually identified only to generic level.

*Analytical methods*

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

*Identification aids*

The following references were used to identify benthic macro-invertebrates: Resh & Jackson (1993), Morse *et al*. (1994), Thorne & Williams (1997), Dudgeon (1999), Pinder, (1999) Merritt *et al*. (2008), Sangpradub and Boonsoong (2006), and Yule and Sen (2004). Sangpradub and Boonsoong (2006) specifically cover the Lower Mekong macro-invertebrate fauna.

## CALCULATION OF BIOMETRIC INDICATORS

This section reviews the calculation and analysis of the different metrics.

### Calculation of abundance

Abundance is a measure 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 of area, volume or sample.

### Calculation of average richness

Average richness refers to the average number of taxa (types) of plants or animals belonging to a particular indicator group (e.g. diatoms, zooplankton) counted in samples from the same site.

### Calculation of ATSPT

A tolerance value was calculated for each taxon collected during the baseline studies conducted in 2004, 2005, 2006 and 2007 (MRC, 2005b; MRC, 2006; MRC, 2008 and MRC,2010a). Tolerance values for new taxa collected in 2008 onward were determined from the average Site Disturbance Scores (SDS) at the sites where these new taxa were found. Tolerance values are derived by assessing the relationship between the presence and absence of species in samples from each study site and the value of an independently measured SDS for each site. A visual method for determining the SDS is described in MRC (2010a).

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.

The ATSPT is then calculated for each sample collected. ATSPT is the average tolerance of all taxa recorded in a sample, calculated without regard to their abundances. A worked example on the calculations is given in MRC (2010a) , see table 2.1.

## USING BIOLOGICAL INDICATORS TO EVALUATE SITES

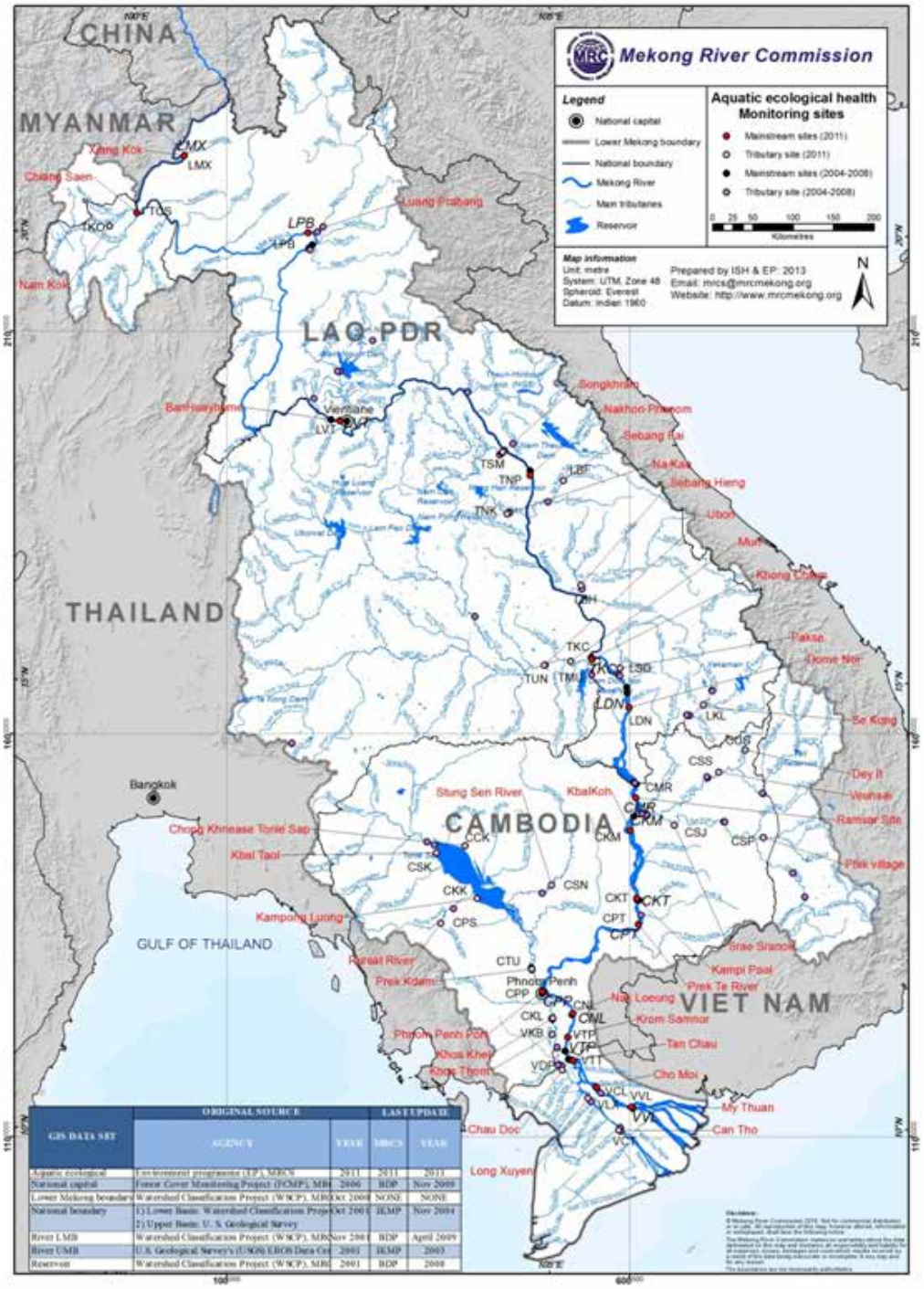
Three types of indicators of the health of the aquatic ecosystem are calculated for each of four groups of organisms included in the biomonitoring programme (benthic diatoms, zooplankton, littoral macro-invertebrates and benthic macro-invertebrates). These indicators are abundance (mean number of individual organisms per sample), average richness (mean number of taxa per sample) and tolerance ATSPT. Signs of a disturbed ecosystem are low abundance (few organisms present), low average richness (low biodiversity), or a ATSPT (signifying a scarcity of disturbance-sensitive species and a predominance of hardy species that are able to withstand disturbances), relative to the conditions found at the reference sites.

Each indicator is calculated for the individual samples of each group of organisms that are collected at a site. The collection of multiple samples per site enables assessment of within-site variability of the indicators and also statistical testing of the significance of differences between sites and within the same site over multiple years. For overall assessment of a site, the values of each indicator from individual samples are averaged.

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 than 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 2.1. The sites are classed and grouped according to the number of the 12 indicators that met the guidelines, based on biological conditions (MRC, 2010a). It is important to remember that while each of the rating criteria has a scientific basis, the classification and guideline system is subjective, and, being a policy decision, can be changed.

## DESIGNATION OF REFERENCE SITES

Reference sites are used in both physical-chemical monitoring (e.g. to set water quality criteria) and biological monitoring programmes worldwide. In biomonitoring, the sites chosen as reference sites are usually selected on the basis of good water quality and habitat, and minimal disturbance from human activities. They are commonly those sites that are in a most natural, or pristine, state but at other times they are the sites with the best attainable condition. Reference sites for the Mekong provide benchmark data against which all sites in the system can be compared (MRC 2010a, Fig. 2).




| GIS DATA SET | ORIGINAL SOURCE | | LAST UPDATE | |
|---|---|---|---|---|
| | AGENCY | YEAR | MRCS | YEAR |
| Aquatic ecological | Environment programme (EP), MRCS | 2011 | 2011 | 2013 |
| National capital | Forest Cover Monitoring Project (FCMP), MRC | 2000 | BDP | Nov 2009 |
| Lower Mekong boundary | Watershed Classification Project (WSCP), MRCOct 2001 | | NONE | NONE |
| National boundary | 1) Lower Basin: Watershed Classification Project Oct 2001<br>2) Upper Basin: U. S. Geological Survey | | BDP | Nov 2004 |
| River LMB | Watershed Classification Project (WSCP), MRCNov 2001 | | BDP | April 2009 |
| River UMB | U.S. Geological Survey's (USGS) EROS Data Cer | 2001 | BDP | 2003 |
| Reservoir | Watershed Classification Project (WSCP), MRC | 2001 | BDP | 2008 |

**Figure 2.1** Reference sites (stars) selected and agreed in 2004–2008 biomonitoring activities

## Characteristics of reference sites

Reference sites are selected from those sampled in the biomonitoring programme by the application of water quality criteria that are based on those applied by the MRC Environment Programme's Water Quality Index (MRC 2008). Site disturbance is scored by the national and international experts present on each sampling occasion, with regard to 13 site-scale activities including disturbances, bank erosion, human activities, agriculture, infrastructure and water behaviour (MRC, 2010a).

The SDS scores can range from 1 (little or none of any of these types of disturbance) to 3 (substantial disturbance of one or more types).

Visual assessment is used because it is not possible to make quantitative measurements of all of these types of disturbance. Visual scoring systems are widely used in stream assessments for features that are not amenable to quantitative measurement. Averaging the scores by several observers even out the influence of individual perceptions.

To be selected as a reference site, a site has to meet all of the following requirements:

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 70mS/m, but due to the brackish water conditions in the Delta, this criteria needed to be reviewed.
3. The dissolved oxygen concentration at the time of biological sampling was greater than 5mg/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

**Table 2.1.** Guideline for biological indicators of ecosystem health based on 2004–2007 baseline studies

| | BIO-INDICATOR GROUPS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Diatoms | | Zooplankton | | Littoral macroinvertebrates | | Benthic macroinvertebrates | | |
| | REFERENCE SITE VALUE | | | | | | | | |
| Biological metrics | 10th percentile | 90th percentile | 10th percentile | 90th percentile | 10th percentile | 90th percentile | 10th percentile | 90th percentile | Guideline of healthy ecosystem |
| Abundance (mean number of individual organisms per standard samples) | 136.22 | 376.34 | 22.33 | 174.07 | 46.68 | 328.56 | 5.37 | 56.34 | Greater than 10th percentile |
| Average richness (mean number of taxa per standard samples) | 6.54 | 11.78 | 9.8 | 20.2 | 5.37 | 18.48 | 1.84 | 7.85 | Greater than 10th percentile |
| Average Tolerance Score per taxon (ATSPT) | 30.85 | 38.38 | 35.54 | 41.8 | 27.8 | 33.58 | 31.57 | 37.74 | Less than 90th percentile |

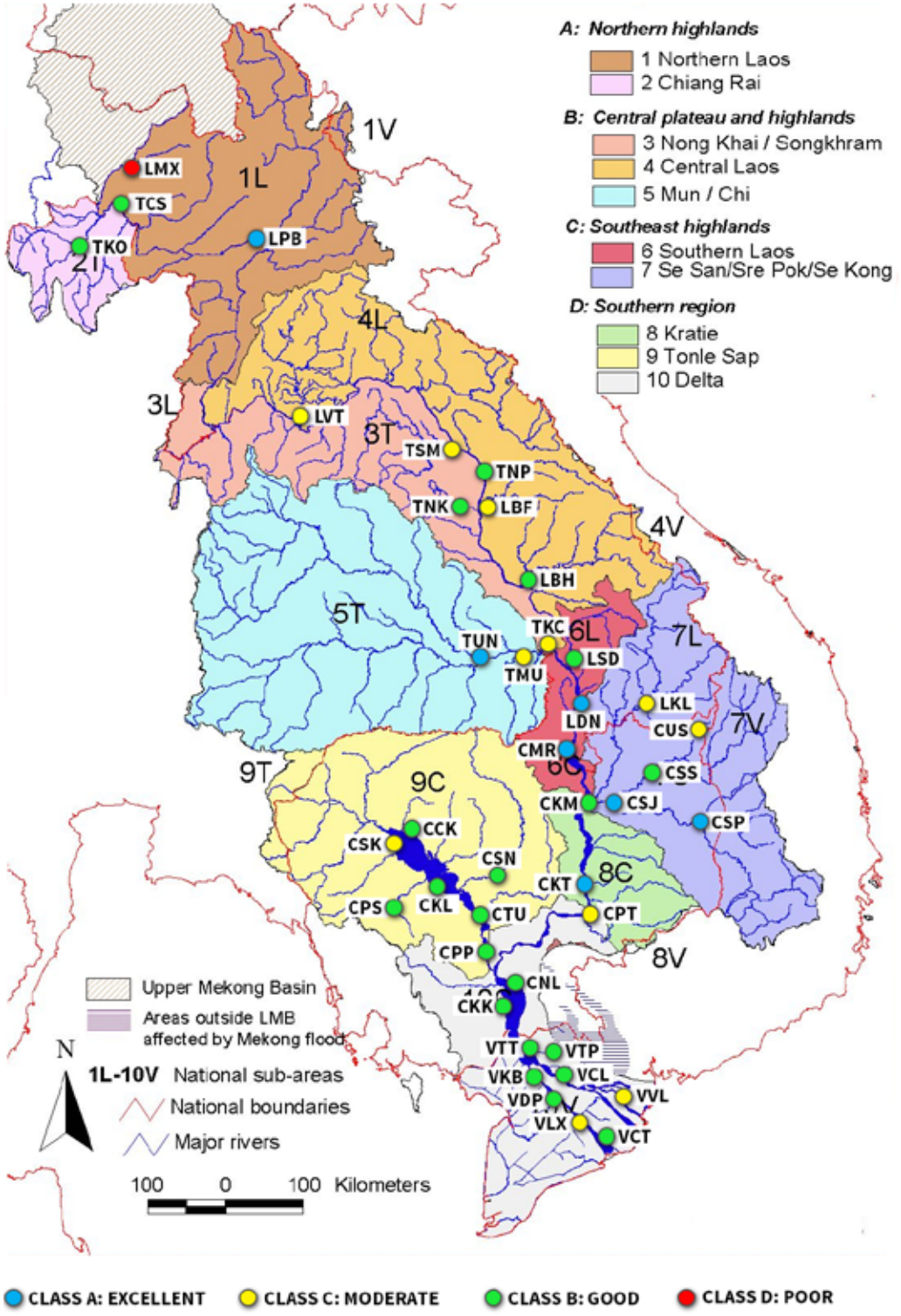



**Figure 2.2** Sampling sites in the Lower Mekong Basin surveyed in 2011 and their ratings

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. 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 has upstream flow because of tidal influence.

## Classification and scoring system for sampling sites

For each biological group, three metrics were used to assess the site – average abundance, average richness, and ATSPT. The final impact of human activities was assessed by comparing how similar the three characteristics for four biological groups are to corresponding values at the 14 MRC reference sites (MRC, 2008, 2010a).

Four biological groups: benthic diatoms, zooplankton, littoral macroinvertebrates and benthic macroinvertebrates were selected for the studies and the three metrics measured for each, giving a total of 12 biological indicators to evaluate sites. The sites were classed in one of the four following groups:

• 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.

• Class 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.

• Class 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.

# RESULTS & DISCUSSIONS

# RESULTS & DISCUSSION

## PHYSICAL ENVIRONMENTAL VARIABLES

The Site Disturbance Score (SDS) is determined by the environmental variables data including site physical condition and water chemistry. The SDS of the 41 sites of LMB, show that most of the sites are low to moderately stressed.

### Lao PDR

All of the physical environmental variables measured in each sample are shown in Appendix 3.1. The variables showed a broad range of values across the eight widely dispersed study sites (Table 3.1). For example, altitude varied from 72 m above sea level (ASL) at sites LKL to 410 m at site LMX. Channel width varied from 80 m at LBF to 1,235 m at LDN. Water transparency (Secchi depth) ranged from 0.25 m at LSD, LKL and LVT to 1.25 m at site LDN. The average transparency of all sites was 0.66 m (with standard deviation of ± 0.41 m).

Water temperature varied slightly from site to site, with an average of 24.2°C (± 3.5°C). The lowest value of 18.3°C was recorded at site LMX and the highest value of 29.4°C at site LSD. Dissolved oxygen (DO) concentrations were generally high compared to those typically reported for tropical waters, with an average of 7.6 mg/L ( 0.3 mg/L).

Water was slightly alkaline at most of the sites, with pH varying from 6.93 to 7.9. Electrical conductivity varied from 73.2 to 479 µS/cm. The highest conductivity was found at site LBH and the lowest value was found at site LKL.

The Site Disturbance Score ranged from 1.66 to 2.18 and only two sites (LVT and LDN) met the reference site level, (both at 1.66). Most of the sites are close to moderate stress (1.8–1.9) and LMX is categorised as moderate stress at 2.18.

### Thailand

The physical environmental variables showed a significant variation across the sampling sites. The water temperature varies from 21.4°C to 29.0°C. Low temperatures were recorded at most of the upstream sites, with the lowest value of 21.4 °C recorded at TNP. Higher temperatures were recorded at TMU, with the highest values of 29.0°C in the Mun River. The dissolved oxygen (DO) concentrations were generally high compared to those typically reported for tropical waters, with an average of 7.1–8.8 mg/L. The highest DO value (8.81 mg/L) was recorded at Mun River (TUN). The lowest DO value was found at TKO (7.1 mg/L). The pH was neutral at most sites, with values varying between 7.1 and 7.8. The highest pH value of 7.78 was recorded at Chiang San (TCS) and the lowest at Kong Chiam (TKC) with the value 7.09. The electrical conductivity varied from 120 to 432 µS/cm. The highest conductivities were found at the TNK site (432 µS/cm) while the

**Table 3.1.** Physical environmental variables at the 41 sites sampled in 2011

| Site Code | Altitude (m) | Width (m) | Average Depth (m) | Secchi depth (m) Turbidity (NTU: Cambodia) | Temperature (°C) | DO (mg/L) | pH | EC (µS/cm) | SDS |
|---|---|---|---|---|---|---|---|---|---|
| LMX | 410 | 120 | 4.16 | 0.5 | 18.3 | 8.13 | 7.85 | 328 | 2.18 |
| LPB | 407 | 245 | 4 | 0.7 | 21.2 | 7.83 | 7.9 | 308 | 1.66 |
| LVT | 178 | 800 | 2.5 | 0.25 | 24.5 | 7.31 | 7.88 | 286 | 1.84 |
| LBF | 134 | 100 | 4.9 | 1.1 | 23.2 | 7.68 | 7.61 | 189.7 | 1.93 |
| LBH | 111 | 153 | 2.6 | 1 | 26.8 | 7.15 | 7.27 | 479 | 1.83 |
| LSD | 101 | 128 | 3.8 | 0.25 | 29.4 | 7.57 | 7.23 | 113 | 1.81 |
| LKL | 72 | 200 | 3.7 | 0.25 | 27 | 7.22 | 6.93 | 73.2 | 1.85 |
| LDN | 82 | 1235 | 3.7 | 1.25 | 24.4 | 7.59 | 7.33 | 239 | 1.66 |
| TCS | 364 | 600 | 10.5 | 0.32 | 22.7 | 8.01 | 7.78 | 309 | 2.3 |
| TKO | 391 | 120 | 1.8 | 0.51 | 27.1 | 7.12 | 7.11 | 120 | 1.9 |
| TSM | 135.5 | 350 | 1.8 | 0.41 | 25 | 7.9 | 7.45 | 244 | 1.9 |
| TNP | 133 | 850 | 10 | 0.38 | 21.4 | 7.56 | 7.45 | 244 | 1.9 |
| TNK | 130 | 15 | 3.5 | 1.6 | 26 | 7.51 | 7.34 | 432 | 2.0 |
| TUN | 95 | 285 | 4.5 | 0.8 | 27.2 | 8.81 | 7.75 | 303 | 2.0 |
| TMU | 98 | 255 | 7.5 | 1 | 29 | 7.41 | 7.33 | 139 | 2.1 |
| TKC | 86 | 1015 | 13.5 | 0.51 | 24 | 7.72 | 7.09 | 237 | 1.9 |
| CMR | 58 | 186 | 3.53 | 11.67 NTU | 26.3 | 8.59 | 7.94 | 216 | 1 |
| CKM | 58 | 431 | 2.95 | 7.33 | 28.93 | 6.78 | 7.52 | 70.5 | 2 |
| CUS | 134 | 47 | 1.14 | 17.00 | 26.13 | 8.17 | 6.82 | 45.3 | 2 |
| CSS |  | 250 | 1.25 | 7.33 | 27.63 | 8.6 | 6.91 | 44.3 | 2 |
| CSP | 100 | 186 | 3.9 | 13.00 | 27.67 | 8 | 6.91 | 59.8 | 2 |
| CSJ | 50 | 576 | 1.25 | 5.67 | 28.47 | 8.21 | 7.19 | 200.6 | 1 |
| CKT | 12 | 55 | 2.3 | 8.00 | 27.87 | 8.79 | 7.8 | 184.2 | 1 |
| CPT |  | 22 | 1.4 | 38.00 | 27.2 | 7.64 | 6.88 | 98.4 | 2 |
| CCK |  |  | 1.25 | 240.00 | 24.2 | 5.82 | 6.86 | 103 | 2 |
| CSK | 5 | 135 | 1.5 | 326.33 | 26.3 | 5.48 | 7.1 | 301.7 | 3 |
| CSN |  | 65 | 1.12 | 154.67 | 28.23 | 5.56 | 6.85 | 58.2 | 2 |
| CTU |  | 497 | 15 | 232.63 | 29.47 | 6.02 | 6.83 | 717 | 2 |
| CPP |  | 536 | 6.8 | 102.67 | 28.33 | 5.73 | 6.87 | 102.1 | 3 |
| CPS |  | 147 | 1.5 | 38.33 | 27.73 | 7.04 | 7.16 | 71.5 | 2 |
| CKL |  | ne | 1.12 | 714.00 | 28 | 4.56 | 7.8 | 69.2 | 2 |
| CNL |  | 2150 | 18.3 | 14.00 | 30.57 | 7.74 | 7.92 | 181.9 | 2 |
| CKK | 3 | 280 | 13.5 | 30.87 | 29.97 | 6.07 | 7.23 | 158.4 | 3 |
| VTP |  | 1720 | 11 | 0.75 | 27.9 | 6 | 8 | 90 | 1.9 |
| VTT |  | 1562 | 3 | 0.9 | 28 | 5.8 | 8 | 120 | 1.8 |
| VKB |  | 187 | 4 | 0.77 | 28.5 | 5.8 | 7.4 | 90 | 1.9 |
| VDP |  | 325 | 12 | 0.65 | 28.7 | 4.9 | 7.5 | 140 | 1.8 |
| VCL |  | 1089 | 7 | 0.58 | 28.5 | 4.9 | 7.6 | 130 | 1.8 |
| VLX |  | 798 | 27 | 0.72 | 29.1 | 6 | 6.3 | 120 | 2 |
| VVL |  | 1012 | 19 | 1 | 28.9 | 3.5 | 7.2 | 150 | 1.9 |
| VCT |  | 1611 | 9 | 0.75 | 29.2 | 2.6 | 7.1 | 140 | 2.1 |

lowest conductivity was found at site in the Nam Kok River, TKO (120 µS/cm).

The physical environmental variables at the sampling sites were mostly within the natural ranges expected for surface waters in this region. All sites had DO values higher than 7 mg/L. However, all measurements were made during daylight, meaning that some values may be affected by significant photosynthesis activity and could be expected to be lower at night.

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, Vietnam, and Cambodia (MRC, 2005) and could be classed in categories 1–2 (extra to very clean surface waters) (PCD, 2004) based on the Water Quality Standards of Thailand.

The SDS in Thailand is highest at TCS (2.3), while most sites indicate moderate or close to moderate stress, ranging from 1.9 to 2.1. No site met the reference site level.

## Cambodia

The 2011 monitoring activity in Cambodia collected samples from 17 sites over the whole Mekong system, consisting of the mainstream Mekong, the Sesan, Srepok and Sekong (3S), lower Mekong, Bassac River, Tonle Sap River, Tonle Sap Lake and some of its tributaries. The longest distance between sampling locations was less than 200 km and so differences in temperature between sampling sites were very small. The highest temperature (30.6°C) was obtained at Nak Leoung on the lower Mekong River (CNL), the lowest temperature (24.2°C) was found at Chong Khneas on the northwestern part of Tonle Sap Lake (CCK). The data showed electrical conductivity ranging between 44 µS/cm and 300 µS/cm, except at Prek Kdam on the Tonle Sap River (CTU) which had an EC of 717 µS/cm. Dissolved oxygen ranged between 4.56 and 8.79 mg/L. The lowest DO was found at Tonle Sap Lake, Kampong Luong (CKK). The data showed that DO in the centre and south of the country was generally lower than in the north. This difference may be explained by the presence of waterfalls and rapids in the Mekong River in the north, which provide significant aeration of water. Turbidity (measured as NTU in Cambodia) varied widely. Sampling sites in Phnom Penh and on the Tonle Sap River and lake had very high turbidity levels. The survey data showed that the turbidity was typically higher in the Tonle Sap River and lake and its tributaries than elsewhere.

The SDS ranged from 1 to 3, with three sites meeting reference site level (SDS 1), CMR, CSJ and CKT. Most of the other sites show moderate stress (SDS 2) and three sites indicate heavy stress (SDS 3), CSK, CPP and CKL.

## Viet Nam

The data measured from 2004 to 2011 along the Vietnamese part of the Mekong River show that the impact of human activities on the river is still moderate. Water transparency (Secchi depth) ranged from 58 cm at VCL to 100 cm at VVL. The Secchi disk

depth is higher at all sites when compared with the results from 2008. Water temperature ranged from 27.9°C at VTP to 29.2°C at VCT whereas dissolved oxygen (DO) ranged from 2.6 mg/L at VCT to 6 mg/L at VTP and VLX. With the exception of VCT and VVL, DO values were within the range defined for aquatic ecosystems (higher than 5 mg/L). The sites VCT and VVL show evidence of human disturbance, with many potential pollution sources being identified by visual inspection during sampling. Both these sites had DO values lower than 4 mg/L, falling within class B2 (very dirty) of Viet Nam's water quality standards. Such a low concentration of DO can seriously harm aquatic ecosystems. The lower DO values were found at sites with more human activities. The water was slightly alkaline at most sites, with pH varying from 6.3 to 8. Electrical conductivity (EC) varied from 90 µS/cm to 150 µS/cm.

The pH and temperature data were within the ranges defined for aquatic ecosystems according to the standards for surface water quality set by Thailand, Viet Nam, and Cambodia (MRC, 2005; PCD, 2004).

The SDS indicate close to moderate stress for all locations, with values ranging from 1.8 to 2.1.

## BENTHIC DIATOMS

The benthic diatom sampling from all sites were calculated in quantitative results. This year the results from Cambodia show extraordinarily high numbers.

### Lao PDR

A total of 20,502 diatom cell counts were collected in Lao PDR, with 96 species identified from 80 samples collected at the eight sites in 2011.

*Average abundance*

The average abundance of benthic diatoms ranged from 26 to 1021 cells (Table 3.2). A comparison of the previous years' samples with those of 2011 showed a high variability over time. For example, in 2008 the average abundance of 58 cells found at LSD increased to 1021 cells found in samples in 2011. However at most (6) sites abundance had decreased.

*Average richness*

The total number of taxa per site (comprising 10 samples each with their average richness determined) ranged from 23 to 79 taxa. The average richness per site ranged from 5 to 26 species (Table 3.2). The lowest average richness was found at both LMX and LKL, and the highest at LSD. The average richness per site in 2011 showed a 7- and 13-fold increase at LDN and LSD, respectively, other sites showed much less change compared to the 2008 survey.

*ATSPT*

The Average Tolerance Score Per Taxon (ATSPT) of diatom samples taken in 2011 ranged from 31 to 39, with the lowest at site LDN (Table 3.2) and the highest at LSD, LKL and LVT which is just outside the range indicating a healthy ecosystem according to the MRC guidelines (see Table 2). ATSPT values within sites and over time showed little change.

**Table 3.2.** The values of average abundance, richness and ATSPT for benthic diatoms (2005–2011)

| | Abundance | | | | | Average richness | | | | | ATSPT | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site Code | 2005 | 2006 | 2007 | 2008 | **2011** | 2005 | 2006 | 2007 | 2008 | **2011** | 2005 | 2006 | 2007 | 2008 | **2011** |
| LMX | 133 | | | 82 | **26** | 10 | | | 3 | **5** | 39 | | | 45 | **33** |
| LPB | 305 | | | 568 | **299** | 12 | | | 5 | **12** | 38 | | | 41 | **38** |
| LVT | | | 1,338 | 373 | **258** | | | 8 | 6 | **8** | | | 39 | 40 | **39** |
| LBF | | | 46 | 75 | **42** | | | 6 | 2 | **7** | | | 36 | 36 | **35** |
| LBH | | | 257 | 197 | **79** | | | 8 | 6 | **8** | | | 36 | 39 | **35** |
| LSD | | | 108 | 58 | **1021** | | | 8 | 2 | **26** | | | 38 | 40 | **39** |
| LKL | 219 | | 63 | 305 | **26** | 7 | | 7 | 5 | **5** | 35 | | 40 | 38 | **39** |
| LDN | | | 266 | 213 | **224** | | | 9 | 3 | **21** | | | 34 | 35 | **31** |
| TCS | | | | 366 | **2911** | | | | 12 | **16** | | | | 37 | **44** |
| TKO | 229 | | | 318 | **1275** | 10 | | | 8 | **20** | 40 | | | 37 | **41** |
| TSM | | | 128 | 252 | **1028** | | | 5 | 11 | **10** | | | 39 | 36 | **40** |
| TNP | | | | 219 | **777** | | | | 6 | **12** | | | | 38 | **41** |
| TNK | | | 101 | 300 | **103** | | | 7 | 8 | **9** | | | 48 | 39 | **38** |
| TUN | | | | 45 | **434** | | | | 7 | **10** | | | | 37 | **40** |
| TMU | | | | 272 | **1471** | | | | 6 | **13** | | | | 39 | **40** |
| TKC | | | | 279 | **1069** | | | | 12 | **10** | | | | 38 | **38** |
| CMR | 206 | 217 | 58 | 439 | **161,269** | 6 | 10 | 7 | 6 | **24** | 33 | 36 | 37 | 33 | **31** |
| CKM | 191 | 250 | 71 | 820 | **594,215** | 9 | 11 | 7 | 10 | **27** | 33 | 37 | 34 | 34 | **31** |
| CUS | 269 | 140 | 287 | 412 | **256,323** | 9 | 6 | 5 | 8 | **24** | 36 | 39 | 38 | 37 | **31** |
| CSS | | | | | **137,012** | | | | | **11** | | | | | **33** |
| CSP | 232 | 308 | 532 | 219 | **178,624** | 10 | 9 | 8 | 6 | **14** | | | | | **33** |
| CSJ | 214 | 314 | 655 | 916 | **92,982** | 7 | 11 | 6 | 9 | **18** | 30 | 36 | 35 | 36 | **31** |
| CKT | | 134 | | 307 | **135,835** | | 8 | | 6 | **21** | 33 | 36 | 34 | 33 | **29** |
| CPT | | | | | **244,500** | | | | | **14** | | 39 | | 36 | **37** |
| CCK | | | | | **81,073** | | | | | **17** | | | | | **37** |
| CSK | | 107 | | 469 | **22,195** | | 5 | | 5 | **14** | | | | | **37** |
| CSN | | | | | **146,095** | | | | | **11** | | 44 | | 41 | **36** |
| CTU | | | | | **251,643** | | | | | **12** | | | | | **34** |
| CPP | | | | | **40,728** | | | | | **14** | | 44 | | 34 | **36** |
| CPS | | | | | **552,748** | | | | | **33** | | | | | **32** |
| CKL | | | | | **23,058** | | | | | **16** | | | | | **34** |
| CNL | | | | | **53,339** | | | | | **11** | | | | | **35** |
| CKK | | 311 | | 64 | **179,141** | | 8 | | 3 | **12** | | | | | **36** |
| VTP | | | | 1,384 | **251** | | | | 13 | **14** | | | | 49 | **45** |
| VTT | | | | 2,362 | **395** | | | | 16 | **17** | | | | 51 | **45** |
| VKB | | | | 510 | **229** | | | | 12 | **12** | | | | 51 | **45** |
| VDP | | | | 4,936 | **212** | | | | 14 | **11** | | | | 50 | **45** |
| VCL | | 180 | | 603 | **811** | | 6 1 | | 3 | **18** | | 49 | | 51 | **45** |
| VLX | | 317 | | 213 | **625** | | 6 | | 12 | **14** | | 51 | | 50 | **46** |
| VVL | | | | 14,925 | **524** | | | | 15 | **19** | | | | 52 | **46** |
| VCT | | 72 | | 362 | **752** | | 5 | | 11 | **20** | | 48 | | 50 | **47** |

## Thailand

The eight sites sampled in 2011 yielded a total of 105 species of benthic diatoms in the 90,983 cell counts from benthic diatom samples collected. The most common species were found in the order Naviculales (19 species). *Cymbella turgidula*, *Navicula symmetrica* and *Nitzschia palea* had the highest abundance and were found at all sites sampled.

*Average abundance*

The average abundance of diatoms ranged from 103 to 2911 at the 2011 sites. The highest abundance occurred at site TCS (2911), while the lowest abundance was found at the lower Mekong river sites in unsuitable substratum such as mud and sand and high turbidity, such as site TNK (103 cells). TNK had the third highest abundance in the previous survey in 2008.

*Average richness*

Species richness per site in 2011 ranged from 9 to 20 at the Thai sites (Table 3.2). The greatest richness occurred at sites on the Kok river (TKO, 20 species) and the Mekong at Chiang San (TCS, 16 species), while the lowest richness was found at the soft substrate sites on the Nam Kham (TNK, 9 species). Most of the sites show increased richness by between 10 and 250%, but two sites (TSM and TKC) show a slight decrease.

*ATSPT*

The Average Tolerance Score Per Taxon (ATSPT) of benthic diatom samples taken in 2011 showed a narrow variation, ranging from 38 to 44. The ATSPT values had increased slightly from the previous survey, indicating a slight deterioration in ecological conditions.

## Cambodia

*Average abundance*

A total of 170 sub-samples were collected over the Cambodia Mekong system. Some 31,507,781 individual benthic diatoms were counted, with 172 species/taxon identified. The average number of diatoms per sampling site ranged from 22,195 to 594,215 individuals (Table 3.2). The highest abundances were found at the Lower Sekong River (CKM) and the Pursat River (CPS). In March these sites have very clear water with a moderate current, creating an environment for benthic diatoms to flourish. The three sampling sites: Phnom Penh Port (CPP), Lower Stung Sangke, Tonle Sap Lake, Battambang Province, (CSK) and Kampong Luong, Tonle Sap Lake, Siem Reap Province (CKK) had fewer than 50,000 benthic diatoms. The abundance of benthic diatoms found over the 17 sampling locations, however, was very high, which may be a result of the local environment of the sites being stable or improved. For all eight sites that were surveyed earlier, the abundance has significantly increased (by a factor of up to 800) compared to the previous survey in 2008.

*Average richness*

The number of species per sampling site ranged from 11 to 33 (Table 3.2). This number is very small compared to the total number of species identified from the 170 sub-samples collected in 2011 (172 spe-

cies). The lowest richness was observed at sites CSN (Stung Chinit, Kampong Thom Province), CNL (Nak Leoung, lower Mekong River) and CSS (Veun Sai District, Se San River). The CSN area has a very intensive dry season rice cultivation, Nak Leoung (CNL) is influenced by domestic wastes from Phnom Penh city and CSS is very close to Veun Sai Central District. The highest richness of taxa of benthic diatoms was found at CPS (Pursat River), which had very good water quality and also a very high abundance of diatoms. All eight locations that were monitored in both 2008 and 2011 had higher average richness in 2011.

*ATSPT*

The Average Tolerance Score Per Taxon (ATSPT) of diatom samples taken in 2011 ranged from 29 to 37. The highest value was found at sites CSK, CPT and CCK, the three sites situated close to densely populated residential areas. The lowest was found at site CKT, (Kampi Pool) on the Mekong mainstream, which has fewer human activities. Six locations showed improvement (i.e. lower ATSPT score) while two locations showed deterioration. Overall, all the site scores meet the MRC guideline values for healthy ecosystems (see Table 2).

## Viet Nam

The eight sites with a total 3797 cell count for diatoms in 2011 have yielded a total of 131 species. Most of the taxa were also found in the previous survey.

The most common taxa were in the order Naviculales (21 taxa) and order Nitzschia (19 taxa). Aulacoseira granulata, Gomphonema olivaceum, Gomphonema sphaerophorum, Navicula gastrum and Nitzschia sp1 had the widest distribution and each occurred at all sites sampled.

The diatom taxa collected in the 2011 survey are slightly increased in diversity compared to those found in the previous investigation (125 taxa in 2008).

*Average abundance*

The average abundance of diatoms ranged from 212 to 811 cells per sample. The greatest abundance was found at site VCL while the lowest was found at site VDP where the substrata of mud and sand were unsuitable for diatoms to grow.

The abundance at VDP, VKB, VTP, VVL and VTT in 2011 was much lower than in the previous survey (2008), while the abundance at VCL, VLX and VCT was higher than in 2008.

*Average richness*

The highest average richness (20 taxa) was found at VCT, where the substratum was characterised as mud and sand flat, with solid litter. The lowest richness was found at VDP (11 taxa) and VKB (12 taxa) where the substratum was characterised as mudflat, sediment, artificial wastes and hazardous wastes (pesticide bottles and discarded electrical goods were found).

The average richness for six out of eight sites in 2011 was slightly higher than in 2008 but for VCL it was much higher (3 to 18).

*ATSPT*

The Average Tolerance Score per Taxon (ATSPT) of benthic diatom samples taken in 2011 showed little variation, ranging from 45 to 47 (Table 3.2). The ATSPT values for sites in the 2011 study are slightly lower (i.e. indicating better conditions) than those found in the previous survey (2008), but none meet the MRC guideline values for healthy ecosystems (see Table 2).

## ZOOPLANKTON

Zooplankton provide a reflection of direct water conditions, whereas the other bioindicators tend to reflect the substrate characteristics at the sampling site. In this survey the results show 27 highly disturbed sites from their ATSPT, especially from the lower reaches.

### Lao PDR

The eight sites in Lao PDR recorded a total of 1419 individual specimens of zooplankton and larvae. These comprised 88 taxa within 24 families and 1 form of larvae. The zooplankton included five main groups: Crustacea, Eurotatorea, Lobosea, Fiosea, Phytomastigophora and larval forms. The most prolific were Eurotatorea of which there were 54 taxa (14 families), while Filosea and Phytomastigophora were represented by only one family. The larval form was present in the highest numbers.

*Average abundance*

In 2011, abundance varied widely across the eight sites, with average values of 27 - 145 individuals per sample. The highest average abundance was found at LDN, while the lowest abundance was found at LBH. The dominant species were Copepods and their nauplius (larvae form) and Keratella spp. These typically occur in sites where the river is wide and deep with slow water currents. In five sites, LSD, LPB, LKL, LBF and LDN, the abundance in 2011 was 2-4 times less than that found in 2008. This may have been caused by collecting samples in strong currents, changing water channel and shallow water. Only two sites (LBH and LVT) showed an increase from 2008. There were increases in only a few taxa and Copepod larvae, which are common and widely distributed.

*Average richness*

The average richness per site ranged from 12 to 28 taxa. The lower average richness was found at LKL and LBH, and the higher at LDN. Species of the Copipods group and Brachionidae family predominated and were widely distributed.

The average richness of all samples in 2011 increased compared to samples taken in 2008, except at LDN.

*ATSPT*

The ATSPT for zooplankton ranged from 38 to 48 (Table 3.3). The lowest occurred at LDN and the highest at LMX. There was little variation in ATSPT between the sites, compared to the previous year. However, compared to 2008 the ATSPT had greatly increased (indicating deteriorated conditions)

at LMX, and slightly increased at LVT and LBF into a less healthy ecosystem (ATSPT above 41.8).

## Thailand

The eight sites sampled in 2011 yielded a total of 27 species of zooplankton out of the 138 individuals collected. Keratella cochlearis and Polyarthra vulgaris were the most common and widespread.

*Average abundance*

The average abundance of zooplankton ranged from 0 to 118 individuals at the 2011 sites. The highest abundance occurred at site TUN (116 individuals), while no zooplankton were found at the Mekong River at Chiang San (TCS) or Nakorn Panom (TNK) sites. The abundance was significantly lower than for the previous survey in 2008.

*Average richness*

Species richness per site ranged from none to 6 at the 2011 sites. The highest richness occurred at sites TUN (6 species) and TMU (5 species), while zooplankton were not found at all at some sites with unsuitable environmental conditions, such as the fast current at TCS and TNK on the Mekong mainstream. The zooplankton richness had significantly decreased from the previous study.

*ATSPT*

The ATSPT of zooplankton ranged from 32 to 54 (Table 3.3). The ATSPT in 2011 had slightly increased compared to the previous study in TKO, TSM, TUN and TKC, indicating poorer ecosystem health.

## Cambodia

A total of 11,329 individuals of zooplankton, comprising 67 species, was estimated from the 51 sub samples collected for EHM 2011.

*Average abundance*

The number of zooplankton at each site ranged from 41 to 4362. Four sampling sites (CPT, CKK, CNL, and CKL) had a very high abundance of zooplankton, with more than 1,000 individuals per site, while seven sites had fewer than 100 individuals. The number of zooplankton at the other six sites ranged from 100 to 1000 individuals. As a whole, the number of zooplankton recorded per site was quite high, indicating that the locations sampled in 2011 were suitable for zooplankton.

*Average richness*

The number of species per site ranged from 3 to 18 (Table 3.3), with the lowest richness at five sites: CMR, CUS, CSS, CSJ and CTU and the highest species richness at CNL. The average species richness of all sampling sites was six species. This variation between sites indicates the sensitivity of zooplankton to environmental conditions.

*ATSPT*

The average tolerance score per taxa (ATSPT) for zooplankton ranged from 39 to 52 (Table 3.3). This value is high compared to ATSPT values for benthic diatoms. It is due to the number of individuals and species richness of zooplankton being much lower than the corresponding figures for benthic diatoms. The lowest ATSPT was calculated for sites CSP, CSJ and CSN, while the highest was for

**Table 3.3.** The values of average abundance, richness and ATSPT for zooplankton (2005–2011)

| | Abundance | | | | | Average richness | | | | | ATSPT | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site code | 2005 | 2006 | 2007 | 2008 | **2011** | 2005 | 2006 | 2007 | 2008 | **2011** | 2005 | 2006 | 2007 | 2008 | **2011** |
| LMX | 76 | | | 47 | **31** | 15 | | | 7 | **13** | 40 | | | 29 | **48** |
| LPB | 26 | | | 231 | **42** | 13 | | | 9 | **16** | 42 | | | 38 | **39** |
| LVT | | | 160 | 17 | **29** | | | 10 | 7 | **14** | | | 40 | 41 | **42** |
| LBF | | | 222 | 508 | **56** | | | 17 | 20 | **21** | | | 39 | 41 | **43** |
| LBH | | | 473 | 19 | **27** | | | 16 | 6 | **12** | | | 41 | 42 | **41** |
| LSD | | | 1,408 | 278 | **102** | | | 26 | 16 | **22** | | | 44 | 40 | **41** |
| LKL | 22 | | 17 | 219 | **40** | 14 | | 10 | 8 | **12** | 35 | | 39 | 40 | **41** |
| LDN | | | 194 | 1,707 | **145** | | | 21 | 40 | **28** | | | 40 | 41 | **38** |
| TCS | | | | 15 | **0** | | | | 3 | **0** | | | | 40 | - |
| TKO | 145 | | | 27 | **3** | 29 | | | 3 | **2** | 42 | | | 38 | **32** |
| TSM | | | 2,586 | 328 | **1** | | | 19 | 8 | **1** | | | 43 | 40 | **43** |
| TNP | | | | 60 | **1** | | | | 7 | **1** | | | | 40 | **50** |
| TNK | | | 473 | 200 | **0** | | | 25 | 6 | **0** | | | 43 | 40 | - |
| TUN | | | | 300 | **116** | | | | 7 | **6** | | | | 40 | **54** |
| TMU | | | | 77 | **10** | | | | 11 | **5** | | | | 39 | **33** |
| TKC | | | | 115 | **1** | | | | 7 | **1** | | | | 39 | **48** |
| CMR | 39 | 24 | 35 | | **56** | 11 | 9 | 12 | | **3** | 38 | 39 | 38 | | **41** |
| CKM | 78 | 21 | 35 | | **100** | 14 | 11 | 14 | | **5** | 39 | 37 | 39 | | **45** |
| CUS | 14 | 176 | 113 | | **55** | 11 | 32 | 28 | | **3** | 37 | 40 | 39 | | **42** |
| CSS | | | | | **41** | | | | | **3** | | | | | **40** |
| CSP | 86 | 70 | 62 | | **57** | 13 | 12 | 15 | | **4** | 36 | 37 | 42 | | **39** |
| CSJ | 119 | 62 | 52 | | **66** | 14 | 20 | 17 | | **3** | 37 | 38 | 38 | | **39** |
| CKT | | 27 | | | **58** | | 12 | | | **4** | | 37 | | | **43** |
| CPT | | | | | **4,362** | | | | | **8** | | | | | **52** |
| CCK | | | | | **312** | | | | | **8** | | | | | **44** |
| CSK | | 1,431 | | | **156** | | 34 | | | **7** | | 46 | | | **48** |
| CSN | | | | | **554** | | | | | **15** | | | | | **39** |
| CTU | | | | | **83** | | | | | **3** | | | | | **48** |
| CPP | | | | | **201** | | | | | **4** | | | | | **52** |
| CPS | | | | | **252** | | | | | **9** | | | | | **42** |
| CKL | | | | | **1,586** | | | | | **7** | | | | | **52** |
| CNL | | | | | **3,216** | | | | | **18** | | | | | **46** |
| CKK | | 844 | | | **1,473** | | 22 | | | **6** | | 48 | | | **50** |
| VTP | | | | 16 | **72** | | | | 6 | **10** | | | | 49 | **44** |
| VTT | | | | 35 | **329** | | | | 5 | **15** | | | | 47 | **45** |
| VKB | | | | 1,115 | **56** | | | | 13 | **11** | | | | 50 | **46** |
| VDP | | | | 32 | **18** | | | | 5 | **11** | | | | 47 | **46** |
| VCL | | 127 | | 11 | **33** | | 15 | | 5 | **6** | | 46 | | 49 | **47** |
| VLX | | 148 | | 39 | **8** | | 16 | | 9 | **5** | | 45 | | 51 | **46** |
| VVL | | | | 7 | **6** | | | | 5 | **2** | | | | 54 | **45** |
| VCT | | 55 | | 47 | **129** | | 11 | | 7 | **10** | | 46 | | 52 | **47** |

CPT, CPP and CKK. Twelve of the 17 sites have ATSPT values higher (i.e. poorer) than the guideline for a healthy ecosystem.

### Viet Nam

The total number of zooplankton specimens collected at 8 sites in 2011 is 1955 individuals. This pool was divided into 5 phyla (Arthropoda, Rotifera, Mollusca, Protozoa and Ciliophora), 7 classes and 13 orders. Only 4 of the orders have been identified: Copepoda, Gastropoda, Ostracoda and Bivalvia.

*Average abundance*

In 2011, the difference in abundance between sites was not as large as for the previous survey in 2008. VTT had the highest abundance with 329 and VCT also had high abundance with 129. Both these sites have a large number of taxa (23 and 20). Abundance at VKB has strongly decreased (by 20-fold) since 2008 from 1115 to 56. VVL, with 6 individuals, has the lowest abundance, which is the same as the previous survey.

*Average richness*

Average richness varied between 2 and 15, with the highest value at VTT and the lowest at VVL. Compared with the year 2008, richness has increased at five sites (VTP, VTT, VDP, VCL and VCT), while only three sites (VKB, VLX and VVL) decreased.

*ATSPT*

All sites have ATSPT values above (i.e. poorer than) the guideline for a healthy ecosystem (see Table 3.3). The scores ranged from 44 to 47.

## LITTORAL MACROINVERTEBRATES

Littoral macroinvertebrates provide a reflection of near shore substrate characteristics. In this survey the results show higher ATSPT than the guidelines, reflecting 31 moderately disturbed sites.

### Lao PDR

The 16,097 individual specimens collected from the eight sites in Lao PDR contained 129 taxa. The highest diversity was seen for insect orders of Ephemeroptera, Odonata and shellfish of Mollusca, with 26, 23 and 23 taxa, respectively. The *Kiefferulus* sp. (Diptera), *Micronecta* sp. (Hemiptera) and *Procloeon* sp. (Ephemeroptera) were found at all sites. The dominant species of littoral macroinvertebrates was *Micronecta* sp., in the order of Hemiptera, comprising 4,954 specimens. The richness in the orders of Trichoptera, Coleoptera, Hemiptera and Diptera was moderate, ranging from 9 to 15 taxa.

*Average abundance*

The average abundance ranged from 8 to 532 individuals per site, the greatest abundance occurred at sites with large macroalgae and submerged vegetation, such as LBH, and the lowest abundance (8) at LMX. The high-abundance groups were insects in the orders Mesogastropoda, Hemiptera, and Ephemeroptera. The average abundance at all sites had increased compared to the 2008 samples, e.g. at LKL average abundance increased about 19-fold. But two sites (LBF and LMX) showed drastically decreased

**Table 3.4.** The values of average abundance, richness and ATSPT for littoral macroinvertebrates (2005–2011)

| | Abundance | | | | | Average richness | | | | | ATSPT | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site code | 2005 | 2006 | 2007 | 2008 | **2011** | 2005 | 2006 | 2007 | 2008 | **2011** | 2005 | 2006 | 2007 | 2008 | **2011** |
| LMX | 30 | | | 24 | **8** | 5 | | | 5 | **4** | 36 | | | 40 | **44** |
| LPB | 76 | | | 23 | **48** | 5 | | | 8 | **7** | 34 | | | 35 | **30** |
| LVT | | | 122 | 34 | **103** | | | 8 | 8 | **11** | | | 34 | 35 | **41** |
| LBF | | | 254 | 795 | **90** | | | 16 | 15 | **6** | | | 35 | 37 | **41** |
| LBH | | | 73 | 35 | **532** | | | 8 | 7 | **19** | | | 36 | 35 | **40** |
| LSD | | | 50 | 83 | **225** | | | 11 | 10 | **10** | | | 37 | 39 | **41** |
| LKL | 48 | | 35 | 11 | **202** | 9 | | 13 | 5 | **14** | 31 | | 33 | 34 | **41** |
| LDN | | | 340 | 369 | **402** | | | 14 | 12 | **13** | | | 33 | 35 | **41** |
| TCS | | | | 21 | **93** | | | | 5 | **9** | | | | 29 | **35** |
| TKO | 52 | | | 54 | **63** | 7 | | | 13 | **13** | 34 | | | 29 | **35** |
| TSM | | | 24 | 52 | **111** | | | 6 | 6 | **13** | | | 38 | 32 | **29** |
| TNP | | | | 8 | **209** | | | | 5 | **16** | | | | 34 | **32** |
| TNK | | | 23 | 24 | **74** | | | 6 | 7 | **14** | | | 38 | 34 | **29** |
| TUN | | | | 107 | **371** | | | | 7 | **14** | | | | 33 | **32** |
| TMU | | | | 21 | **213** | | | | 6 | **16** | | | | 33 | **35** |
| TKC | | | | 22 | **522** | | | | 6 | **16** | | | | 33 | **34** |
| CMR | 112 | 311 | 311 | 587 | **309** | 5 | 10 | 8 | 4 | **9** | 34 | 30 | 34 | 27 | **26** |
| CKM | 104 | 26 | 33 | 56 | **107** | 10 | 9 | 9 | 5 | **15** | 32 | 29 | 34 | 29 | **34** |
| CUS | 121 | 179 | 10 | 83 | **24** | 15 | 5 | 3 | 4 | **7** | 34 | 33 | 34 | 32 | **34** |
| CSS | | | | | **68** | | | | | **21** | | | | | **35** |
| CSP | 229 | 54 | 136 | 22 | **36** | 20 | 16 | 17 | 3 | **12** | 28 | 27 | 31 | 13 | **30** |
| CSJ | 83 | 46 | 88 | 128 | **22** | 13 | 11 | 14 | 6 | **9** | 32 | 30 | 32 | 37 | **28** |
| CKT | | 97 | | 105 | **133** | | 11 | | 6 | **10** | | 30 | | 27 | **30** |
| CPT | | | | | **43** | | | | | **11** | | | | | **43** |
| CCK | | | | | **15** | | | | | **7** | | | | | **44** |
| CSK | | | | | **26** | | | | | **4** | | | | | **60** |
| CSN | | | | | **28** | | | | | **10** | | | | | **43** |
| CTU | | | | | **57** | | | | | **11** | | | | | **43** |
| CPP | | | | | **20** | | | | | **6** | | | | | **55** |
| CPS | | | | | **17** | | | | | **7** | | | | | **36** |
| CKL | | | | | **24** | | | | | **8** | | | | | **47** |
| CNL | | 92 | | 299 | **9** | | 4 | | 5 | **3** | | 43 | | 31 | **39** |
| CKK | | 163 | | 17 | **111** | | 11 | | 3 | **20** | | 39 | | 38 | **45** |
| VTP | | | | 7 | **7** | | | | 3 | **2** | | | | 50 | **33** |
| VTT | | | | 546 | **243** | | | | 5 | **7** | | | | 52 | **46** |
| VKB | | | | 37 | **117** | | | | 8 | **11** | | | | 52 | **39** |
| VDP | | | | 15 | **106** | | | | 7 | **13** | | | | 53 | **42** |
| VCL | | 39 | | 49 | **961** | | 7 | | 13 | **9.4** | | 42 | | 58 | **45** |
| VLX | | 30 | | 51 | **19** | | 5 | | 14 | **5.1** | | 44 | | 54 | **43** |
| VVL | | | | 173 | **83** | | | | 12 | **11** | | | | 56 | **45** |
| VCT | | 24 | | 95 | **37** | | 4 | | 11 | **7.6** | | 43 | | 55 | **42** |

abundance, compared to 2008 whereas the other six stations show an increase in abundance due to increases in some groups such as water bugs, snails, mayfly and flies, probably because in those groups tolerance to disturbance is moderate to high.

*Average richness*

The number of taxa collected per site ranged from 16 to 56. The average richness per site ranged from 4 to 19 taxa (Table 3.4). The highest richness occurred at LKL and the lowest at LMX. In general, the values of richness in the 2011 survey vary little compared to the 2008 survey. However, there was about a three-fold decrease in richness at LBF. This data is related to the zooplankton and benthic macroinvertebates, probably because this site was affected by operation of the Nam Theun 2 hydropower dam. On the other hand, a few sites showed a similar-sized increase in richness.

*ATSPT*

The ATSPT for littoral macroinvertebrates ranged from 30 to 44 (Table 3.4). In general, in 2011 the range in the ATSPT values at the sites was narrow. However, the ATSPT values were higher compared to those of 2008 and previous years. The average ATSPT in the 2011 site was 40 while that of the site in 2008 was 36. All sites, except LPB, have ATSPT higher than the MRC healthy guideline, indicating less healthy ecosystem.

## Thailand

The eight sites sampled in 2011 yielded a total of 199 species of littoral macroinvertebrates from 16,556 individuals collected. The *Labiobaetis* sp. in Order Ephemeroptera had the highest occurrence (2,963 individuals) and *Cloeon* sp., *Caridina* sp. and *Micronecta* sp. had a common distribution at all sites sampled.

*Average abundance*

The average abundance ranged from 63 to 522 individuals at the 2011 sites (Table 3.4). The highest abundance occurred at site TKC, while the lowest abundance was found at the MeKok River at Chiang Rai (TKO) that has unsuitable substratum (muddy and high turbidity). However, the abundance at all sampling sites had increased compared to the previous study in 2008.

*Average richness*

Species richness per site ranged from 9 to 16 at the 2011 sites (Table 3.4), similar to that of the sites in Lao PDR. The highest richness occurred at sites TNP, TMU and TKC, while the lowest richness was found at the site TCS (9 taxa). The overall richness increased compared to the previous study in 2008.

*ATSPT*

The ATSPT of littoral macroinvertebrate samples taken in 2011 ranged from 29 to 35. Overall, the ATSPT of littoral macroinvertebrates at the Thai sites was almost unchanged compared to the 2008 investigation. Four sites (TCS, TKO, TKC and TMU) have deteriorated and now fall below the guideline for a healthy environment (33.58), while the other four sites have improved and meet the guideline.

## Cambodia

A total of 10,479 individuals of littoral macroinvertebrates were found in 2011, consisting of 127 taxa.

*Average abundance*

The number of individuals per site ranged between 9 and 309. The broad range may be due to samples being collected in gravel beds and sites with fast-flowing currents. Four sites had high abundance, the highest at CMR (309) followed by CKM, CKT, and CKL. At the other 12 sites, the number of individuals varied from 9 to 68, with CNL (Neak Leoung) the lowest.

*Average richness*

Species richness of littoral macroinvertebrates per site showed values from 3 to 21 species. The average species richness of the 17 sampling sites was 10 species. The highest number of species was found at sites CSS and CKL followed by CKM. The poorest species diversity was found at Neak Leoung (CNL). Although the highest number of individuals was found at the Ramsar site near Stung Treng (CMR), there was only 9 species identified in this sample.

*ATSPT*

The ATSPT for littoral macroinvertebrates ranged from 26 to 60 (Table 3.4). ATSPT values are quite high compared to the ATSPT for benthic diatoms and benthic macroinvertebrates but similar to the value for zooplankton. The lowest value occurred at the Ramsar site (CMR) where the number of individuals was highest. The highest value was found at CSK, followed by Phnom Penh port (CPP), CKL, CKK, CSN, CPT, and CTU.

The higher ATSPT values were mostly found at sampling sites located in Tonle Sap Lake and other lower Mekong locations, due to high disturbance from human activities, including fisheries. Only four sites of 17 meet the healthy guideline level (below 33.58), namely CMR, CSP, CSJ and CKT.

## Viet Nam

In 2011, there were 15,726 individuals and 93 taxa of littoral macroinvertebrates collected at the eight sampling sites. In total, 42 families, 21 orders, and 6 classes from 3 phyla of Arthropoda, Miollusca and Annelida were represented. The total number of individuals at each site showed a large variation.

*Average abundance*

The average abundance in the 2011 survey compared with 2008 increased at three sites: VDP (from 15 to 106), VKB (from 37 to 117) and VCL (from 49 to 961), decreased at four sites and remained constant at one. At VCL, although the number of taxa is not high, the number of individuals of two taxa *Micronecta sp*. and *Grandidierella vietnamica* (phylum Arthropoda) is extremely high (4302 and 4090 individuals in raw data), which gives this site the highest average abundance.

*Average richness*

Overall, the average richness for 2011 is slightly lower than in 2008. The richness has increased at three sites and decreased at five. VDP has the highest average richness, although the number of taxa in raw data at this site is lower (32 taxa) compared with

VKB (37 taxa) and VVL (34 taxa). The richness of VTP and VLX are lowest, consistent with the results of taxa number.

*ATSPT*

The ATSPT varies from 33 to 46. The highest values of ATSPT occur at three sites: VTT, VCL and VVL (46, 45, 45) (Table 3.4). The number of taxa found at VTT is not high (15 taxa), and it even includes taxa with a high tolerance to pollution. In general, in 2011 at all sites examined, the ATSPT values are better (lower) than those of 2008. This indicates that at the eight sites in Viet Nam in 2011, the stresses have decreased (SDS lower), followed by an increase in the taxa with less tolerance to environmental pressures. All sites except VTP still have a poorer ATSPT than the healthy guideline level.

## BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates provide a reflection of deeper zone substrate characteristics. In this survey the results show higher ATSPT than the guidelines, reflecting 25 moderately disturbed sites, especially in lower reaches.

### Lao PDR

In 2011, a total of 632 specimens of benthic macroinvertebrates belonging to 45 taxa were collected from eight sites. In terms of diversity, the most diverse were snails, with 11 taxa, followed by mayflies with 10 taxa. The insect order of Diptera and Oligochaeta were widely distributed, with the Chironomidae family found at all sites.

*Average abundance*

The average abundance was highly variable between sites, ranging from 1 to 18 individuals per site. The highest average abundance occurred at sites with muddy clay mixed sand, submerged plants and litter substrates such as LDN (18), while the lowest occurred at sites with sandy and rocky substrata, such as LVT (1). The high abundance was the result of Kiefferulus sp (Chironomids, Diptera) and Oligochaeta spp. However, there was a substantial decrease in abundance in 2011 compared to 2008, except for LPB and LKL.

*Average richness*

Average richness showed a narrow variation at the eight sites sampled in 2011. Richness ranged from 5 to 18 taxa in raw data, with an average richness from 1 to 4. The highest average richness occurred at both LDN and LBH, and the lowest at four sites with sandy and rocky substrata: LMX, LVT, LBF and LKL. In general, the taxa richness decreased by 1–5 since 2008 at six sites. There was no change at LMX and average richness of LPB was slightly increased.

*ATSPT*

Benthic macroinvertebrate samples taken in 2011 showed a narrow variation, with values ranging from 36 to 44 (Table 3.5). The highest value was found at LMX and the lowest at LDN. Generally, the changes in ATSPT since 2008 were very small. Only LDN met the healthy guideline level of 37.74.

**Table 3.5.** The values of average abundance, richness and ATSPT for benthic macroinvertebrates (2005–2011)

| | Abundance | | | | | Average richness | | | | | ATSPT | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site code | 2005 | 2006 | 2007 | 2008 | **2011** | 2005 | 2006 | 2007 | 2008 | **2011** | 2005 | 2006 | 2007 | 2008 | **2011** |
| LMX | 4 | | | 10 | **4** | 2 | | | 1 | **1** | 35 | | | 41 | **44** |
| LPB | 6 | | | 6 | **7** | 2 | | | 2 | **3** | 33 | | | 36 | **38** |
| LVT | | | 6 | 7 | **1** | | | 3 | 3 | **1** | | | 39 | 40 | **42** |
| LBF | | | 38 | 26 | **3** | | | 6 | 6 | **1** | | | 38 | 40 | **40** |
| LBH | | | 7 | 20 | **10** | | | 3 | 5 | **4** | | | 38 | 38 | **40** |
| LSD | | | 13 | 11 | **9** | | | 5 | 4 | **3** | | | 40 | 40 | **40** |
| LKL | 25 | | 4 | 2 | **2** | 6 | | 2 | 2 | **1** | 35 | | 37 | 40 | **41** |
| LDN | | | 51 | 50 | **18** | | | 8 | 7 | **4** | | | 36 | 37 | **36** |
| TCS | | | | 14 | **441** | | | | 1 | **16** | | | | 26 | **25** |
| TKO | 12 | | | 68 | **302** | 4 | | | 3 | **26** | 34 | | | 29 | **24** |
| TSM | | | 9 | 59 | **0** | | | 3 | 2 | **0** | | | 37 | 32 | - |
| TNP | | | | 79 | **184** | | | | 2 | **16** | | | | 33 | **26** |
| TNK | | | 3 | 12 | **115** | | | 2 | 2 | **21** | | | 42 | 35 | **32** |
| TUN | | | | 12 | **235** | | | | 2 | **27** | | | | 36 | **33** |
| TMU | | | | 7 | **282** | | | | 1 | **23** | | | 46 | 32 | **25** |
| TKC | | | | 51 | **68** | | | | 3 | **10** | | | | 31 | **27** |
| CMR | 20 | 24 | 11 | 10 | **49** | 4 | 3 | 3 | 3 | **7** | 37 | 43 | 37 | 26 | **20** |
| CKM | 4 | 3 | 4 | 6 | **13** | 2 | 2 | 3 | 2 | **4** | 35 | 36 | 37 | 26 | **37** |
| CUS | 23 | 8 | 5 | 7 | **4** | 5 | 3 | 3 | 3 | **1** | 36 | 39 | 37 | 34 | **39** |
| CSS | | | | | **3** | | | | | **2** | | | | | **30** |
| CSP | 25 | 6 | 7 | 6 | **10** | 6 | 3 | 3 | 2 | **4** | 38 | 31 | 33 | 23 | **25** |
| CSJ | 3 | 3 | 5 | 4 | **4** | 2 | 2 | 3 | 2 | **3** | 37 | 33 | 36 | 27 | **30** |
| CKT | | 8 | | 11 | **38** | | 2 | | 3 | **3** | | 31 | | 31 | **23** |
| CPT | | | | | **4** | | | | | **2** | | | | | **51** |
| CCK | | | | | **40** | | | | | **5** | | | | | **43** |
| CSK | | 11 | | 20 | **21** | | 3 | | 4 | **4** | | 47 | | 34 | **59** |
| CSN | | | | | **14** | | | | | **4** | | | | | **38** |
| CTU | | | | | **62** | | | | | **4** | | | | | **42** |
| CPP | | | | | **13** | | | | | **4** | | | | | **58** |
| CPS | | | | | **7** | | | | | **3** | | | | | **41** |
| CKL | | | | | **55** | | | | | **12** | | | | | **49** |
| CNL | | | | | **53** | | | | | **7** | | | | | **44** |
| CKK | | 17 | | 11 | **10** | | 5 | | 3 | **4** | | 52 | | 39 | **51** |
| VTP | | | | 18 | **47** | | | | 5 | **6** | | | | 50 | **49** |
| VTT | | | | 47 | **49** | | | | 9 | **6** | | | | 54 | **49** |
| VKB | | | | 145 | **205** | | | | 8 | **10** | | | | 55 | **48** |
| VDP | | | | 108 | **49** | | | | 11 | **9** | | | | 56 | **46** |
| VCL | | 9 | | 301 | **32** | | 3 | | 10 | **5** | | 53 | | 56 | **46** |
| VLX | | 24 | | 74 | **141** | | 5 | | 11 | **10** | | 57 | | 56 | **48** |
| VVL | | | | 60 | **31** | | | | 9 | **6** | | | | 56 | **48** |
| VCT | | 8 | | 115 | **67** | | 3 | | 7 | **7** | | 63 | | 55 | **49** |

## Thailand

The eight sites sampled in 2011 yielded a total of 4,887 individual benthic macroinvertebrates comprising 131 species. Stenothyra sp. was the most abundant with 739 individuals, while Oligochaeta sp. and Bithynia sp. were common species at all sites sampled.

*Average abundance*

The average abundance of benthic macroinvertebrates ranged from none to 441 individuals at the 2011 sites. The highest abundance occurred at site TCS and TKO (441 and 302), where there was suitable substrate for benthic organisms, such as cobble and gravel. No macroinvertebrates were found at the tributary junction of the Songkram-Mekong rivers (TSM) which has sandy substrata. However, the average abundance increased compared to the previous study (2008) at all sampling sites except TSM.

*Average richness*

Species richness per site ranged from none to 27 at the 2011 sites. The highest richness occurred at sites TUN (27 species) and TKO (26 species), while the TSM site (muddy sand substratum) did not contain any benthic macronivertebrates.

*ATSPT*

In Thailand, all sites met the healthy guideline for ATSPT (below 37.74). The lowest was TKO (24) and the highest TUN (33). All sites had improved since 2008 (at TSM no sample could be evaluated). This may be due to changed substrata in the Mekong and some tributaries, such as the Mun and Kok Rivers.

## Cambodia

A total of 3,788 specimens of benthic macroinvertebrates, representing 107 taxa were found at the Cambodian sites. These organisms are typically more abundant in substrates of muddy clay mixed sand, submerged plants and debris, such as Tonle Sap Lake and other locations in the lower parts of the country.

*Average abundance*

The average abundance showed a large variation between sites, ranging from 3 to 62. The highest abundance was found at CTU (62) followed by CKK (55), CNL (53), CMR (49) and CCK (40). The sites with a muddy and sandy clay bed were found to have higher abundance, while the sites with sandy and pebble substrata (namely CSS, CUS, CPT, CPT, and CPS) were found to have lower abundance.

*Average richness*

Species richness over the 17 sampling sites ranged from 1 to 12, which is likely a result of samples collected from diverse types of environment. The highest richness occurred at sites with soft substrata with mud and litter debris and some submerged plants, such as CKK (12), CMR and CNL (7), and CCK (5), while the lowest richness was found at sites with sandy and rocky substrata, such as sites CUS (1), and other sites with sandy and rocky or gravel beds.

*ATSPT*

The ATSPT for benthic macroinvertebrate samples taken in 2011 ranged from 20 to 59. The lowest ATSPT was found at the Ramsar

**Table 3.6.** Assessment of all sites in 2011 following the suggested guidelines

| Site code | Diatom | | | Zooplankton | | | Littoral | | | Benthos | | | No. meeting guideline | Class |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean No. taxa | Mean No. individuals | Mean ATSPT | Mean No. taxa | Mean No. individuals | Mean ATSPT | Mean No. taxa | Mean No. individuals | Mean ATSPT | Mean No. taxa | Mean No. individuals | Mean ATSPT | | |
| LMX | | | ✓ | ✓ | ✓ | | | | | | | | 3 | D |
| LPB | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | 11 | A |
| LVT | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | | | | | 6 | C |
| LBF | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | | | | | 6 | C |
| LBH | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | 9 | B |
| LSD | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | 9 | B |
| LKL | | | | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | 5 | C |
| LDN | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | 11 | A |
| TCS | ✓ | ✓ | | | | | ✓ | ✓ | | ✓ | ✓ | ✓ | 7 | B |
| TKO | ✓ | ✓ | | | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | 8 | B |
| TSM | ✓ | ✓ | | | | | ✓ | ✓ | ✓ | | | | 5 | C |
| TNP | ✓ | ✓ | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 8 | B |
| TNK | | ✓ | ✓ | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 8 | B |
| TUN | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 10 | A |
| TMU | ✓ | ✓ | | | | | ✓ | ✓ | | ✓ | ✓ | ✓ | 7 | C |
| TKC | ✓ | ✓ | | | | | ✓ | ✓ | | ✓ | ✓ | ✓ | 7 | C |
| CMR | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 11 | A |
| CKM | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | 9 | B |
| CUS | ✓ | ✓ | ✓ | | ✓ | | ✓ | | ✓ | | | | 6 | C |
| CSS | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | 9 | B |
| CSP | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | 10 | A |
| CSJ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | 10 | A |
| CKT | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 10 | A |
| CPT | ✓ | ✓ | ✓ | | ✓ | | ✓ | | | ✓ | | | 6 | C |
| CCK | ✓ | ✓ | ✓ | | ✓ | | ✓ | | | ✓ | ✓ | | 7 | B |
| CSK | ✓ | ✓ | ✓ | | ✓ | | | | | ✓ | ✓ | | 6 | C |
| CSN | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | | 9 | B |
| CTU | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | | ✓ | ✓ | | 8 | B |
| CPP | ✓ | ✓ | ✓ | | ✓ | | ✓ | | | ✓ | ✓ | | 7 | B |
| CPS | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ | | 8 | B |
| CKL | ✓ | ✓ | ✓ | | ✓ | | ✓ | | | ✓ | ✓ | | 7 | B |
| CNL | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | ✓ | ✓ | | 7 | B |
| CKK | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | | ✓ | ✓ | | 8 | B |
| VTP | ✓ | ✓ | | ✓ | ✓ | | | | ✓ | ✓ | | | 7 | B |
| VTT | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | | 7 | B |
| VKB | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | | 8 | B |
| VDP | ✓ | ✓ | | ✓ | | | ✓ | ✓ | | ✓ | ✓ | | 7 | B |
| VCL | ✓ | ✓ | | | ✓ | | ✓ | ✓ | | ✓ | ✓ | | 7 | B |
| VLX | ✓ | ✓ | | | | | | | | ✓ | ✓ | | 4 | C |
| VVL | ✓ | ✓ | | | | | ✓ | ✓ | | ✓ | ✓ | | 6 | C |
| VCT | ✓ | ✓ | | ✓ | ✓ | | ✓ | | | ✓ | ✓ | | 7 | B |

site (CMR) while the highest values were found at the CSK site, followed by CPP, CPT, CKL, CNL, and CKK. In total, nine sites are lower (better) than the healthy guideline level. Six sites deteriorated and two sites improved since 2008.

## Viet Nam

A total of 9,223 benthic macroinvertebrates were collected at eight sites. They comprise 83 taxa from six classes in three phyla. The taxa of phylum Anthropoda and Mollusca have the higest taxa number (36 each), while Phylum Annelida has the lowest taxa number (11).

*Average abundance*

The average abundance of benthic macroinvertebrates at each site ranged from 31 to 205 (Table 3.5). Sites VLX and VKB had the highest(141 and 205 respectively). These sites have substrata of clay, sand, alluvium, mudflats and fallen tree trunks. Not only did they have the highest abundance, the two sites also had the highest individual counts (994 and 832 respectively, from raw data). In contrast, the sites with sandy clay, alluvium, and domestic waste substrata (VTP, VTT, VDP, VVL and VCL) had lower abundance. Abundance increased at four sites and decreased at four compared with the 2008 survey.

*Average richness*

Average richness in 2011 varied between 5 and 10. The highest average richness was found at two sites: VKB and VLX, where the substratum was soft mud, and consisted of debris and submerged plants. VCL has the lowest richness because substrata contains sand and rock. Compared with 2008, the richness decreased at five sites, increased at two sites and remained stable at one. In general, the change in richness values could be caused by natural fluctuations in environmental conditions.

*ATSPT*

The sites have ATSPT values in a narrow range (46–49) which in no case meets the healthy guideline level. In general, at the sites with a high site disturbance score (SDS), ATSPT are also high, and conversely, ATSPT will be low at the sites with low SDS. Compared with 2008, the 2011 values are lower (better), especially at sites VCL and VDP.

# EVALUATION OF SITES

Using the monitoring results for the three biological metrics (average abundance, average richness and average tolerance score per taxon) and the four biological groups (benthic diatoms, zooplankton, littoral macroinvertebrates and benthic macroinvertebrates) reported in the previous chapters, all sites have been classed in accordance with the scoring system described in Chapter 2. The site assessment and classification for 2011 is summarised in Table 3.6, and the historical development since 2005 is summarised in Table 3.7.

## Lao PDR

In 2011, Lao PDR had one site assessed as class D (Poor), three as class C (Moderate), two as class B (Good), and two sites were assessed class A (Excellent). The site

**Table 3.7.** Site assessment (2005–2011)

| Country | Site code | Location | Year | | | | |
|---|---|---|---|---|---|---|---|
| | | | 2005 | 2006 | 2007 | 2008 | 2011 |
| Lao PDR | LMX | Mekong River, Ban Xiengkok, Luangnamtha | B | | | D | D |
| | LPB | Mekong River, Done Chor, Luang Prabang | A | | | B | A |
| | LVT | Mekong River, Ban Huayhome, Vientiane | | | B | C | C |
| | LBF | Se Bang Fai River, Se Bang Fai, Khammouan | | | B | B | C |
| | LBH | Se Bang Hieng River, Songkhone, Savannakhet | | | A | C | B |
| | LSD | Sedone River, Ban Hae, Pakse | | | B | B | B |
| | LKL | Se Kong River, Ban Somsanouk, Attapeu | A | | B | C | C |
| | LDN | Mekong River, Done Ngiew, Pathumphone | | | A | B | A |
| Thailand | TCS | Mekong River, Chiang San | | | | B | B |
| | TKO | Kok River, Chiang Rai City | A | | | A | B |
| | TSM | Songkram River at Mekong junction, Nakorn Phanom | | | C | A | C |
| | TNP | Mekong River, Nakorn Phanom City | | | | C | B |
| | TNK | Nam Kham River, Na Kae, Mukdaharn | | | C | B | B |
| | TUN | Mun River, Ubon Rachathani City | | | | A | A |
| | TMU | Mun River, Kong Chiam, Ubon Rachathani | B | | | B | C |
| | TKC | Mun River at Mekong junction, Ubon Rachathani | | | | A | C |
| Cambodia | CMR | Mekong River, Ramsar Site, Stung Treng | B | A | B | B | A |
| | CKM | Se Kong River, Kbal Koh, Stung Treng | A | B | B | A | B |
| | CUS | Se San River, Dey It, Rattanakiri | A | B | B | A | C |
| | CSS | Se San River, Veunsai, Ratanakiri | | | | | B |
| | CSP | Srepok River, Phik, Rattanakiri | A | A | A | B | A |
| | CSJ | Se San River, downstream from the Srepok River junction | A | B | A | A | A |
| | CKT | Mekong River, Kampi Pool, Kratie | | A | | A | A |
| | CPT | Prek Te River, Preh Kanlong, Kratie | | | | | C |
| | CCK | Tonle Sap Lake, Chong Khnease, Siem Reap | | | | | B |
| | CSK | Stung Sen River, Kampong Thom | | C | | B | C |
| | CSN | Stoeng Sangke River, Battambang | | | | | B |
| | CTU | Tonle Sap River, Prek Kdam Ferry, Kandal | | | | | B |
| | CPP | Tonle Sap River, Phnom Penh Port | | | | | B |
| | CPS | Pursat River, Damnak Ampil, Pursat | | | | | B |
| | CKL | Tonle Sap Lake, Kampong Luong | | | | | B |
| | CNL | Mekong River, Nak Loeung, Prey Veng | | | | | B |
| | CKK | Bassac River, Khos Khel, Kandal | | B | | C | B |
| Viet Nam | VTP | Mekong River, Thuong Phuoc, Dong Thap | | | | C | B |
| | VTT | Mekong River, Thuong Thoi, Dong Thap | | | | C | B |
| | VKB | Bassac River, Khanh Binh, An Giang | | | | B | B |
| | VDP | Bassac River, Da Phuoc, An Giang | | | | C | B |
| | VCL | Mekong River, Cao Lanh, Dong Thap | | C | | C | B |
| | VLX | Bassac River, Long Xuyen, An Giang | | C | | B | C |
| | VVL | Mekong River, My Thuan, Vinh Long | | | | C | C |
| | VCT | Bassac River, Phu An, Can Tho | | C | | B | B |

LMX was classed as Good in 2005, but fell to Poor in 2008, and remained so in 2011 because all biometric indicators were low and indicate impact by intensive boat traffic. The ranking at LBF fell from class B in 2008 to class C in 2011, possibly due to water fluctuations caused by the operation of Nam Theun 2 hydropower dam. LKL and LVT remained in class C, meaning no change since 2008. Sites LPB and LDN improved and were assessed as class A in 2011, while LBH moved from class C to B. LSD remained unchanged in class B.

## Thailand

Sites were divided into three classes; TUN in class A; TCS, TKO, TNP and TNK in class B; and TSM, TMU and TKC in class C. Sites ranged from moderately good (class C) to excellent ecological health (class A), reflecting moderate impacts from human activities. The abundance and richness increased in all biological groups except zooplankton. No reference sites were investigated. The Site Disturbance Scores for the eight sites were all close to moderate although impacts at some sites have been increasing in terms of SDS. The increase is due to factors such as more construction, bank enforcement, tourist activities and navigation, e.g. sites TCS and TMU. Four sites were downgraded to a lower class, three sites remained the same as the previous survey in 2008 and one site improved from class C to B.

## Cambodia

The sampling sites in Cambodia are located in different types of ecosystems, comprising the mainstream of the Mekong, the Bassac River (a branch of the Mekong), Tonle Sap River, Tonle Sap Lake and its tributaries. Each ecosystem is characterised by specific types of substrata. The sampling sites had substrates characterised by sandy rock, sandy clay, mud, sand, clay, boulders and gravel. Water transparency ranged from very turbid to clear, and some sites had dense aquatic vegetation.

Of the 17 sampling sites monitored in Cambodia in 2011, four sites (CMR, CSP, CSJ and CKT) were classed as A. The majority of sampling sites (10 sites) were classed B, and three sites (CUS, CPT and CSK), were classed C. No sampling site was classed D. This means that the four 'Excellent' river sections or lake areas had very little or only slight disturbance, while 10 river sections or lake areas had some or moderate disturbance and three river sections or lake areas were highly disturbed. Of the eight sites assessed in both 2008 and 2011, three improved by one class, three deteriorated by one or two classes and two remained in the same class (A).

## Viet Nam

In 2011, the site assessment showed class improvement from C to B at four out of the eight sites. Two sites were assessed as class C and showed signs of an unhealthy ecosystem (VLX and VVL). Compared with the 2008 survey, three sites remain in the same class: VKB, VCT (B), and VVL (C). In contrast, VLX was downgraded from class B to C.

# CONCLUSIONS

# CONCLUSIONS

This report covers the ecological health monitoring activities that were transferred to the Member Countries in 2008. During the EHM 2011 biomonitoring survey, a total of 41 sampling sites were monitored; eight sites in each of Lao PDR, Thailand and Viet Nam and 17 sites in Cambodia. Sampling took place in March–April 2011. Nine sites in Cambodia were included for the first time. Sites were classed as either: Excellent (A), Good (B), Moderate (C) or Poor (D). Of the 2011 sites, seven were in Class A, with only little impact from human activities; 22 in Class B, 11 in Class C and one in Class D. All 'Excellent' sites are in or near to rocky rapids and clear water zones. Lower ecological health scores may be caused by increasing human activities and population, which is likely to affect both habitats and water quality.

In order to illustrate the status and trends, the 2011 results are summarised and compared to results of previous monitoring from 2005 to 2008. Xiangkok (LMX) is the most degraded site in the survey, moving from 'Good' status in 2005 to 'Poor' from 2008 to present. Nine sites show degradation since 2008, typically moving from 'Good' to 'Moderate' status but also three showed serious degradation from 'Excellent' to 'Moderate' ecological health. Seven sites improved from 'Moderate' to 'Good' and four sites from 'Good' to 'Excellent'. Eleven sites remained the same since 2008 – five 'Good', three 'Excellent' and three 'Moderate'. Hence, overall, the sites with improved ecological health since 2008 outnumbered the sites where ecological health had deteriorated. Several sites have changed since 2005 in terms of hydrographic behaviour and amounts of sediment (sand, silt and clay) accumulation. These factors could have affected the species occurrence in the area and caused the recorded changes.

There is no systematic geographic trend in ecological health of the Lower Mekong Basin (see Figure 4). The Mekong mainstream has sites in all four classes and not in descending quality from upstream to downstream as could be intuitively expected. The two most upstream sites in the Mekong (LMX and LPB) illustrate the variation: the most upstream site (LMX) is class D whereas further downstream at LPB the quality has improved to class A. At the remainder of the mainstream sites the quality varies between class A and C without any clear pattern.

The general change in ecological health from 2008 to 2011 for all sites as a whole is very small (see Figure 5). In 2011, there is one less class A site and one more class B, while the number of class C and D sites are unchanged. This does not mean that individual sites have not changed – they have, as indicated above – but the number of sites in different classes is almost constant. Therefore, it can be concluded that

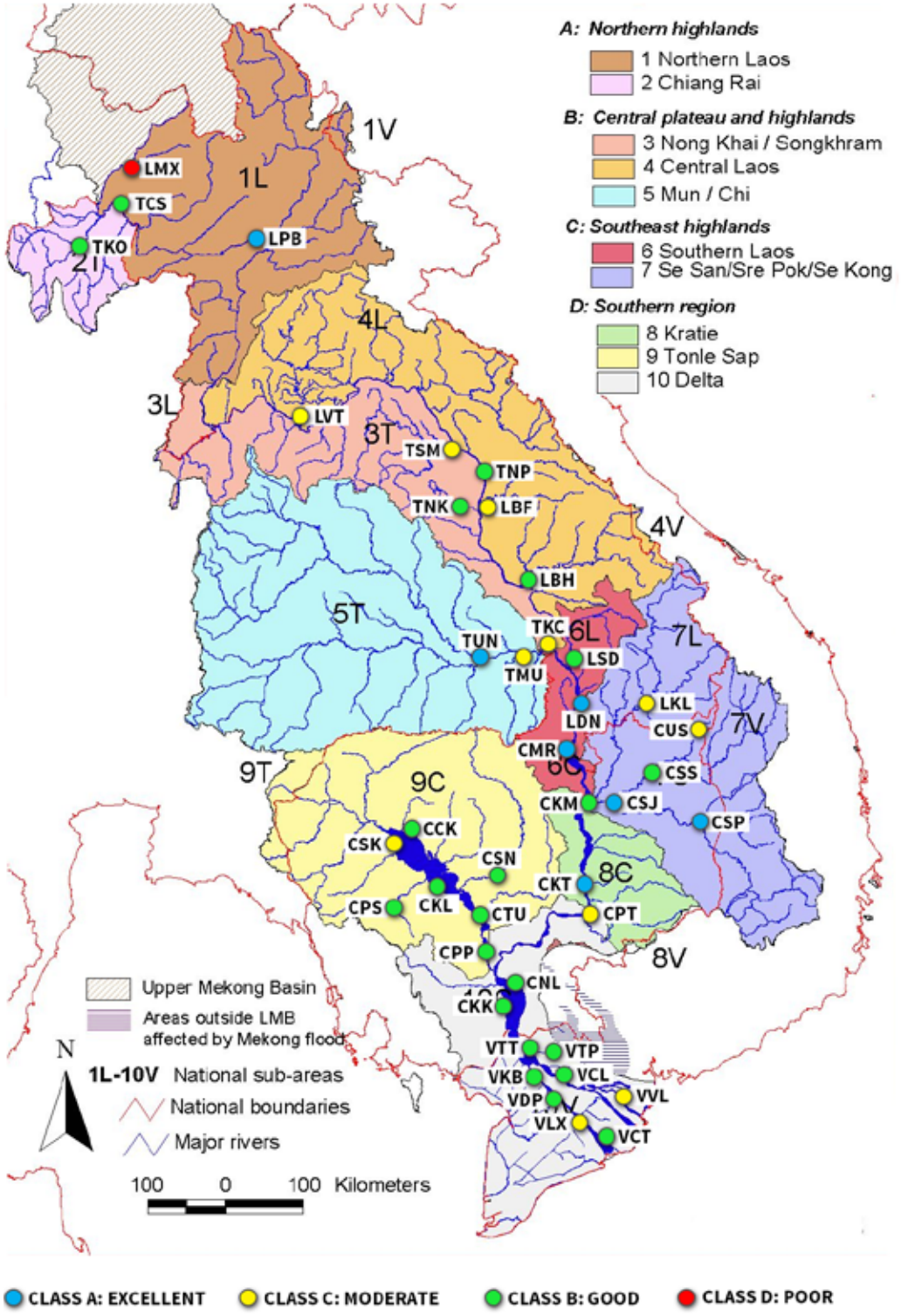



**Figure 4.1** Ecological health rating in the Lower Mekong Basin (2011 survey)

the overall ecological health of the Lower Mekong Basin remains unchanged in 2011 compared with 2008. However, when expanding the assessment period and looking only (see Table 3.7) at the 10 sites that have been monitored since 2005, a more gloomy picture appears: six sites have deteriorated (three of them by two class levels), three remain unchanged and one has improved by one class level.

Monitoring of fishes and/or larger invertebrates using a simple method might add to the future ecological health assessment and consideration of such aspects is recommended for potential strengthening of the ecological health monitoring system.

The trends of degradation and improvement in isolated locations give indicative points of increasing environmental impacts caused by human activities and degradation of habitats in some parts of the Mekong River – and improvements in others. The trends can be better projected by repeated sampling at the same sites. Further investigations into the causes and effects on biophysical and biological conditions are needed to identify necessary remedial actions and possible restoration efforts, including environmental outlook in the Mekong basinwide.

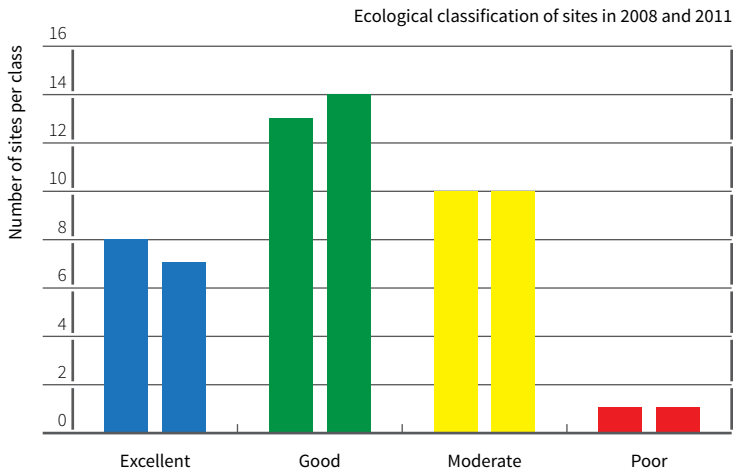



**Figure 4.2** Comparison of number of sites per ecological class in 2008 and 2011

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# APPENDIX 1.
# List of participants on the sampling field trip in 2011

| Participants on the sampling field trip in Lao PDR, 29 March – 9 April, 2011 | | |
|---|---|---|
| Niane Sivongxay, | Zooplankton (Team Leader) | Lao National University |
| Chanthima Ponthalith, | Benthic Diatom | Lao National University |
| Viengkhone Vannachack | Litteral and Benthic Macroinvertebrate | Lao National University |

| Participants on the sampling field trip in Thailand, 30 March -10 April, 2011 | | |
|---|---|---|
| Mr. Tatporn Kunpradid | EHM / National Expert, Team member | Chiang Mai Rajabhat University |
| Mr.Kittithon Chaisri | Researcher | Chiang Mai University |
| Mr Nirut Tengpongsathorn | Researcher | Chiang Mai Rajabhat University |
| Ms. Sujeephon Atibai | Researcher | Department of Biology, Faculty of Science<br>Khon Kaen University |
| Mr. Paiboon Gatewongsa | Researcher | Department of Biology, Faculty of Science,<br>Khon Kaen University |
| Mr. Prayut Udonphimai | Researcher | Department of Biology, Faculty of Science ,<br>Khon Kaen University |
| Ms. Ruamporn Ngamboriruk | Senior Policy and Plan Specialist,<br>EP Coordinator | TNMCs, Dept. of Water Resources |

| Participants on the sampling field trip in Cambodia, 27 March -9 April, 2011 | | |
|---|---|---|
| Chheng Phen | | Inland Fisheries Research for Development Institute (IFReDI) |
| Thach Phanara | | Inland Fisheries Research for Development Institute (IFReDI) |
| Chhek Roth | Member | Ministry of Environment MOE |
| Nhim Sophea | Benthic macroinveterbrate | Ministry of Environment MOE |
| Phin Rady, | | |
| Chea Vannara | Member | Ministry of Water Resource and Meteorology (MoWRAM) |
| Hing Sopheavy | Member | |
| Chin Deth | Member | |
| Kim Sopheap | Zooplankton | |
| Seoun Norng | | |
| Min Malay | | |

| Participants on the sampling field trip in Viet Nam 24th March – 03th April 2011 | | |
|---|---|---|
| Do Thi Bich Loc | Benthic Diatoms (team leader) | Tropical Biology Institute, Ho Chi Minh City |
| Pham Thanh Luu | Benthic Diatoms | Tropical Biology Institute, Ho Chi Minh City |
| Phan Doan Dang | Zooplankton | Tropical Biology Institute, Ho Chi Minh City |
| Huynh Vu Ngoc Quy | Littoral macro-invertebrate | Tropical Biology Institute, Ho Chi Minh City |
| Le Van Tho | Benthic macro-invertebrates | Tropical Biology Institute, Ho Chi Minh City |
| Nguyen Van Sang: | Benthic macro-invertebrates | Tropical Biology Institute, Ho Chi Minh City |
| Le Thi Nguyet Nga | Environmental Variables | Tropical Biology Institute, Ho Chi Minh City |
| Thai Thi Minh Trang | Environmental Variables | Tropical Biology Institute, Ho Chi Minh City |

## APPENDIX 2.
## Description of 41 sampled sites in EHM 2011

| Site Code | Location | Date | Coordinates | | | GPS elevation (m) | Width (m) | Depth (m) | | | Land Use Cover | | Substratum | | Potential human impacts |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UTM | UTM (N) | UTM (E) | | | Left | Middle | Right | Left bank | Right bank | Littoral | Channel | |
| LMX | Mekong River, Ban Xiengkok, Luangnamtha | 29-Mar-11 | 47Q | 2311778 | 670860 | 410 | 120 | 3 | 7.5 | 2 | Villages; port and washing place | Burmese side with vegetable farms; bamboo woodlands and cattle ranching | Cobble; gravel; filamentous algae; clay and grass on the bank | R-upper: sand; litter debris<br>M-middle: little sand and mud<br>L-lower: little debris and sand | Ripples from large boats cause bank erosion; domestic and farm wastes |
| LPB | Mekong River, Done Chor, Luang Prabang | 30-Mar-11 | 48Q | 2206957 | 206113 | 407 | 245 | 3 | 6 | 3 | Village; University downstream; large sand and gravel collection; road from left to the island | Steep, eroded bank; some trees on face; many trees on top; village downstream | Cobble; gravel; filamentous algae; clay and khai trees (Homonoia riparia) on the bank | R: sand: rock; litter debris<br>M: sand<br>L: mud and clay | Sand and gravel exploitation; navigation and overfishing |
| LVT | Mekong River, Ban Huayhome, Vientiane | 01-Apri-11 | 48Q | 1988731 | 239871 | 178 | 800 | 2-2.5 | Could not take sample (bedrock) | Could not take sample on Thai side | Lao Villages; port and vegetable farms | Thai Villages; port and vegetable farms | Small island-cobble, gravel, sand; debris, grass covered bank | R-upper: sandy; clay; litter debris<br>M-middle: sand; litter debris; little mud<br>L-lower: litter debris and sand | Agricultural runoff; domestic wastes and sewages; fish farming and navigation |
| LBF | Se Bang Fai River, Se Bang Fai, Khammouan | 08-Apri-11 | 48Q | 1959958 | 454745 | 72 | 100 | 4 | 7 | 3.8 | Housing; pumping; some trees on bank; washing place | Housing; floating pump; washing place; vegetable farms downstream | Small boulders on bedrock; sand; filamentous algae on bed rock | R: mud and sand<br>M: sand<br>L: mud | Farm and domestic wastes; bank erosion downstream |
| LBH | Se Bang Hieng River, Songkhone, Savannakhet, | 07-Apri-11 | 48Q | 1887920 | 498434 | 134 | 153 | 2.4 | 3 | 2.5 | Villages; some trees on bank; small pier; washing place | Washing place; vegetation gardens downstream | Boulders on bedrock; sand; mud; filamentous algae | R: clay; mud; sand<br>M: mud; sand<br>L: muddy sand and litter debris; | Farm and domestic wastes |
| LSD | Sedone River, Ban Hae, Pakse | 06-Apri-11 | 48P | 1671756 | 587623 | 101 | 128 | 3 | 5 | 3 | Villages and banana orchards | Maize; vegetable farms | Bedrock; mud; sand; filamentous algae | R: sand; mud<br>M: sand; debris<br>L: mud; clay; fine sand | Agricultural runoff; domestic and farm wastes; pumping |
| LKL | Se Kong River, Ban Somsanouk, Attapeu | 04-Apri-11 | 48P | 1623478 | 670696 | 111 | 200 | 4 | 5 | 2 | Banana orchards; bamboo; bank erosion | Villages and orchards; bank erosion | Cobble; pebble; gravel; khai trees; water channel changed from last year | R: sand; mud<br>M: sand; few granules<br>L: fine sand; litter debris | Domestic and farm wastes; fishing; navigation |
| LDN | Mekong River, Done Ngiew, Pathumphone | 05-Apri-11 | 48P | 1657517 | 596193 | 82 | 1235 | 2.5 | 6 | 2.8 | Villages and vegetable farms | Maize and tobacco fields; bank erosion | Sand; mud filamentous algae; khai trees | R: clay; mud; sand<br>M: muddy sand;<br>L: muddy sand | Fishing and navigation |
| TCS | Mekong River, Chiang San | 7-Apr-11 | 47N | 614706 | 2240577 | 364 | 600 | 0.5 | 10.5 | 2 | Water buffalo; soil erosion; algae and aquatic plant | Mud; aquatic plants and some housing; market | Sand and clay; firm sand; gravel | L: sand and gravel<br>M: firm sand<br>R: bedrock and cobble | Navigation; construction; domestic solid and organic wastes |
| TKO | Kok River, Chiang Rai City | 8-Apr-11 | 47N | 582587 | 2201804 | 391 | 120 | 0.5 | 1.8 | 0.5 | Sand bank and paddy field | Irrigation bank and flood plain | Cobble and gravel; sand | | Agriculture runoff; navigation; small village |
| TSM | Songkram River and Mekong River junction, Nakorn Phanom | 1-Apr-11 | 48N | 443522 | 1951853 | 135.5 | 350 | 0.4 | 1.8 | 0.6 | Forest; land slide; some housing; aquatic plants and algae | Small scale agriculture; docks; floating houses and fish cages | Sand and clay; firm mud and firm sand | R: sand; mud<br>M:sand; mud<br>L: clay and sand | Domestic and farm wastes; agriculture runoff; livestock damage to bank |
| TNP | Mekong River, Nakorn Phanom City | 31-Mar-11 | 48N | 476331 | 1926537 | 133 | 850 | | 10 | 1.5 | Agriculture; some housing; shoreline | Agriculture; some trees on bank; small scale fish farms | Muddy and rocky bed; wood debris | R: mud and clay<br>M: bedrock and cobble<br>L: mud and clay | Solid waste; agricultural runoff; fish farming; bank erosion |

| Site Code | Location | Date | Coordinates | | | GPS elevation (m) | Width (m) | Depth (m) | | | Land Use Cover | | Substratum | | Potential human impacts |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UTM | UTM (N) | UTM (E) | | | Left | Middle | Right | Left bank | Right bank | Littoral | Channel | |
| TNK | Nam Kham River, Na Kae, Mukdaharn | 2-Apr-11 | 48N | 450889 | 1874470 | 130 | 15 | 1 | 3.5 | 1.5 | Soil erosion; some houses; wood and leaf debris | Soil erosion and land slide | Sand and clay; gravel; sand and mud | R: gravel and sand<br>M: mud<br>L: sand and mud | Solid wastes; bank erosion |
| TUN | Mun River, Ubon Rachathani City | 4-Apr-11 | 48N | 494846 | 1685195 | 95 | 285 | 2 | 4.5 | 1.5 | Some housings, small scale farmlands and fish cages | Aquatic plants and few houses | Sand and silt | R: sand<br>M: sand and clay<br>L: sand and firm mud | Navigation; agriculture |
| TMU | Mun River, Kong Chiam, Ubon Rachathani | 3-Apr-11 | 48N | 552828 | 1691933 | 98 | 255 | 2.5 | 7.5 | 3 | Fields, agriculture, houses and floating houses, soil erosion, cattle grazing | Fish farms and floating houses | Sand and gravel | R: sand and gravel<br>M: sand and silt<br>L: sand and mud | Domestic and farm wastes, sewage; agriculture runoff |
| TKC | Mun River and Mekong River junction, Ubon Rachathani | 5-Apr-11 | 48N | 554100 | 1693503 | 86 | 86 | 2.5 | 13.5 | 3 | Village; agriculture; cattle grazing; fish farms | Bedrock and cobble; with many small channels and soil erosion | Sand and mud | R: sand<br>M: sand and clay<br>L: sand and firm mud | Agriculture runoff, livestock damage to banks, urban runoff |
| CMR | Mekong River, Ramsar Site, Stung Treng | 8-Apr-11 | 48N | 618663 | 1504098 | 58 | 1857 | 1,15 | 3.53 | 0.95 | Tourist boat dock, fishing boats and market | Slope covered with flooded forest, farms | Grasslands; sand; pebbles; and boulders | | Tourist boat dock; fishing boats and market |
| CKM | Se Kong River, Kbal Koh, Stung Treng | 9-Apr-11 | 48N | 606331 | 1539069 | 48 | 431 | 2.2 | 2.95 | 1.2 | Slope covered with forest and bamboo trees, and farm | Slope covered with sand, riparian shrubs, forest, and bamboo trees | Sand; pebbles; and channel | | Few villages |
| CUS | Se San River, Dey It, Rattanakiri | 5-Apr-11 | 48N | 717794 | 1490553 | 134 | | 0.65 | 1.13 | 0.93 | Slope covered with grasses, riparian shrubs, corn farming, rice field | Slope covered with 100 m long sand bank, trees, and farmland | Boulders; cobbles; sand | Boulders | Ferry dock, lower Se San hydropower dam |
| CSS | Se San River, Veunsai, Ratanakiri | 6-Apr-11 | 48N | 695488 | 1546145 | | 250 | 0.82 | 1.25 | 0.75 | Slope; 30 meters from residential housing and trail; crop trees; forest | Forest and bamboo trees | Pebbles; sand | Sandy; pebbles | Ferry dock and residential housing |
| CSP | Srepok River, Phik, Rattanakiri | 7-Apr-11 | 48N | 765124 | 1525674 | 100 | 186 | 1.9 | 3.9 | 1.7 | Slope covered with bamboo trees and forest | Slope covered with bamboo trees and forest | | Sandy soil, sand, boulders | Ferry dock and residential housing |
| CSJ | Se San River, downstream from the Srepok River junction | 10-Apr-11 | | 621744 | 1498832 | 50 | 576 | 0.75 | 1.25 | 0.82 | Slope, forest, and farm | Forest, bamboo trees and farms | Sand; pebbles; boulders | Islands with farmlands | Village farm; hydropower dam |
| CKT | Mekong River, Kampi Pool, Kratie | 3-Apr-11 | 48N | 610914 | 1393502 | 12 | 55 | 1.2 | 2.3 | 2.1 | Tourist-boat dock, national road, houses, crops, vegetables, rice field. Islands with flooded forest | Houses, trees, bamboo trees, rice fields, farmland | Sand, boulders and cobble | | Tourist-boat, housing, crops |
| CPT | Prek Te River, Preh Kanlong, Kratie | 4-Apr-11 | 48N | 613899 | 1374811 | | 22 | 1.4 | | | Grasses, riparian shrubs, trees, bamboo trees, crops, and houses | Slope, covered with grasses, riparian shrubs, corn farming, rice fields | Muddy | | Crops and houses; high disturbance from overfishing, gillnets. |
| CCK | Tonle Sap Lake, Chong Khnease, Siem Reap | 31-Mar-11 | 48N | | | | | 1.25 | | | | Fishing and tourist boats; Shore Lake covered with flooded forests of Barringtonia asiatica. | Muddy soil; shells of freshwater clams; gillnet waste | | Village, fishing and tourist boats and algae bloom. |
| CSK | Stung Sen River, Kampong Thom | 30-Mar-11 | 48N | 357473 | 1461902 | | 135 | 0.5 | 1.5 | 0.45 | Slope covered with water hyacinth, riparian grasses, riparian shrubs, and flooded forest. | Residential village; Disturbance from transportation and fishing boats | Muddy soil; bricks; wooden stick and debris | | Residential village, navigation |
| CSN | Stoeng Sangke River, Battambang | 29-Mar-11 | 48N | 490910 | 1401770 | | 65 | 0.76 | 1.12 | 1.3 | Erosion, was shrubs and rice field | Slope covered with farmlands; riparian grasses and shrubs | Sandy soil; sand | | Agricultural crops; paddy fields |

| Site Code | Location | Date | Coordinates | | | GPS elevation (m) | Width (m) | Depth (m) | | | Land Use Cover | | Substratum | | Potential human impacts |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UTM | UTM (N) | UTM (E) | | | Left | Middle | Right | Left bank | Right bank | Littoral | Channel | |
| CTU | Tonle Sap River, Peek Kdam Ferry, Kandal | 20-Apr-11 | 48N | 478364 | 1307071 | | 497 | 1.35 | 15 | 6.5 | Slope, from bank, water hyacinth, riparian grasses and shrubs, rice field | Houses and National Road #5. | Muddy soil and clay | | Houses and national road |
| CPP | Tonle Sap River, Phnom Penh Port | 27-Mar-11 | 48N | 491666 | 1280205 | | 536 | 3.5 | 6.8 | 3.8 | Water hyacinth, riparian shrubs, about 4-5 big trees, national road and residential housing | Ferry port and national road | Pebbles; muddy soil | | National road and residential housing |
| CPS | Pursat River, Damnak Ampil, Pursat | 1-Apr-11 | 48N | 381258 | 1382944 | 100 | 147 | 0.8 | 1.5 | 1.2 | Bank erosion, riparian grasses, trees. housing and farmlands; cash crops and rice fields. | Slope covered with sand, park for villagers, boulders, riparian grasses, and housing about 300m from river, marsh/small lake with lotus | Sandy; sandy soil; boulder; cobble | | Houses; agricultural crops and rice fields |
| CKL | Tonle Sap Lake, Kampong Luong | 2-Apr-11 | 48N | | | | | 1.12 | | | | Rice fields and river were flooded forest area with B. asiatica grasses, Ipomia aqautica water plants; and floating houses, fishing activities | Muddy | | Floating houses; overfishing |
| CNL | Mekong River, Nak Loeung, Prey Veng | 18-Apr-11 | 48N | 528321 | 1250852 | | 2150 | 2.2 | 18.3 | 3.4 | Slope, riparian grasses and shrubs, water hyacinth, rice fields and small lake | Riparian grasses and shrubs, farmland. | | | Ferry Port; sand pumping and fishing activities |
| CKK | Bassac River, Khos Khel, Kandal | 10-Apr-11 | 48N | 503786 | 1245255 | 3 | 280 | 1.54 | 13.5 | 7.4 | Slope covered with riparian grasses and shrubs, water hyacinth, farmlands (corn, paddy and vegetables) | Riparian grasses and shrubs, houses, national road and farmlands. | Muddy soil | | Farmlands, rice field |
| VTP | Mekong River, Thuong Phuoc, Dong Thap | 1/4/2011 | 48N | 519833 | 1205862 | | 1720 | 11 | 11 | 3 | Housing, grasslands | Housing, fruit garden, grass cover | Clay, solid waste: plastic bags, plastics, leather, clothes, wood, glass etc | R: Sandy mud; detritus; solid waste<br>M: Sand<br>L: clay; detritus; solid waste | Boat transportation, soil erosion, sand exploitation, construction fish farming, and fishing, domestic sewage and solid wastes |
| VTT | Mekong River, Thuong Thoi, Dong Thap | 2/4/2011 | 48N | 528955 | 1194541 | | 1562 | 1 | 3 | 2 | Farmlands of bean, chilli, fruit orchards, maize, etc, grass cover, housing | Soil erosion, agricultural farms such as bean, chilli, maize, etc, grass cover | Muddy sand flats, sunken wood | R: sand; clay; detritus<br>M: sand; silt; detritus<br>L: silt; sand; detritus | Agricultural farm, soil erosion, boat transportation, cattle ranching, domestic solid wastes and sewage, overfishing |
| VKB | Bassac River, Khanh Binh, An Giang | 26/3/2011 | 48N | 509484 | 1210968 | | 187 | 6 | 4 | 5 | Farmlands of maize, grain, grass cover, housing, water hyacinth | Bank erosion, housing, water hyacinth | Muddy sand flat, detritus, sediment with solid wastes, sewages and hyacinth | R: fine organic silt; solid waste<br>M: sand; organic detritus<br>L: silt; sand; organic detritus; solid waste | Domestic solid waste and sewage, agriculture runoff, boat transportation, sand exploitation, fish farming and capture, bank erosion from cattle. |
| VDP | Bassac River, Da Phuoc, An Giang | 27/3/2011 | 48N | 514693 | 1188129 | | 325 | 10 | 12 | 2 | Farmlands; maize, legumes, chilli pepper etc., housing, water hyacinth | Housing, farmlands; fruit orchards, with, bank erosion, bush tree, rice mill factory, water hyacinth | Mudflat, domestic and agriculture waste including toxic waste; pesticide bottle, and water hyacinth | R: clay; sand and detritus<br>M: sand; clay<br>L: clay; solid waste | Boat transportation, agriculture, intensive fish farming, and catching, domestic sewages and wastes, bank erosion, and pollution. |

| Site Code | Location | Date | Coordinates | | | GPS elevation (m) | Width (m) | Depth (m) | | | Land Use Cover | | Substratum | | Potential human impacts |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UTM | UTM (N) | UTM (E) | | | Left | Middle | Right | Left bank | Right bank | Littoral | Channel | |
| VCL | Mekong River, Cao Lanh, Dong Thap | 30/3/2011 | 48N | 563807 | 1153868 | | 1089 | 3 | 7 | 6 | Farmlands; maize, bean, chilli pepper etc., grasslands, housing, water hyacinth | Housing, farmlands and grasslands, water hyacinth | Mudflat, dead trees, plastic solid wastes, water hyacinth and grassland | R: clay; sand<br>M: Sand; clay<br>L: Mudflat; sand; solid waste | Agricultural activities, fish culture and capture, organic waste, sand pumping, domestic waste and sewage |
| VLX | Bassac River, Long Xuyen, An Giang | 25/3/2011 | 48N | 551904 | 1143527 | | 798 | 13 | 27 | 17 | Housing, farmlands, bank erosion, fish farming, water hyacinth and grasslands | Housing; small factory; fish farming; gas stations; water hyacinth | Mudflats, organic matter; solid wastes and toxic agricultural waste (pesticide bottle); water hyacinth | R: Sandy silt; sulfide mud; solid waste<br>M: sandy silt<br>L: silt | Boats, domestic pollution, small factories and agriculture runoffs, bank erosion |
| VVL | Mekong River, My Thuan, Vinh Long | 29/3/2011 | 48N | 603712 | 1134604 | | 1012 | 2 | 19 | 4 | Farmlands; fruit orchards; houses; hotel; water hyacinth | Housing; construction material storage; water hyacinth | Sediment, sand, detritus, death tree, plastic solid wastes, water hyacinth | R: silty; mud; solid waste<br>M: sand<br>L: silt and muddy detritus; solid waste | Intensive boat, sand exploitation, overfishing, intensive fish farming pollution from domestic, small factories and agriculture wastes |
| VCT | Bassac River, Phu An, Can Tho | 28/3/2011 | 48N | 589060 | 1106773 | | 1611 | 6 | 9 | 7 | Housing, fruit orchards, bank erosion, water hyacinth | Fruit orchards, housing, water hyacinth | Muddy sand flats, domestic solid wastes, dead trees, water hyacinth | R: sandy mud, with solid waste<br>M: silt, sand<br>L: sand, silt, with solid waste | Intensive boat transportation, oil spill from storage, domestic sewage and small industrial wastes and overfishing |