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Managing Health of Large Rivers in Developing Regions : a Case Study from the Mekong.

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ABSTRACT
A healthy river is considered to contain a diversity of habitats, intact linkages between ecosystem components and functional ecological processes. The river health strategy being developed for the Mekong recognizes the need to manage the physical habitat, the flows, the harvest, the water quality and the catchment condition in order to manage river health. A biological assessment programme has been developed as one tool to assess river health. Diatoms, zooplankton and benthic invertebrates are being evaluated at a series of sites throughout the basin. Preliminary analysis of the data indicates that most sites are in good or excellent condition, but there is some impairment of river health at some localities near large cities such as Phnom Penh and in the delta.

INTRODUCTION

The Mekong River, one of the world's largest, flows from the Himalayas to the South China Sea through the territory of six southeast Asian countries. Rising in Tibet in China the river flows through Myanmar, Lao PDR, Thailand, Cambodia and Viet Nam. The river forms a transport artery for those that live along it, as well as providing a source of water, food and mineral wealth. Many of those who live in the basin, variously estimated at about 65 million people, are subsistence farmers dependant on the rice they grow or the fish they catch.

The Mekong River Basin will change rapidly over the next few decades. Population growth in the basin is rapid as a result of increased political stability and the relative youth of the population. Annual growth of Cambodia's population is estimated at 2-3%, while that of Laos is similar, reaching up to 3-4 % in some provinces (MRC 2003). Much of the population of the basin is very poor, so there is a high demand for development as a pathway to poverty alleviation. The as a result the basin has become a geographical focus for a number of development agencies, including the Asian Development Bank, the World Bank and national aid agencies from developed countries. A number of large development projects have commenced or are under consideration, including the first large dam on the Mekong, in Yunnan Province China, Nam Theun II hydropower project in Lao PDR and a number of hydropower and agricultural development projects in Viet Nam and Cambodia.

The Mekong River Commission is developing a number of activities to ensure that rapid development does not cause unacceptable deterioration to the health of the Mekong River. A Mekong river health strategy is in the course of development, which will focus on five main elements which require management if river health is to be maintained. Monitoring procedures are already operating for several of these elements and a newly established monitoring activity is addressing the overall ecological health of the river.

DEVELOPMENT OF A RIVER HEALTH STRATEGY

This River Health Strategy is intended to provide a framework for managing the Mekong River. Within the framework the four lower Mekong governments (Lao PDR, Thailand Cambodia and Vietnam) will be able to work in partnership to make decisions on the management of rivers in the lower Mekong basin. It can also be used to integrate activities within countries, and within the MRC secretariat.
The strategy includes a common vision for the management of rivers in the lower Mekong basin which is based on the existing 1995 on cooperation for the sustainable development of the Mekong River Basin.

The 1995 Agreement recognized that the Mekong Basin and related natural resources are assets of immense value to all the riparian countries for the economic and social well-being and living standards of their peoples. The countries realized that there was a need to cooperate in the sustainable development, conservation and management of the water and related resources of the Mekong. The countries agreed to cooperate to promote development of the basin while protecting the environment, natural resources, aquatic life and conditions and ecological balance from pollution or harmful effects from development plans. In short they agreed to maintain the ecological health of the river.

What constitutes a healthy river? Like the concept of human health, the concept of river health is difficult to define. But just as indicators such as body temperature, blood pressure and pulse rate (among others) can be used as indicators of human health, there are things that can be used to indicate river health.

River health is a term used to describe the ecological condition of a river. That will include a range of physical and biological components which together comprise the riverine ecosystem. Three major aspects of the system can be identified.

Maintaining the *diversity* of habitats and biota is essential to maintaining river health. Healthy rivers have a range of habitats – deep pools, shallow riffles, sand bars, beds of aquatic plants, trunks and branches of dead trees and more. The variety of habitats is one of the important factors in enabling a variety of organisms to live in the river. The biodiversity is promoted by the diversity of habitats in river which are patchy in both space and time.

The *linkages* between the various components of the riverine ecosystem are very important. The river is more than just a river channel. The downstream estuary is very important. It is the breeding area for some species, and a passageway for other species which move between the river and the sea. Nutrients and sediment pass out through the estuary to fertilize the inshore marine systems. Similarly the linkages between the river channel and the floodplain are also important both for the ecology of the in-channel biota and the floodplain biota allowing passage of water, nutrients and the dispersal of animals and plants. The biota of floodplain communities that are flooded once per year will change if they are flooded only once every five years. The biota of communities which are flooded for 4 months every year will change if the period of inundation changes to one month per year.

Finally the *ecological processes* must be fully functional in healthy rivers. The movements of nutrients that spiral through the riverine system, the levels of primary production and respiration and the flows of energy through food webs must be functionally with the normal ranges for the river reach. These are the processes which support, and are supported by, the biota of the riverine ecosystem.

MANAGEMENT COMPONENTS

Five main areas of environmental management have been identified for the Mekong to be adequately managed.

Managing the harvest is conceptually the most straightforward management issue. If too many individuals of any species are removed from the river the species numbers will decline and the species will eventually disappear from the stream. Fish are the most conspicuous group of harvested organisms, but in the Mekong system the list is long: dolphins, snakes, crocodiles, turtles, frogs, insects, river weed, snails, mussels and more are all harvested or have been in the past. In addition to directly harvested species there may be species which are unintentionally caught and killed as by-catch. For example dolphins are no longer harvested but are occasionally trapped in fishing nets and killed. Elimination or reduction of harvest target species may have impacts on the abundance of other species which may have been the food, or competitors with the harvested species.

Habitat quality is obviously and important factor in determining the presence of organisms. Very few fish or other aquatic organisms will live in concrete drains even if the water quality is good and there is no fishing. Fish require a more complex habitat. Organisms require water of suitable depth, and appropriate bottom material and appropriate shelter. They may also need to move to different types of habitats at different times of their life cycles – for example fish moving from deep to shallow waters to spawn, or from the channel to the floodplain to feed; so barriers may disrupt the habitat.

The flow pattern of a river plays a key role in regulating the life cycles of the organisms in the river. Many aquatic insects and some fish lay their eggs during the low flow season when eggs are less likely to be washed away. Other fish and aquatic insects reproduce during the high flows when habitat is more abundant. A change in flow for many species seems to trigger migration behaviour. Changes in flow characteristics of the river can interfere with these cues, or reduce breeding success of riverine species.

Water quality is the fourth key factor directly impacting the aquatic biota. As water quality deteriorates the number of species which can survive and thrive in a water body decreases. Water quality can be quite difficult to assess, partly because it is often variable in time. Dissolved oxygen is often appreciably lower at night – especially in rivers with high densities of algae. Industrial toxicants are also often present in a stream only intermittently, or unexpectedly.

The fifth factor influencing stream health is the condition of the catchment which is indirect, but crucial. The catchment condition influences the amount, timing and quality of the water flowing in to the river. Thus it determines, to a large extent, water quality. Catchments with large areas of bare soil will contribute to river sedimentation. Intensive agriculture, poorly managed, can lead to excessive nutrients and pesticides contaminating the river. Urban catchments have higher flood peaks and lower base flows because much of the rainfall runs off the paved surfaces directly to the river rather than passing through the soil.

The MRC is developing tools and management programmes to allow the four member countries to cooperate in managing and monitoring all five components, but it was realized that a monitoring programme to directly assess river health was also required.

MONITORING RIVER HEALTH

Very few monitoring programmes have ever been conducted to track the ecological health of large tropical rivers. There has been some work on large temperate rivers such as the Mississippi in the US and the Rhine and the Danube in Europe, but far less on tropical rivers. In some cases there has been less need for ecological health monitoring because the rhealth of the river is known or assumed to be good. This is the case for several large South American rivers. However in many cases there was simply a lack of resources and desire.

Development of a monitoring programme for the Mekong therefore required some initial work to identify the ecological components of the system that could most usefully and readily assessed. This initial evaluation was conducted in 2003 using local experts working with mentors.

The mentoring system was adopted through a desire to balance capacity building, high quality outputs and ownership of the programme. The present programe includes two highly experienced international mentors who assist with sampling, data analysis and interpretation, and report production. The actual work is conducted by a group of national experts drawn from universities and research organizations. At present 7 experts are used with two from each country except Cambodia, from which we have only one.

To develop biomonitoring programmes it is essential to have adequately trained participants. Participants in the Mekong biomonitoring exercise were selected because of the expertise in the taxonomy of one of the selected indicator groups, and their ability to conduct field sampling. It is not possible to provide this sort of expertise through programmes of short courses, the participants need to have basic skills before recruitment to the programme.

A wide range of possible indicators was evaluated in 2003. These included both components of the biota and ecological processes. Biotic components assessed included phytoplankton using field based fluorimetry, benthic diatoms, benthic invertebrates in several habitats (littoral and soft sediments), zooplankton and fish. Primary production and respiration were also measured using a light and dark bottle method.

Of the indicators tested several were abandoned because they were too time consuming. For example to measure primary production required an incubation period of at least 6 hours, and to collect a reasonable sample of the fish assemblage required netting over night, preferably for several nights. So neither of these components were included in the final suite of indicators. Both were recognized as being potentially important and worth reconsidering if more rapid techniques become available. In view of the dependence of the people of the basin on fish, having a fish indicator would be particularly useful.

APPLICATION OF RIVER HEALTH MONITORING IN THE MEKONG

The river health monitoring programme in the Mekong is now into the third year but development of monitoring tools is still a major component of the activity. There are several tool sets required. One is a set of taxonomic keys to allow important components of the biota to be identified. A key to the invertebrates has been completed and is in the final editing process. It is intended to produce keys to other components of the biota over the next few years. Once keys are available it is hoped that they will stimulate both taxonomic and ecological research within the basin.

An additional tool that will be required is some kind of metric that can be used to quantify river health. At present we have data on the five biological components together with some physicochemical data collected at the time of sampling. The results are not concordant, and were not expected to be. If several different biological components or the biota and the physico-chemical gave identical results then there would be no need to monitor them all, since the results from several would be redundant.

The physico-chemical measures taken at the time of sampling provide a limited view of the present condition of the river. The parameters measured include temperature, dissolved oxygen, conductivity and turbidity. However all these parameters change over time, and the measurements are taken only once, at the time of the biological sampling. Furthermore they do not include many other physico-chemical parameters which are known to influence river health, such as nutrients or toxic substances. Thus it is not surprising that there may not be concordance between these parameters and the biota. There is other data available over much of the basin from the extensive monthly series of physico-chemical water quality monitoring assessments, although not necessarily from the sites at which the river health monitoring is conducted. This can also be used in river health evaluations.

Amongst the biological parameters there are also good reasons for expecting different outcomes for different taxa. The diatoms and benthic invertebrates are greatly affected by the substrates present. These obviously differ between sites causing differences in the assessments (Table1). Zooplankton are not so dependant of substrate, but are favoured in areas where the river is large and slow flowing, and are less abundant where the river is shallow and turbulent. However the shallow turbulent sections are often the places where littoral invertebrate diversity is greatest.

Where there are significant water quality problems we expect that all the biological components would indicate stress. The possible exception would be zooplankton and phytoplankton where there was intermittent pollution, since healthy assemblages may be present in water flowing down from upstream of a pollution source. Where only one of the benthic assemblages shows apparent stress it is most likely due to a habitat effect, which may be natural or of human origin.

In table 1 the differences in responses of the various biological components is obvious. For example site LNO on the Nam Ou River in Laos ranked very poorly based on zooplankton but was ranked highly on species richness of benthic invertebrates and diatoms. The site was shallow and turbulent, presumably not an ideal habitat fro zooplankton. Most of the sites that ranked best for zooplankton were in the lower reaches of the river – in Cambodia and Viet Nam, where the river is large, slow flowing and more laminar in flow.

The preliminary first attempt to evaluate the sites of the Mekong sampled so far was based on fairly subjective assessments (Table 2). No sites appeared to suffer significant impairment, based on all biological indicators. However it would be preferable is an explicit metric can be developed which could be used to evaluate sites based on biological data, and possibly incorporating physico-chemical data as well. This remains a goal of the programme.

MRC is now attempting to combine the bioassessment data for the Mekong with the results of the chemical water quality monitoring programme and a diagnostic study which collected data on toxic materials such as pesticides, metals and persistent organic compounds to develop a basin report card. Such a card can be widely distributed and easily updated. Reports could be produced which address a range of basin issues, including landuse, fisheries and broad river health issues. We expect the reports to provide a stimulus to encourage informed public debate and also to encourage people within the basin to think in terms of the basin as a whole.

CONCLUSION

The development of tools to assess river health in the Mekong River Basin has demonstrated that river health assessment can be implemented as a management tool in large tropical river basins, even where capacity is relatively weak. Mentoring is a valuable technique to build capacity as well as ensuring high quality results, but work needs to be directed both to development of assessment tools and the assessment process.

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Table 1. Ranking of sites in the Mekong River Basin based on various biological criteria. Shadings indicate site ranking with the best quality 25% of sites indicated unshaded and successive quartiles more heavily shaded. Sites for which no data are available are indicated with hatching. The numbers indicate the absolute ranking position for the indicator with 1 being the "best" site. Note that rankings are purely relative, sites ranked in the lowest 25% are not necessarily poor quality. The diatom indicator species column tested a system based on arbitrarily defined indicator species, and no sites were ranked very high quality.

Site	Zooplankton Species Richness	Littoral Invertebrate Species Richness	Diatom Indicator Species	Diatom Species Richness	Benthic Invertebrate Diversity
LNO	19	3	2	4	1
LVT	18	15	2	13	19
LPB	16	17	2	2	3
LNG	7	6	-	6	6
LKD	20	9	-	8	13
LPS	4	18	2	16	3
TMU	1	15	-	11	11
TCH	7	6	4	8	6
TSK	16	8	4	3	12
TKO	12	12	3	1	9
CPP	3	20	4	19	2
CTU	5	19	4	16	8
CPS	5	9	2	20	16
CSS	9	4	-	18	17
CSP	14	1	-	14	15
CKT	11	5	-	6	18
VTC	2	12	3	5	10
VCD	10	11	3	15	5
VSS	15	12	-	12	-
VSP	13	1	2	10	14

Table 2. Final combined assessment of sites evaluated in the 2004 bioassessment exercise conducted by the MRC).

Site Code	Site name	
Excellent Condition		
Good Condition		
Some Impairment		
LNO	Nam Ou	
LVT	Vientiane	
LPB	Luang Prabang	
LNG	Nam Ngum	
LKD	Nam Ka Dinh	
LPS	Pakse	
TMU	Mun River	
TCH	Chi River	
TSK	Songkrahm River	
TKO	Kok River	
CPP	Phnom Penh Port	
CTU	Tonle Sap u/s Phenom Penh	
CPS	Pursat River	
CSS	Se San River	
CSP	Sre Pok River	
CKT	Kratie	
VTC	Tan Chau	
VCD	Bassac u/s Chau Doc	
VSS	Se San	
VSP	Sre Pok	