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Perceptions, data, and river management: Lessons from the Mekong River

Ian C. Campbell[1]

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[1] Workshops to identify transboundary and basin-wide environmental issues and a diagnostic study by consultants identified priority environmental concerns of resource managers in the lower Mekong River basin. The issues identified, in priority order, were water quality, reduction in dry season flows, sedimentation, fisheries decline, wetland degradation, and flooding. An analysis of the available data found no evidence that water quality was poor except in the delta, where nutrient levels were high and increasing. Dry season flows have not decreased, and in the immediate future they are more likely to increase. Suspended sediment levels in the river are not high, and there is no indication that sediment loads are substantially increasing. Fish catch per unit effort has declined over the past decades, as have catches of large fish, but total fish catch has increased. Flooding does not appear to have increased in frequency or extent. There is no reliable quantitative information available on changes in wetland extent or condition, although it is reasonable to assume that both have declined. Reasons for the mismatch between perceptions and the data may include a failure by management agencies to analyze and publish data and provide adequate responses to issues raised in the popular press. This results from a lack of capacity in many government agencies and the Mekong River Commission, where there are high staff turnover rates and a dependence on short-term experts with limited experience in the basin.

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1. Introduction

[2] Resource managers make management decisions on the basis of their perceptions of the most critical pressures on the resource and the tools they have available to manage. If the perceived pressures are not the real pressures managers are likely at best to waste time and money addressing less important issues, and at worst to allow significant resource degradation as they fail to respond to important pressures.

[3] There appears to be a general assumption that resource managers have reasonably accurate perceptions about the resources they manage. For example, the Global International Waters Assessment (GIWA) is conducting an entire assessment of the condition of global waters based on the perceptions of experts, including researchers and resource managers [*Global International Waters Assessment*, 2002] (available at http://www.giwa.net/methodology/GIWA_Methodology_DA-CCA-POA_English.pdf). However, the assumption that the experts' perceptions reflect reality has rarely been able to be tested. Within the Mekong countries [e.g., see *Enters*, 1995] and in other developing regions such as the Himalayas [e.g., see *Ives and Messerli*, 1989] researchers have previously argued that community perceptions of environmental problems do not match reality, but strong evidence to support these contentions has been lacking.

[4] River basin managers in developing countries face greater challenges than those in developed countries. In developed countries managers are likely to have access to abundant high-quality data and interpretations and analysis of that data. There is often also a relatively well informed public debate about controversial issues and policy formation is informed by advice from national experts familiar with the data, issues, policy context and national culture. In contrast, in developing countries data are often sparse, interpretations and analysis uncommon, and management policy is often greatly influenced by consultants from elsewhere who may or may not have a sound appreciation of the local situation.

[5] The Mekong River Commission (MRC) was established in April 1995 under an Agreement on cooperative sustainable development between the Governments of Laos, Thailand, Cambodia and Vietnam, to promote sustainable development of the Mekong River basin. It is primarily funded though support from international aid agencies and multilateral development banks, and amongst other activities collects and collates a range of environmental data from the basin.

[6] A series of activities conducted by the Commission provided an opportunity to compare the perceptions of Mekong River basin managers with data collected on the environmental condition of the river. A study commissioned by MRC and UNEP based on reports by national experts, workshops and existing data identified priority environmental issues in all 6 Mekong basin countries [*Mekong River Commission and U.N. Environment Programme* (*MRC and*

[1]Rhithroecology, Blackburn South, Victoria, Australia.

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UNEP), 1997]. Additionally, workshops were conducted in the four lower Mekong countries in 2001 at which participants were asked to identify the most important transboundary environmental issues affecting the river and then to rank these in order of priority. These workshops were conducted under the Water Utilization Programme (WUP) which is funded by the World Bank under the GEF program to support development of a basin modeling package, the formulation of rules for water utilization and institutional strengthening of the MRC member countries. I have compared the results from these two activities with data from various sources to try to establish to what extent the concerns of the managers are supported by data on the river system collected by the Mekong River Commission and others.

[7] Mekong River is one of the largest in the world with a mean annual discharge exceeding 475×10^9 m^3 [*Mekong River Commission* (*MRC*), 2003]. The river rises on the Tibetan Plateau at an altitude of about 5200 m and flows southeast to the South China Sea though the territory of 6 developing countries: China, Myanmar, Laos, Thailand, Cambodia and Vietnam. About 80% of the 60 million people inhabiting the lower basin are subsistence farmers, usually supplementing their rice harvests with wild resources including fish and other wetland animals and plants [*MRC*, 2003].

2. Methods

2.1. Environmental Perceptions

[8] Information on perceptions of the environmental situation in the Mekong River basin has been derived from two sources. One is the outcome from a series of national and regional workshops conducted as part of the Water Utilization Programme of the Mekong River Commission. The other is a review of various published and unpublished documents and reports.

[9] The MRC Water Utilization Programme conducted a series of national and regional workshops during March and May 2000 to identify transboundary environmental issues in the lower Mekong basin [*MRC*, 2002]. National workshops, coordinated by the National Mekong Committee of each country, were held in Cambodia, Laos, Thailand and Vietnam. Approximately 160 people attended the workshops, with the fewest at any workshop being 21. Participants were almost entirely staff from government agencies with at least 10 different agencies represented in each workshop. Agencies represented in each workshop included those with responsibility for environmental policy and pollution control, water resources and energy supply in each country.

[10] The output from each workshop included two prioritized lists of transboundary issues: one a list of issues where it was considered by the participants that their own country was impacted by a process outside the country, and the other where participants considered that their own country may be impacting another. Participants in the Thai workshop produced only the first list, so 7 lists were produced from the 4 workshops. Each workshop was free to include as many or as few issues on its lists as it wished. The greatest number of issues included was 9.

[11] For use in this study I ranked the issues in importance by how many of the 7 lists in which each issue appeared, and what ranking it achieved in each list. The ranking was assessed by allocating the top priority issue 9 points (since the longest list had 9 issues), the second top issue 8 points and so on until all the issues on each list had points allocated. The number of points each issue received was then summed. The maximum score possible for any issue was 7 for the number of lists and 63 ($= 9 \times 7$) for the rank sum.

[12] The second major source of information on environmental perceptions was the Mekong River Basin Diagnostic Study conducted by MRC and UNEP in 1997 [*MRC and UNEP*, 1997]. This study was undertaken by consultants working with government agencies and contracted national specialists from each of the countries in order to "better understand the major environmental problems and their causes" in the Mekong River basin. The study included the whole basin, including the area of the upper basin in China and Myanmar, and was based on reviews of published literature, unpublished documents and databases, consultations with officials and the expert opinion of the consultants. It identified five priority issues under the heading "physical resources," six under the heading "ecological resources management" and four under "quality of life management."

2.2. Environmental Conditions in the Basin

[13] Information on environmental conditions in the basin was derived from a variety of data sources. These included the water quality database held by the Mekong River Commission, and a variety of published and unpublished reports.

[14] The MRC water quality database includes the results of water quality analyses conducted at 99 sites across the basin monthly since 1985 (since 1992 in Cambodia). The sites were located to allow monitoring of the main stream, major tributaries and potentially significant sources of water pollution (Figure 1). They included 9 mainstream sites upstream of the junction of the Bassac and Mekong (which defines the beginning of the delta) stretching from Phnom Penh in Cambodia to Chiang Saen in northern Thailand. Sites were also located above the junction with the Mekong of all the major tributaries with the exception of the Se San, Se Kong and Sre Pok in Cambodia.

[15] In order to detect water quality issues at specific locations sampling sites were also located downstream of most major cities including Chiang Rai, Khon Kaen and Ubon Ratchathani in Thailand, Luang Prabang, Vientiane and Pakse in Lao PDR, and Kratie and Phnom Penh in Cambodia. The exceptions are Battambang and Siem Reap in Cambodia. Political instability prevented monitoring sites being established in some parts of Cambodia when the monitoring network was being established; however, it has recently been revised and new sites are in the process of being established.

[16] Within the Mekong Delta a network of 46 sites was established (Figure 1) mainly to address the issue of drainage from acid-sulphate soils. It was originally intended to operate most of these sites for only two or three years but they were never shut down. Several of the sites in the Vietnamese highlands were shut down because of accessibility problems after 1995, so data from 1992 to 1995 were used from these sites.

[17] Chemical analyses are carried out by a designated water quality laboratory in each MRC member country using standardized procedures, and results are forwarded to the MRC where they are checked before inclusion in the database. For most of the sites there were no flow gauging facilities, so flow data are not available.

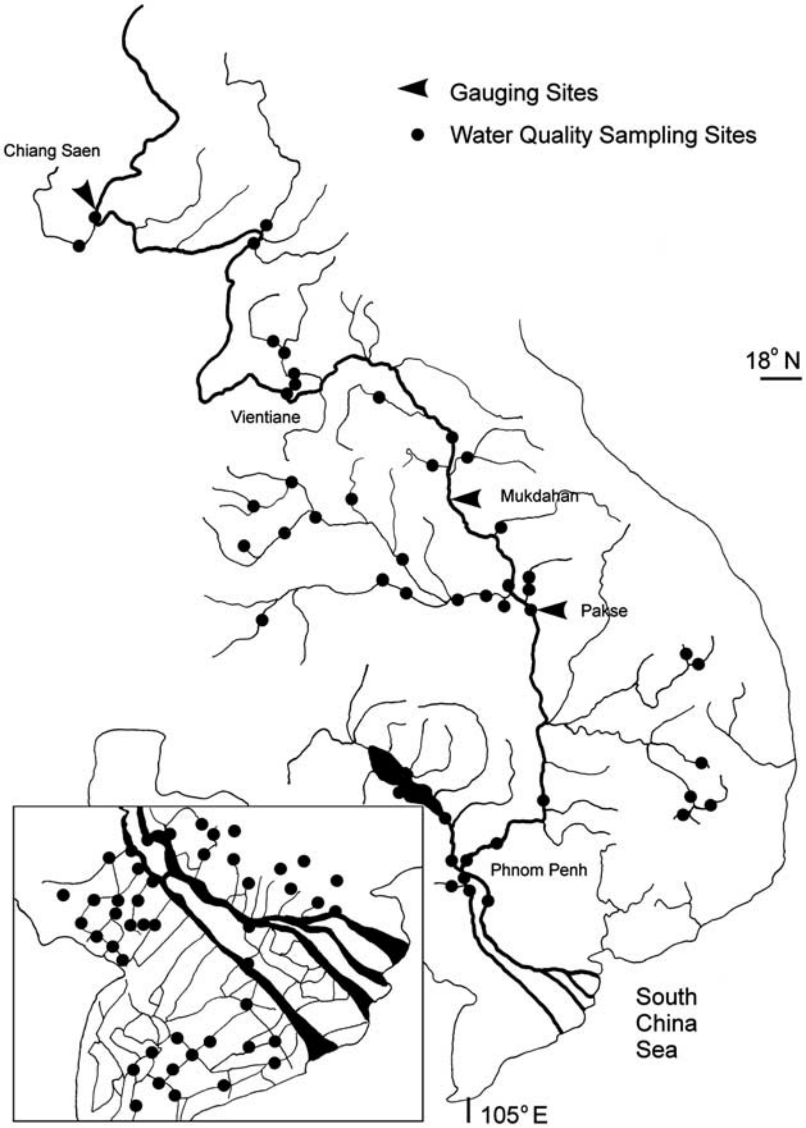

Figure 1. A map of the lower Mekong River basin showing locations of the sampling sites used by the MRC for water quality monitoring and the three discharge gauging sites for which data were discussed in this study. The map is based on one originally produced by the MRC Environment Programme. The inset shows an enlargement of the Cau Mau Peninsula.

[18] For this paper I considered results from the database for six parameters: conductivity, total phosphorus, total nitrogen, nitrate plus nitrite, chemical oxygen demand and total suspended solids. Conductivity data were analyzed because of the issues of salinization in northeast Thailand [*Ghassemi et al.*, 1995] and seawater intrusion in the delta [*Miller*, 2000; *Kam et al.*, 2001] (the latter is available at http://www.inrm.cgiar.org/documents/cali_workshop.htm). The nutrients total phosphorus, total nitrogen and nitrate plus nitrite were analyzed as indicators of potential eutrophication from urban runoff, agricultural fertilizers or aquaculture waste. Total nitrogen is a more useful indicator than nitrate plus nitrite but is not analyzed by all country laboratories so the data set is incomplete. Chemical oxygen demand (COD) was used as an indicator of organic pollution (more widely used parameters such as total organic carbon or BOD are not analyzed) and total suspended solids data were analyzed as one indicator of sediment issues.

[19] For each of these parameters data for the period 1999–2003 from sites in 10 major subareas of the lower Mekong (Figure 2) were pooled and compared using box and whisker plots generated with the SYSTAT computer package. The subareas used were those developed by the Basin Development Plan, a basin-wide development planning activity conducted by the Mekong River Commission. The subareas are loosely based on subbasins with some lumping of small subbasins to reduce the overall number. The only data available for subarea 7 were for the period 1992–1995 so these were used for this subarea only. For the total phosphorus and nitrate plus nitrite, conductivity and suspended solids linear regression analyses on the complete data set (1992–2003 for sites in Cambodia and 1985–2003 for other sites) have also been conducted and have been reported in detail elsewhere [*MRC*, 2003], but a summary is included here.

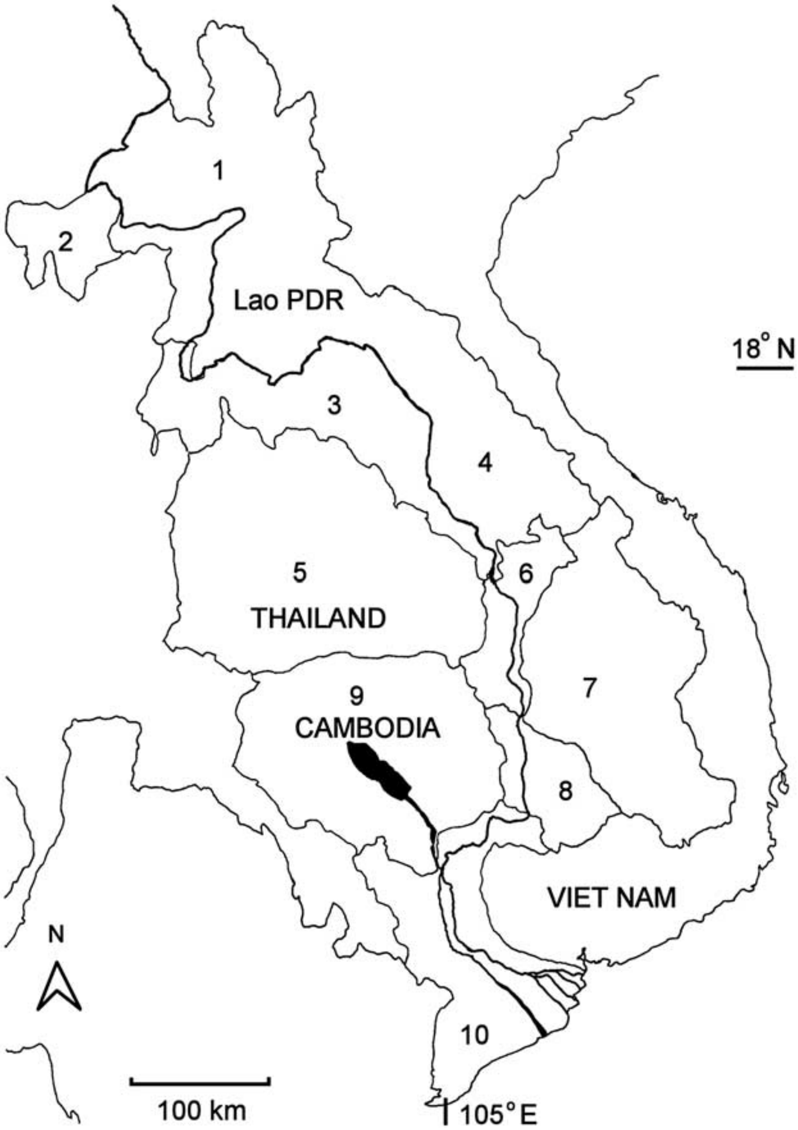

Figure 2. A map of the lower Mekong River basin showing the subareas designated by the Mekong River Commission Basin Development Plan and used as a basis for water quality assessment in this study. The map is based on a map originally produced by the MRC Basin Development Programme.

[20] Many water quality parameters may be influenced by flow at the time of sample collection. Conductivity is generally inversely correlated with discharge while many others are usually positively correlated [e.g., *Chapman*, 1996]. To confirm these relationships, regressions of concentration versus discharge on the day of sampling were tested for all the parameters at the Chiang Saen and Pakse sites, at which flow data were available. In addition, at these two sites the distribution of daily flows on the sampling dates was compared with the distribution of all daily flows during the 5-year sampling periods, and the distribution of daily flows during the period from 1960 to 2003. If the sampling dates included a higher proportion of high flows and lower proportion of low flows than usual the median and percentile values of the positively correlated parameters would be higher than the true value and vice versa.

[21] The MRC water quality database contains little data on toxic chemical contaminants such as pesticides, metals and persistent organic contaminants. However, a recent study conducted by *Bureau de Geologie Appliquée and Centre d'etude du Machinisme Agricole du Génie Rural des Eaux et Forêts* (*BURGÉAP and CEMAGREF*) [2004] provides information on levels of such contaminants at about 20 sites throughout the basin.

[22] Information on sediment in the river was derived from the data on suspended sediment previously discussed, and also from two unpublished reports. *Bountieng* [2003] compared channel cross-section profiles at Thanaleng-Nongkhai profiles over the period from 1995 to 2002 to see if there was any pattern of change that could indicate infilling or scouring over that period. *Walling* [2005] has recently reviewed sediment transport data collected at 5 sites on the river and also considered whether there was evidence of a change in sediment load over the periods for which data are available.

[23] Analysis of flow patterns was based on hydrological data collected by line agencies in the Mekong basin is compiled by the MRC into a database and publicly released in a series of hydrologic yearbooks [e.g., *MRC*, 1998]. Data

Table 1. Ranking of Transboundary Issues by Participants in National Workshops Conducted by the Mekong River Commission Water Utilisation Programme in 2001[a]

Issue	Rank Sum	Number of Lists
Water quality	40	5
Dams and reduced dry season flows	35	5
Sedimentation	26	4
Flooding	25	4
Decline in the fishery	24	4
Degradation of wetlands	12	2

[a]The maximum number of lists in which an issue could appear is 7, and issues that appeared in only a single national list are not included. Rank sum is derived by summing the rankings in each workshop, with 9 points allocated to the most serious issue and 1 point allocated to the least serious; the maximum number of points possible was 63.

from 124 sites are available but for the purposes of this paper I analyzed data from four sites on the main stream for which reliable long-term data records are available: Chiang Saen, Mukdahan, Pakse and Kratie. The data analyzed include the whole available record at Chiang Saen (1961–2004) and Pakse (1924–2004) and the records from 1950 to 2004 at Mukdahan. For the sites at Chiang Saen, Mukdahan and Kratie monthly discharges were evaluated for trends using linear regression. For each month the slope of the line was noted (positive or negative) and whether the slope was significantly different from 0 ($p = 0.05$). These data were compared with monthly rainfall data from the closest localities within the basin with reliable long-term records (at Vientiane, Mukdahan and Ubon Ratchathani) to see whether patterns in rainfall and discharge are similar. At Pakse, where there is a very long discharge record, annual minimum and maximum daily flows were analyzed for trends over time.

[24] Analyses of the Mekong floods were conducted for the hydrological monitoring site at Pakse, in southern Lao PDR, which has the longest flow record of any site in the lower Mekong (1924–2004). Three analyses were conducted. First was a regression of the highest daily flow each year against year to see whether there is a trend of increasing flood heights. Second was a regression of the number of flood days each year to see if there has been an increase in the number of inundation days, and third was a regression between the number of flood years per decade versus decade to see whether there is evidence of an increase in frequency of flood years. The flood level was taken as the MRC designated flood level, which is determined to be a gauge height of 12 m or the equivalent flow based on the present rating curve. This would be a source of some error since the rating curves have changed slightly over the years, but the errors are likely to be small. Apart from the long hydrological record, Pakse was chosen as the data set because the location, in southern Lao is downstream of many of the larger tributaries that have joined the Mekong, so it probably provides a good representation of the basin as a whole, and is fairly close to the Cambodian floodplain, the area of the most extensive seasonal inundation in the basin.

[25] Data and the trends in the fishery in Cambodia have been examined by *Hortle et al.* [2005]. There are no basin-wide analyses of trends in the fishery because of the difficulty in collecting reliable data. The Cambodian component of the fishery is evidently the largest component, and data on the Cambodian dai fishery, although they comprise a relatively small component of the total Cambodian fishery, are considered to be the most reliable catch data available.

[26] No quantitative data were available on wetland degradation. As a result only general comments can be made about this issue.

3. Results

3.1. Environmental Perceptions

[27] The ranking of transboundary issues through the workshops process produced 6 issues that were included in more than one list (Table 1). These have been tabulated on the basis of their combined scores with the issue with the highest score, water quality, being identified as the most serious in the view of the participants. A further 5 issues, including the issue of bank erosion in Lao PDR were identified in a single list only and will not be discussed further.

[28] The diagnostic study produced a total of 13 priority issues. These were listed in order of priority within three categories, but no ranking was allocated between categories. The priority issues relating to quality of life issues are not listed here since they do not relate directly to environmental issues as they were understood for the purpose of the workshop process. The diagnostic study, as a UNEP-MRC joint study, also addressed issues beyond the MRC mandate, which encompasses the rivers and aquatic resources of the basin, and largely excludes terrestrial systems and groundwater.

[29] Physical resources management issues listed from highest priority to lower priorities were as follows: (1) Deteriorating water quality threatens resources and sustainability. (2) Changes in hydrological regimes due to development projects. (3) Sedimentation is critical and intensifying. (4) Deteriorating groundwater quality threatens resource use and sustainability. (5) Soil quality is expected to further deteriorate in some areas.

[30] Ecological resources management issues commencing with the highest-priority issues were as follows: (1) Terrestrial ecosystems in the MRB are being continually degraded. (2) Aquatic ecosystems are being degraded by development activities. (3) Fish throughout the MRB are adversely impacted by development activities and unsustainable harvesting. (4) Wetlands are threatened by population growth, increased exploitation of biological resources, timber harvest and development activities. (5) Wildlife throughout the MRB is adversely impacted by development activities and unsustainable hunting. (6) Biodiversity throughout the MRB is declining.

[31] Notably, both lists rank water quality, changes to the hydrological regime, sedimentation, fisheries decline and wetlands impacts as high-priority issues. The only issue on the WUP workshop list that does not feature in the diagnostic study is the issue of flooding. The workshops were conducted shortly after the record flood in the year 2000 so that inclusion is not surprising. The diagnostic study also identified aquatic ecosystem degradation as an issue, which is consistent with issues 1–3 under physical resources and 2 and 3 under ecological resources as well as the degradation of wetlands category in the WUP list.

3.2. Environmental Conditions

[32] For nutrients, but not other water quality parameters, results from subarea 10 were noticeably higher than results

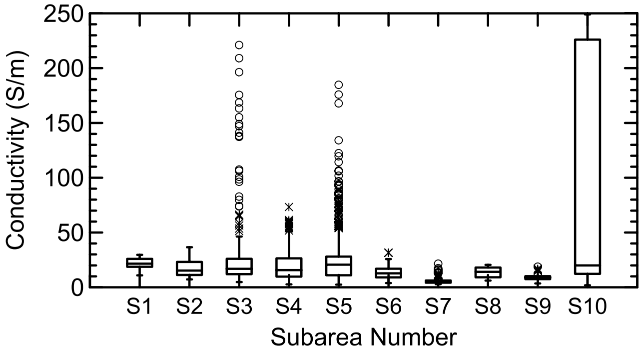

Figure 3. Box and whisker plot of monthly measurements of conductivity collected between 1998 and 2003 at sites within the 10 subareas indicated in Figure 2. The central horizontal line indicates the median value, and the upper and lower edges of the box (hinges) indicate the 25th and 75th percentile values, while the whiskers extend 1.5 Hspreads of the hinges. Data points outside this range are indicated with asterisks or circles. Data are from the MRC water quality database.

from other subareas (Figures 3–6). Median conductivity levels ranged from 5.0 to 22 mS cm^{-1} (Figure 3) with the greatest range in subarea 10 reflecting the tidal influence in the estuary. The highest median COD value occurred in subarea 10 (Figure 4) but at 3.6 mg/L was still relatively low, as was the 75th percentile value in the same subarea at 5.5 mg/L. Median and 75th percentile total phosphorus concentrations (Figure 5) were low, medians below 0.05 mg/L and 75th percentiles below 0.08 mg/L, in all subareas except subareas 2 and 10. Subarea 10 was particularly elevated with a median value of 0.10 mg/L and a 75th percentile of 0.17 mg/L. In subarea 2 the values were lower at 0.05 and 0.10 mg/L respectively. Total nitrogen data are only available for 5 of the 10 subareas (Figure 6). Of the 5 only subarea 10, with a median of 1.1 mg/L and a 75th percentile value of 1.7 had a median value above 0.5 mg/L or a 75th percentile value over 0.7 mg/L. Nitrate results showed a rather different pattern (Figure 7) with the highest median values in subareas 3 and 2 (0.31 and 0.30 mg/L respectively) although the highest 75th percentile value was

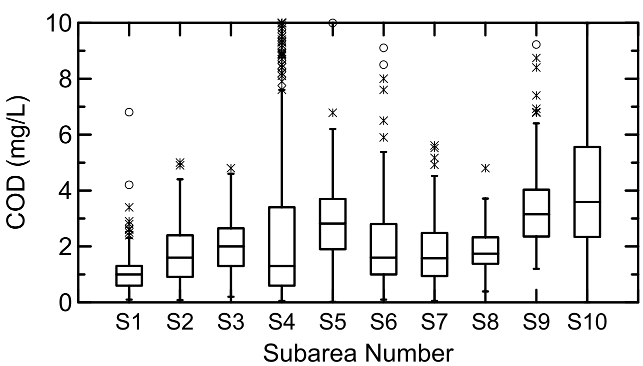

Figure 4. Box and whisker plot of chemical oxygen demand (COD) values determined using the permanganate method from samples collected between 1998 and 2003 at sites within the subareas indicated in Figure 2. See Figure 3 for details.

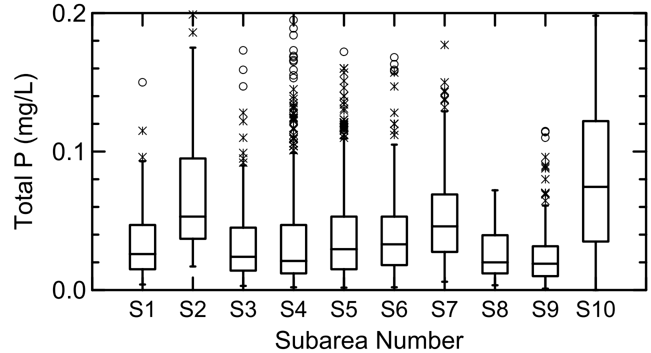

Figure 5. Box and whisker plot of total phosphorus values from samples collected between 1998 and 2003 at sites within the subareas indicated in Figure 2. See Figure 3 for details.

subarea 10 with 0.50 mg/L. Subarea 2, the Kok River basin, had the highest median and 75th percentile values for total suspended solids (Figure 8), 168 and 367 mg/L respectively. The next highest median value was 79 in subarea 6, and the next highest 75th percentile was 165 mg/L in subarea 8.

[33] At Chiang Saen the regression of TSS on flow was positive and significant ($p < 0.05$) and that for conductivity was negative and significant. No other parameters were significantly related to flow. At Pakse TSS, total phosphorus and COD all had significant positive regressions against flow, while conductivity had a significant negative relationship. There was not a significant regression for nitrate plus nitrite or COD.

[34] Flows on the sampling days at Pakse did not differ appreciably from flows during the 5-year sampling period. The mean flow on the sampling days did not differ statistically from the mean daily flow for the 5-year period (t-test, $p = 0.91$), and the distribution of flows on the sampling days was similar to the distribution of daily flows during the 5-year period (Figure 9). Ten percent of the sampling days had flows exceeding 29,455 m^3s^{-1}, and ten percent of the daily flows during the period also exceeded this flow. Twelve percent of the sampling days had flows

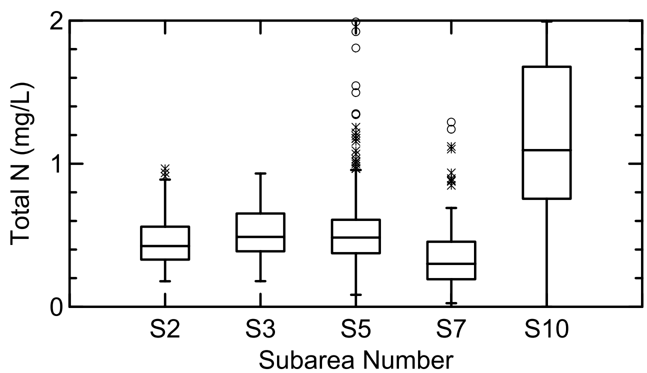

Figure 6. Box and whisker plot of total nitrogen values from samples collected between 1998 and 2003 at sites within the subareas indicated in Figure 2. Some national laboratories were unable to analyze for this parameter, so data are not available from every subarea. See Figure 3 for details.

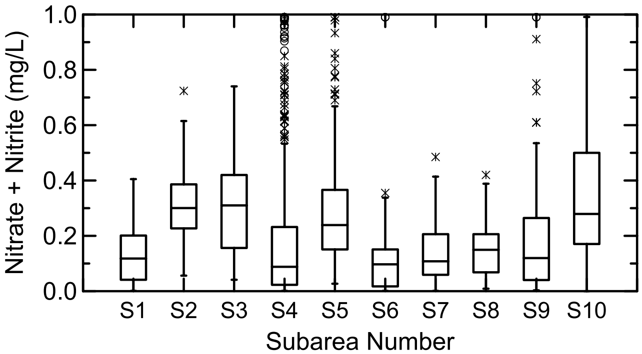

Figure 7. Box and whisker plot of nitrate plus nitrite values from samples collected between 1998 and 2003 at sites within the subareas indicated in Figure 2. See Figure 3 for details.

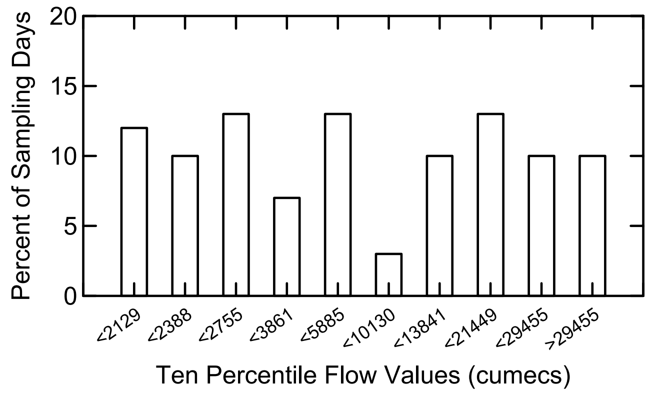

Figure 9. A comparison of the distribution of daily flows on sampling days with the tenth-percentile flows (in cumecs or m^3 s^{-1}) during the 5-year sampling period at Pakse. If the flow distributions were identical between the sampling days and the daily flows for the 5-year period, each column would comprise 10% of the flows.

lower than 2129 m^3s^{-1} compared with 10% of the daily flows.

[35] Compared with the daily flow distribution over the 43-year period for which flow data were available (Figure 10), the sampling days under represented low flows and over represented high flows. Only 7% of sampling day flows were less than 1800 m^3s^{-1} and only 5% between 1801 and 2130 m^3s^{-1} whereas there were 10% of daily flows in these categories over the 43-year period. Fifteen percent of sampling day flows exceeded 25,600 m^3s^{-1} compared with 10% over the longer period.

[36] At Chiang Saen the match between sampling days and daily flows was even better (Figures 11 and 12). Once again the mean flow on sampling days did not differ from mean daily flow of the 5-year period (t-test, p = 0.87). Nine percent of sample day flows were less than 830 m^3s^{-1} compared with 10% of daily flows over the 5-year period (Figure 11). Similarly, 9% of sample day flows were less than 836 m^3s^{-1} compared with 10% of daily flows over the 43-year period (Figure 12). For the high flows 9% of sample day flows exceeded 6329 m^3s^{-1} compared with 10% for the 5-year sampling period and 11% of sample flows exceeded 5910 m^3s^{-1} compared with 10% of daily flows over the 43-year period.

[37] Significant deterioration in water quality was only strongly evident for nutrients at sites in the delta. For total phosphorus and total nitrogen, sites within the Mekong delta almost all indicate deteriorating trends (Table 2) but elsewhere in the basin only 6% of "sites × parameters" show worsening trends, with 20% indicating improvement and 74% showing no statistical trend. Improvements were most apparent in suspended solids concentrations and conductivity. For the latter the improvements were mainly apparent in the delta and the Thai tributaries in the Mun-Chi basin.

[38] The hydrological trend analysis indicated the flows tended to increase in the dry season (January-May) and decrease in the wet season (June-November) (Table 3). At Chiang Saen, there was a statistically significant (p = 0.002) decline in monthly discharge during August, but the trends are not statistically significant for any other month (Table 3). March, April and May have positive slopes for the regression lines, while the months from June to December have negative slopes.

[39] Downstream, at Mukdahan and Pakse, the patterns are similar for most months (Table 3). At Mukdahan

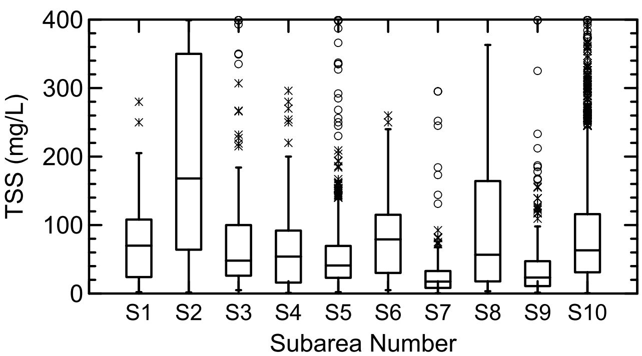

Figure 8. Box and whisker plot of total suspended solids (TSS) values from samples collected between 1998 and 2003 at sites within the subareas indicated in Figure 2. See Figure 3 for details.

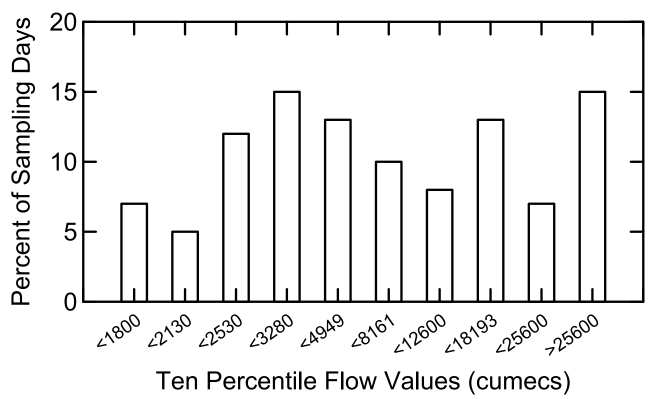

Figure 10. A comparison of the distribution of daily flows on sampling days with the tenth-percentile flows (in cumecs or m^3 s^{-1}) during the 43-year period for which daily flow data were available at Pakse. If the flow distributions were identical between the sampling days and the daily flows for the 5-year period, each column would comprise 10% of the flows.

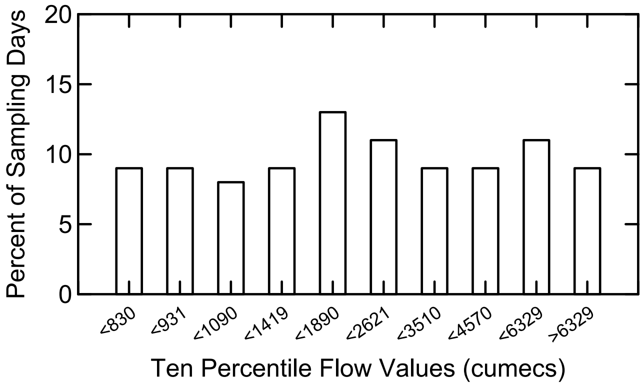

Figure 11. A comparison of the distribution of daily flows on sampling days with the tenth-percentile flows (in cumecs or $m^3\ s^{-1}$) during the 5-year sampling period at Chiang Saen. If the flow distributions were identical between the sampling days and the daily flows for the 5-year period, each column would comprise 10% of the flows.

significant dry season increases occurred in March ($p = 0.022$) and April ($p < 0.001$), and significant decreases occurred in September ($p = 0.021$) and October ($p = 0.035$). At Pakse, there has been a significant decline in discharge in October ($p = 0.019$) and November ($p = 0.047$) and increases in March ($p < 0.001$), April ($p < 0.001$) and May ($p = 0.023$). The pattern is more strongly developed at Mukdahan and Pakse, than at Chiang Saen, with significant changes apparent in four months at Mukdahan and five at Pakse.

[40] The pattern of decreased flows in the wet season, and increases in the dry season, were not congruent with changes in rainfall patterns. An analysis of the monthly rainfall records from Vientiane, Mukdahan and Ubon Ratchathani did not find trends consistent with the trends in discharge [*MRC*, 2003]. However, the rainfall data examined are from only 3 locations because there are few rainfall data collection stations in the basin with long-term records, and of course discharge in a river the size of the

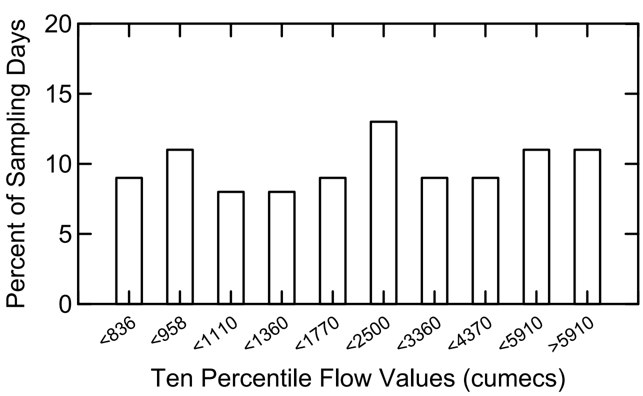

Figure 12. A comparison of the distribution of daily flows on sampling days with the tenth-percentile flows (in cumecs or $m^3\ s^{-1}$) during the 43-year period for which daily flow data were available at Chiang Saen. If the flow distributions were identical between the sampling days and the daily flows for the 5-year period, each column would comprise 10% of the flows.

Table 2. Trends, Based on Significant Linear Regressions in Conductivity, Total P, Total N, and Total Suspended Solids at 87 Sites Across the Lower Mekong Basin Between 1985 and 2000[a]

	Conductivity			Total P			Total N			TSS		
Location in Basin	I	NC	D	I	NC	D	I	NC	D	I	NC	D
Main stream	0	11	0	2	9	0	0	1	1	5	6	0
Lao tributaries	0	10	1	2	7	2	NA	NA	NA	3	6	2
Thai tributaries	4	10	1	2	13	0	5	10	0	8	7	0
Cambodian tributaries	0	5	0	0	5	0	NA	NA	NA	1	4	0
Vietnam Delta	9	31	1	0	2	39	1	10	30	0	35	6
Vietnam Highlands	0	3	1	0	3	1	0	3	1	0	4	0
Total	13	70	4	6	39	42	6	24	32	17	62	8

[a]TSS, total suspended solids; I, improvement; NC, no statistical change; D, deterioration; NA, parameter not analyzed. The numbers refer to the number of sites. Data are from *MRC* [2003].

Mekong is affected by upstream rainfall as well as local rainfall. Nevertheless, from this data it does not appear that changes in rainfall have been responsible for the pattern of change in river discharge.

[41] Data from Pakse on annual minimum daily flow and annual maximum daily flow were similar. There was a significant ($p = 0.01$) increase in annual minimum daily discharge over the period of record but no significant ($p = 0.44$) change in annual maximum daily flow although the slope of the regression line was negative.

[42] For suspended sediments (Figure 8) the ranges of values found are high, but median values are not particularly large. Only in subareas 2 and 8 did the 75th percentile values exceed 150 mg/L. Almost 20% of sites showed a decrease in TSS concentrations since 1985 (Table 1) while only 10% showed an increase. Notably, all the mainstream sites from Chiang Saen to Pakse had significant decreases in TSS.

[43] Suspended solids concentrations may not necessarily reflect changes in sediment load so measurements of channel cross section taken at Nong Khai in December 1995 and December 2002 were also compared [*Bountieng*, 2003]. The two measures differed by only 6%, with the cross section in 2002 larger than that in 1995.

Table 3. Pattern of Change in Discharge at Chiang Saen (1961–1999), Mukdahan (1950–2000), and Pakse (1950–2000)[a]

	Chiang Saen	Mukdahan	Pakse
Jan.	n	n	p
Feb.	p	p	p
March	p	p[b]	p[b]
April	p	p[b]	p[b]
May	p	p	p[b]
June	n	n	n
July	n	n	p
Aug.	n[b]	n	p
Sept.	n	n[b]	n[b]
Oct.	n	n[b]	n[b]
Nov.	n	n	n[b]
Dec.	n	n	n

[a]Negative slopes to the regression lines (i.e., discharge decreasing over time) are indicated by "n," while positive slopes (i.e., discharge increasing over time) are indicated by "p."

[b]The slope of the line was statistically significantly different from 0 ($p < 0.05$).

[44] Analysis of floods at Pakse showed no significant trend in the maximum annual daily flow (p = 0.44), the number of inundation days (p = 0.49) or the number of flood years per decade (p = 0.28). The slopes of the regression lines were negative for the maximum annual daily flow and number of inundations days, but positive for the number of flood years per decade.

[45] Inland fisheries in developing countries are by nature difficult to monitor so there are limited reliable data. The fishery is diffuse with almost all the catch consumed by the fishers or passing through small local markets. However, there is good evidence that the catches of large fish species such as the giant barb, *Catlocarpio siamensis* and the Mekong giant catfish *Pangasianodon gigas* have declined. For the former, *Matson et al.* [2002] cite a catch in Cambodia in 1964 of 200 t while the catch in 2000 was 10 fish. *Allan et al.* [2005] present data for the same species from Thailand also showing a declining catch since 1990 under sustained fishing effort.

[46] Data on the total fish catch for the Dai fishery on Tonle Sap River show no sign of decline over a 10-year period. The slope of the regression line of the catch data reported by *Hortle et al.* [2005] versus year was not significantly different from 0 (p = 0.52) although there was a significant positive relationship between flood height and total catch (p = 0.04). *Van Zalinge* [2003] reports that the overall annual fish catch in the Tonle Sap Great Lake area increased from 125,000 t in the 1940s to 235,000 t in 1995–1996 although the catch per fisher declined from 347 kg to 196 kg during the same period as the number of fishers increased from 360,000 to 1.2 million. He suggests that the total catch has probably continued to increase since 1996.

4. Discussion

[47] Water quality was the issue of greatest concern raised in the WUP workshops and also the most serious issue in the physical resources issues list of *MRC and UNEP* [1997]. Reduced dry season flows and hydrological impacts were second most serious in the WUP workshops and ranked number 2 on the physical resources list, sedimentation, fisheries decline and wetland degradation all appeared on 2 lists and flooding and aquatic habitat degradation each on a single list.

[48] The evaluation of Mekong water quality based on the MRC water quality monitoring data has some potential limitations. Chemical water quality is influenced by the river discharge both prior to and at the time the sample was collected [e.g., see *Bartram and Balance*, 1996; *Campbell and Doeg*, 1989; *Chapman*, 1996], so it is important that discharges at sampling times are representative of discharges through the period for which water quality is being characterized and that extreme values are neither under nor overrepresented. It is also critical that tests for temporal trends are robust, reflecting actual trends in water quality and not patterns of discharge.

[49] The influence of river discharge should not be a confounding factor in this analysis because the analyses are based on percentiles, the sites are mainly on large rivers, and both wet and dry seasons were sampled. In recognition of the variability of water quality parameters most recent water quality guidelines, including those I have used for comparison here, are set using percentile values. That is, they specify that a particular parameter should be below a certain value in a certain percentage of samples. For example, *Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand* (*ANZECC and ARMCANZ*) [2000] specify trigger levels of total P of 0.05 mg/L based on the 80th percentile of existing data. The *U.S. Environmental Protection Agency* (*USEPA*) [2000] recommends using the 75th percentile value for developing nutrient criteria for rivers and streams. Using medians and percentile values in data analysis reduces the impact of small numbers of extreme values compared with analyses based on arithmetic means or maximum values.

[50] The majority of the sampling sites included in the MRC water quality network are on large rivers. The exceptions are sites on the channels draining Tat Luang swamp, which receives the effluent from Vientiane in Lao PDR, and some of the sites on canals in the Mekong Delta. Large rivers are far less prone to brief extreme "spikes" of discharge or concentrations of water quality parameters because of their size and dilution capacity [e.g., see *Bartram and Balance*, 1996].

[51] Monthly sampling over a 5-year period, including both wet and dry seasons, seemed adequate to represent the range of daily discharges. Discharges on the sampling days at Chiang Saen and Pakse seem adequately to represent the range of daily discharges during the sampling period, and even over the longer 43-year period (Figures 8–11). Neither low flows, during which extreme values of parameters such as conductivity and concentrations of industrial pollutants would be encountered, nor high flows, which would lead to extremes of parameters such as nutrients and suspended solids, were underrepresented. While it is not possible to be certain whether this is also true for other sampling sites, it seems likely to be true at least at the large river sites. By pooling the data for each subarea and comparing medians and 75th percentile values the analysis should reduce the influence of low-frequency extreme values.

[52] Testing the full set of up to 15 years of monthly measurements for evidence of trends using linear regression is an extremely robust method of trend detection. Wet season, dry season and transition months are included so the data sets have the highest levels of variance, reducing the likelihood of a type I error. Conducting the analysis on only wet season or dry season months would have reduced the variance and provided a more sensitive analysis, but the effort required would have been substantial for probably little additional return and the risk of a type I error would have increased. Trends could also have been sought using visual graphical methods or by testing for nonlinear change. The former have the disadvantage of lack of objectivity, and the linear test should have detected even nonlinear change if it were present, although the fit may be poor.

[53] The data indicate that water quality in the lower Mekong basin is generally good, except for high nutrient levels in the Mekong Delta. The levels of total P recorded in the Mekong, a large turbid river, are comparable to levels set as trigger values for ecosystem protection in lowland Australian rivers (0.05 mg/L) [*ANZECC and ARMCANZ*, 2000] and well below those presently recommended for the

lower reaches of the Mississippi in the United States (0.128 mg/L) [*USEPA*, 2001]. *Pantulu* [1986] suggested, without presenting any data, that the Mekong silt is nutrient deficient. Nutrient levels in the river are not particularly low, and the concentration of both phosphorus and nitrogen on suspended particles is related to total nutrient levels in the river [*Chapman*, 1996], so the claim appears doubtful.

[54] Neither salinity, as indicated by conductivity, nor organic pollution seem to be a widespread problem in the basin. Conductivity levels are also well below levels thought harmful to freshwater life [e.g., *Hart et al.*, 1990, 1991] except in the estuarine delta. At many sites in the delta conductivity has fallen [*MRC*, 2003], but this is probably due to the construction of barrages to reduce seawater intrusion. There is no evidence of a general increase in salinity since 1985, although the issue is often raised in the international and regional literature [e.g., see *Miller*, 2000]. Finally, *Chapman* [1996] cites 20 mg/L as an upper limit for COD levels in unpolluted waters and none of the Mekong subbasins have median values greater than 4 mg/L.

[55] In the delta (subarea 10), levels of total phosphorus are at levels that should cause concern. The median concentration was 0.096 mg/L with a 75th percentile value of 0.165 mg/L. This is well in excess of both the USEPA values set for the lower Mississippi noted previously, and the 0.075 mg/L level that *Dodds et al.* [1998] suggest as the boundary between mesotrophic and eutrophic temperate streams.

[56] Concentrations of nitrogen are also high in the delta with a median value of total nitrogen of 1.1 mg/L, a 25th percentile of 0.8 mg/L and a 75th percentile of 1.7 mg/l and nitrate plus nitrite median concentration of 0.37 mg/L and a 75th percentile of 0.50 mg/L. The *USEPA* [2001] designated 0.76 mg/L as the total nitrogen reference condition for Ecoregion X (which includes the lower Mississippi) based on the 25th percentile. *Dodds et al.* [1998] identified 0.7 mg/L total N as the oligotrophic-mesotrophic cutoff and 1.5 mg/L as the mesotrophic-eutrophic cutoff for temperate streams, and these levels were later adopted by *USEPA* [2000].

[57] It is of further concern that the nutrient levels show statistically significant increases at most sites in the delta [*MRC*, 2003], indicating that the situation in the delta is deteriorating. The sources of nutrients are unknown but are most likely to be from runoff from fertilizer applied to crops on acid sulphate soils, urban runoff, or from the aquaculture industry.

[58] In a survey of about 20 sites within the lower Mekong basin to detect toxicants in water and sediments [*BURGÉAP and CEMAGREF*, 2004] found no levels of significant concern. The sites were selected to give basin-wide coverage and to detect potential transboundary problems, but also at sites close to major cities where industrial pollution was most likely. Toxicants tested included trace metals, pesticides, PCBs, PAHs and dioxins and furans. Both water and sediments were analyzed. No levels above probable effects thresholds were detected.

[59] Similarly, a bioassessment exercise that surveyed 20 sites basin-wide in 2003–2004 found 3 sites showing some apparent impairment and the rest of good to excellent quality [*Campbell*, 2005]. This provides strong evidence that at those sites there were no unsuspected stressors. Sites surveyed included a number near major cities such as Phnom Penh, Ubon Ratchathani and Vientiane, where impacts would be most likely to be apparent.

[60] There is no apparent water quality problem in the lower Mekong basin outside the Mekong Delta, where nutrient levels are elevated, but is there evidence that water quality is rapidly deteriorating? The data from the trend analysis suggest not. Only within the delta was there a significant cluster of sites showing trends of water quality deterioration. Outside the delta, there is more evidence of water quality parameters improving than there is of deterioration (Table 2).

[61] The absence of rapid deterioration in water quality is not surprising. There is little industrial development in the lower Mekong basin. Lao PDR is a landlocked, primarily agrarian country with a small population, which has difficulty attracting large-scale industry, while the major manufacturing industry in Cambodia is garment manufacturing, which has low pollution potential. In both Thailand and Vietnam the areas of most rapid industrial development are associated with large cities outside the Mekong basin, such as Bangkok and Ho Chi Minh City. Many of the larger cities in the basin, including Vientiane and Phnom Penh, discharge their urban wastewater to large natural wetlands thus achieving a significant level of treatment before waste water flows to the river. The greatest short-term risk to water quality would occur if these wetlands were to be removed or drained.

[62] There is no evidence that dry season flows have been reduced. Concerns about reduced dry season flows arise most strongly in Vietnam because of concern that saline intrusion from the South China Sea in to the Mekong Delta has been increasing. This is probably due to increasing extraction of river water to irrigate dry season rice in the delta. The Vietnamese feel threatened by proposals for large-scale irrigation developments in upstream countries, especially in northeastern Thailand [e.g., see *Hewison*, 1994] (available at http://www.nectec.or.th/thai-yunnan/24.html), which would be based on either water diverted from the Mekong, or water taken from Lao tributaries transported to Thailand via a tunnel under the Mekong [e.g., see *Samabuddhi*, 2002], and could result in reduced dry season flow.

[63] Low dry season flows occurred in the 2003–2004 season and concerns have been raised in the popular press in the region [e.g., *Tangwisutijit*, 2004] and elsewhere [e.g., *Pearce*, 2004] that these may be being caused by dams in China. Two dams have been completed in China and two more are under construction [*Hori*, 2000; *Podger et al.*, 2004]. However, almost all of the large dams that have been built or proposed, including all those in China, are intended for hydropower rather than for extractive use such as irrigation or domestic water supply. The operation of hydropower dams increases dry season flows and reduces wet season flows. The low flows in 2003–2004 attributed by some in the press to impacts of Chinese dams were more intense downstream in Cambodia than in Laos and Thailand, closer to the dams, indicating that they were caused by low rainfall in the lower basin, rather than any activities upstream [*Campbell and Manusthiparom*, 2004].

[64] Modeling suggests that increases in dry season flows resulting from hydropower dam operation could be appreciable along the full length of the river [*Podger et al.*, 2004].

The actual size of the change would depend on the size and location of the dams and their operating rules, but they could be large enough to have appreciable ecological and subsistence impacts on the river.

[65] It is not clear what is meant by ''sedimentation'' as an issue of concern. It could mean a perception that the river is more turbid than previously because of elevated amounts of suspended sediment, it could be a concern that the channel is becoming increasingly obstructed by sediment, or it could be concern about erosion in the catchment. I only sought data relevant to the first two of these concerns.

[66] None of the data indicate that suspended sediment is a problem in the Mekong. The 75th percentile suspended solids levels for 8 of 10 subareas are below the 150 mg/L global median natural concentrations based on 60 rivers cited by *Chapman* [1996]. The two exceptions are the catchment of the Kok River in Thailand, a small catchment which has been the site of fairly intense recent development and which had a 75th percentile value of 367 mg/L, and a small area in central Cambodia which had a 75th percentile value of 165 mg/L. Neither of these values is exceptionally high, and there is no evidence that the high levels in the Kok are causing appreciable impact in the main stream.

[67] There are no data to support the proposition that the river channel is filling with sediment. The limited data of *Bountieng* [2003] do not indicate a change in channel cross-sectional area at Vientiane between 1995 and 2002. *Rutherfurd et al.* [1996] found that in a 45 km stretch of river between Vientiane and Nong Khai, the river is actively meandering but not at an unusual rate for a river of its size and type.

[68] *Walling* [2005] suggests that on the basis of available data, sediment loads in the Mekong over the past 40 years appear to have been relatively stable. His analysis is based on data from 6 sites and although the data sets all had discontinuities which made conclusions somewhat tentative it is apparent that there have been no large basin-wide increases or decreases. There appeared to be an increase in transport at Jinhong from the 1970s to 1990, the most recent data available, but no comparable increase at Nong Khai or 4 other sites downstream. A site at Mukdahan appears to have an increased load after 1990, presumably because of sediment sources downstream of Nong Khai.

[69] Sediment related concerns are frequently discussed in the popular press in the Mekong region. In Lao PDR and the delta in Vietnam the main focus of concern has been bank erosion, which is causing problems for a number of towns and villages. Elsewhere there is apparently a belief that past and present large-scale deforestation due to logging and clearance for agriculture must have contributed to soil erosion, which must be causing sedimentation problems in the Mekong and other rivers. *Enters* [1995] suggests that, in spite of perceptions and opinions in the press, there is little evidence that deforestation in the Chiang Mai valley in Thailand has caused increasing sediment loads in the Ping River, where loads decreased from 1975 to 1985. *Gupta and Chen* [2002] suggested that erosion following land clearance for shifting agriculture in Lao PDR is limited to a relatively brief period from the onset of the wet season rains until herbaceous ground cover becomes established. Prior to that period there is no runoff to transport sediment, and after it the ground cover protects the soil.

[70] While there is no evidence of a decline in the overall Mekong fish catch, there is evidence that the fishery is under pressure, and the data are limited. The most reliable data set on fishery trends, the Tonle Sap River dai fishery, constitutes only about 1% of the total Mekong catch, and it is difficult to assess to what extent it represents the situation basin-wide. Although the overall catch is believed to be higher now than at any time previously, there has been a marked decline in the catch per unit effort at least in Cambodia over the past 20 years [*Van Zalinge*, 2003] and a dramatic increase in the number of fishers. The fishery is important to the population of the Mekong providing over 80% of the animal protein with an estimated value of almost US$1.5 billion per year [*MRC*, 2003].

[71] It is evident that the fishery is under pressure because the abundance of large fish in the basin has declined [*Matson et al.*, 2002] with the catch increasingly comprising small species with annual life cycles. Very large fish species, such as the Mekong giant catfish (*Pangasianodon gigas*), are now rare. Pressure is also increasing on fish populations because of modifications of the floodplains, which are important feeding areas during the flood season, and construction of small weirs mainly for irrigation on floodplain channels which block fish migration routes [*Van Zalinge*, 2003]. Without improved management, including limitations on access and protection of habitat it is only a matter of time before total catch also begins to decline.

[72] There has been a great deal of time and money expended on wetland inventories and wetland mapping in the Mekong region [e.g., see *Van Oertzen*, 1999] (available at http://www.un.org.kh/fao/pdfs/section1/chapter7/7.pdf), but it is as yet not possible to document the extent of wetland loss or degradation. It is obvious that there has been wetland loss through landfills around major cities such as Phnom Penh and Vientiane, and wetlands have been degraded through construction of drainage canals, such as that through That Luang swamp near Vientiane. Other wetlands have been converted to rice fields (which are in themselves engineered wetlands), but data on what proportion of the total this represents are lacking. It is impossible to draw definitive conclusions about the scale of this problem in the lower Mekong basin.

[73] On the basis of the data presented here there is no evidence that flooding is increasing in frequency, spatial extent or water depth. The Mekong is a flood pulse river with an annual flood that is highly predictable in timing and size [*MRC*, 2003]. However, the floods in 2000 and to a lesser extent 2001 had a severe impact on many people living on the floodplain with over 500 people dying in the Vietnamese portion of the delta in the year 2000 floods and flood damage costs of over US$285 million [*MRC*, 2003].

[74] Donors have funded a substantial program on flood management at the Mekong River Commission in the absence of any detailed analysis of the flood situation in the basin. There has been an increase in the numbers of people killed and otherwise impacted by floods, which reflects an increase in the number of people living in the flood plain, and the value of the infrastructure present. Furthermore, extensive construction of levees in the delta in Vietnam to regulate the flood for rice growing may be exacerbating flood conditions in both the Vietnamese and Cambodian parts of the delta.

[75] The data indicate that water quality, reduction in dry season flows, and sedimentation, the three concerns rated most serious both by the natural resource managers and the consultants who prepared the MRC and UNEP report, are not serious issues in the lower Mekong either now or in the immediate future. There is no evidence that the total yield from the fishery is in decline although many of the larger, late-maturing species have declined in number. There is insufficient data to evaluate wetland and aquatic habitat degradation. Floods cause serious economic losses and loss of life, but any increase in flood problems appears to be largely related to population increase and inappropriate development on the floodplain.

[76] Several reasons can be postulated for the disparity been perceptions and environmental conditions in the Mekong. The local press provides frequent extensive coverage to concerns raised by local people and NGOs. However, government and intergovernmental agencies in the region have a poor record of transparently providing data and analysis that would allow participants in civil society and the media to evaluate the concerns raised. In some cases, data are lacking, but in others there appears to be a lack of capacity to analyze and interpret available data. Often there seems to be a reluctance to release information beyond statements denying the existence of problems. In the absence of informed discussion and reliable data issues of concern continue to be repeated until it becomes accepted that there is a serious problem whether or not that is the case.

[77] There is a notable lack of accurate biophysical information and analysis published for the Mekong region either by government agencies or the Mekong River Commission. The MRC has a good record of publishing fisheries information, but a poorer record in other areas. For example, water quality data were collected from 1985 but no analyses or interpretations of the data were published until 2003. Similarly, even though water sharing is one of the key issues for the Mekong basin, no analysis of the hydrology of the basin has ever been published. The MRC's public output on hydrology has been restricted to production of hydrology yearbooks. More recently, a series of more analytical documents have been produced [e.g., *MRC*, 2003; *Hook et al.*, 2003], but it remains to be seen if that pattern will continue.

[78] The management issue for which managers perceptions most closely matched the real situation is the concern about the fishery. Even for this issue managers and consultants have interpreted decline in catch per unit effort and decline of large species with decline of the fishery, even though total catch has not been declining. Notably, the fishery is the issue about which there has been the greatest level of information and analysis published. For example, the MRC has published both a technical report series (e.g., see *Matson et al.* [2002], and well as a more general publication "Catch and Culture"). There have also been a number of other researchers drawing attention the Mekong fish and fisheries and human impacts on them, most notably T. R. Roberts [e.g., *Roberts*, 1993, 1995] and I. Baird [e.g., *Baird et al.*, 2001].

[79] Perceptions of the Mekong basin and its environment by many of those outside the Mekong region match the perceptions of the resource managers within it. For example, *Barlow and Clarke* [2002, p. 30] wrote "The Mekong River, which begins in China and drains through Myanmar (formerly Burma), Laos, Cambodia and portions of Thailand and Vietnam, is choking with industrial and human waste," a statement which they did not support with any data or references and which is clearly untrue. The concern that Chinese dams reduce dry season flows has also been widely reported outside the basin [e.g., *Pearce*, 2004; *Vidal*, 2004].

[80] Environmental managers in developing regions such as the Mekong often lack the resources, capacity or the incentive to properly analyze the environmental conditions in the systems they have responsibility to manage. International experts who work in these regions as consultants or advisers often have limited time to conduct investigations or analyses, and may also bring with them inaccurate preconceptions of likely problems.

[81] In the Mekong several opportunities to conduct proper analyses of the data being collected have been missed. Most notably, this was true when the 1997 Mekong River Basin Diagnostic Study was conducted. However, the high rate of turnover of Mekong River Commission staff, and the extensive use of short-term consultants have also been contributing factors preventing development of broadscale understanding of the basin based on data rather than perceptions or models. Government agencies and the MRC have devoted too little effort to analyzing the data collected and publishing those analyses in publicly available formats.

5. Conclusion

[82] This study has demonstrated that, for one of the world's largest and most significant rivers there was, and probably continues to be, a significant mismatch between the manager's perceptions of the problems in the basin and the reality. Five of six issues identified in workshops as high-priority issues are not causing present problems, although two could become so in the future if they are not addressed quickly. Similarly, 4 of 6 priority issues identified by the consultants who produced the MRC-UNEP Diagnostic Study [*MRC and UNEP*, 1997] that can be evaluated from this data set are not pressing issues.

[83] This study also has lessons for organizations responsible for managing river basins, especially in developing regions. It is critical that they collect or have access to data from the river basin, that the data are analyzed, and that the results and conclusions are published in publicly available forms. If that is not done, large amounts of time and effort are likely to be expended on uninformed arguments about what the priority issues are, or on addressing problems that are not critical. *Dudgeon* [2003, 2005] has made a similar point repeatedly in relation to conservation management of tropical Asian rivers.

[84] For river basin organizations to collect high-quality data and analyze the data appropriately they must have a core of technically competent long-term staff. That remains a challenge in many developing regions. The Mekong River Commission has suffered from high staff turnover rates, a shortage of technically competent staff and a low priority given to publication of data.

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I. C. Campbell, Rhithroecology, 15 York Street, Blackburn South, Vic 3130, Australia. (i.c.campbell@bigpond.com)