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TECHNICAL NOTE

on

Conceptual Framework for the Methodology and Tool of Wetland Ecosystem Functions, Assets and Services Assessment and Management (WEFASAM) and Assessment of Potential Indicators (including Wetland Biodiversity Indicator Assessment; WBIA)

A Working Document

Prepared by Environmental Management Division

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1. Introduction

Wetlands are a crucial component of the socio-ecological system in the Lower Mekong Basin (LMB). It is therefore crucial to be able to compile more accurate information, and monitor trends, at national and basin scales on these important ecosystems in order to inform policy and management. At the heart of developing an improved wetlands inventory system for the LMB are indicators. Section 2 of this report provides an overview of the state of, and trends in, wetlands in the lower Mekong River Basin based on existing information sources. Particular attention is given to indicators used by these information sources. Section 3 provides further details on the *Methodology and Tool of Wetland Ecosystem Functions, Assets and Services Assessment and Management (WEFASAM)* – which is under development to support improved information to further improve wetland inventories in the LMB. This gives further details of the concept of the WEFASAM that are important to understand, including how these relate to the assessment, identification and development of indicators. The section also expands details for undertaking assessments of the importance of wetlands including their monetary and non-monetary values. This will be an important area to develop further as the WEFASAM progresses, in order to better populate wetland inventories with more meaningful data on the benefits and value of wetlands and, hence, making wetlands inventories more useful and relevant to various stakeholders. Section 4 then provides an overview of the objectives and needs for improved indicators for wetlands in the LMB, focussing in particular on how to identify and develop a suite of indicators that can provide an improved overview of the importance of wetlands in the LMB and the status and trends in their benefits.

Wetlands are important hotspots of biodiversity and play a significant role in the economy of the region due to the resources and ecosystem services they provide to support food security and livelihoods (please see ***Box 1-1***).

Box 1-1. Ecosystem Services provided by LMB wetlands

Provisioning Services – food from fish and other biota, fuel wood, timber and non-timber forest products (including for construction, tools and handicrafts), medicines

Regulating Services – water regulation (including flood control), groundwater recharge, removal of pollutants, waste treatment, erosion protection, natural hazard protection

Cultural Services – spiritual, religious, cultural and historical values, aesthetic appreciation of natural features (including iconic wildlife), educational, training and recreational opportunities

Supporting Services – habitat for resident and transient species, breeding, spawning and nursing grounds, soil formation and sediment retention, store of genetic material (biodiversity)

Source: *adapted from information in MRC (2015a)*

The Ramsar Convention defines wetlands as:

…areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres (Ramsar, 1974).

As all four countries of the Lower Mekong Basin (Cambodia, Lao PDR, Thailand and Viet Nam) are signatories to the Ramsar Convention, this is the definition which is used in this Technical Note.

Wetland areas are widespread throughout the LMB. ***Figure 1-1*** illustrates the distribution and extent of six wetland types as compiled from country data in 2003 and used by the Basin Development Plan Programme as part of the Assessment of Basin-wide Development Scenarios (MRC, 2010a). These types are: (i) seasonally inundated forest; (ii) seasonally inundated grassland; (iii) marsh, swamp, lake and pond; (iv) mangrove; (v) rice field; and (vi) aquaculture. They were simplified from a total of 60 types which are identified in the original 2003 database and from which it is possible to delineate wetland classes in a range of different ways depending on the analytical requirement (see MRC, 2015a, for example).

The occurrence and the character of wetlands including the range of habitat types which they exhibit are subject to a range of natural drivers and human-induced threats. The fundamental natural drivers of geomorphology and climate interact to influence the key wetland characteristics of hydrology, physio-chemical environment and biota (as shown in ***Figure 1-2***). Each of these key characteristics also interacts with each other to determine the specific wetland ecology that occurs.

Beyond these natural influences the ecological character and the condition or health of wetlands in the LMB is clearly not permanent and is subject to a range of human-induced pressures or threats. These threats impact on the hydrology, physio-chemical environment and the biota and include modifications to the hydrological regime, vegetation clearing and disturbance, expansion of agriculture and urban developments, over-exploitation of resources, pollution, sedimentation and erosion, and the spread of invasive alien species, amongst others (e.g. MRC, 2003; 2010).

These pressures have the potential to greatly reduce wetland extent in the LMB and to impact on the health of wetlands that remain, thus impacting on their capacity to continue to provide the resources and ecosystem services upon which the population currently depends (please see in ***Box 1.1***). For example, over-exploitation of wetland fish resources will in-time have a significant impact on the capacity of fisheries to support an increasing population, particularly in rural areas. Conversion of mangrove forests to shrimp aquaculture, while potentially maintaining the overall quantity of wetland area, reduces the erosion protection and flood regulation services provided by these natural ecosystems.

It is estimated that approximately 30% of LMB wetlands are within the flood zone of the Mekong River (MRC, 2010a). ***Figure 1-3*** illustrates the extent of the 2,000 flood in the LMB. Considered to be the worst flood in the region for 40-50 years (MRC, 2003) it might be expected that most wetlands associated with mainstream flooding of the Mekong River would be found throughout this flooded area, some more permanent than others. Wetlands not within this area would be expected to be supported by local hydrological conditions or be artificial. MRC (2015a) identify more than 78% of wetlands as being man-made (or artificial) wetlands, and many of these have been created by converting natural wetland areas to aquaculture and rice fields.

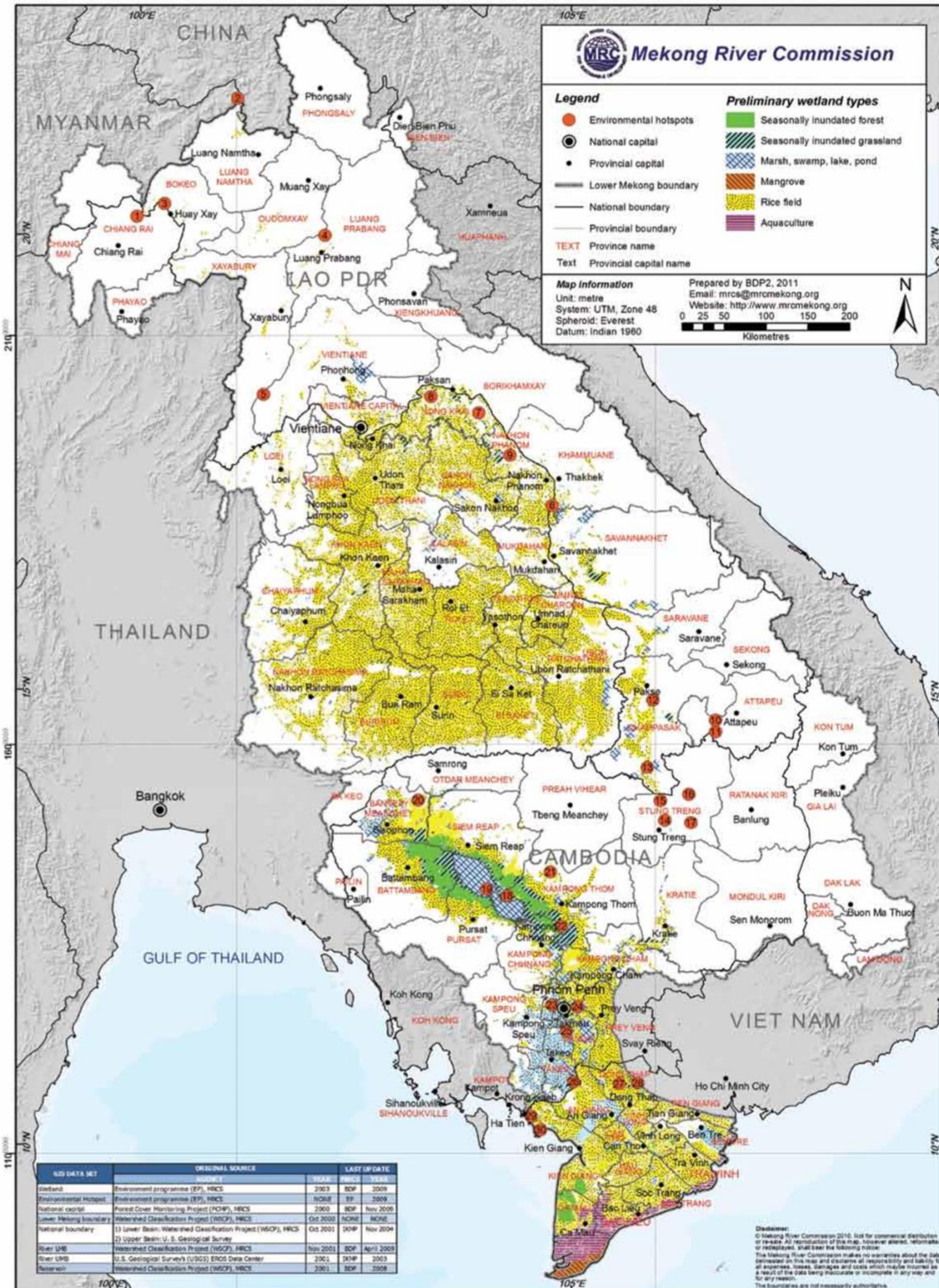


Figure 1-1: Wetlands and identified environmental hotspots of the Lower Mekong Basin as presented in MRC (2011). This map is based on the MRC's preliminary 2003 database, re-classified in 2009.

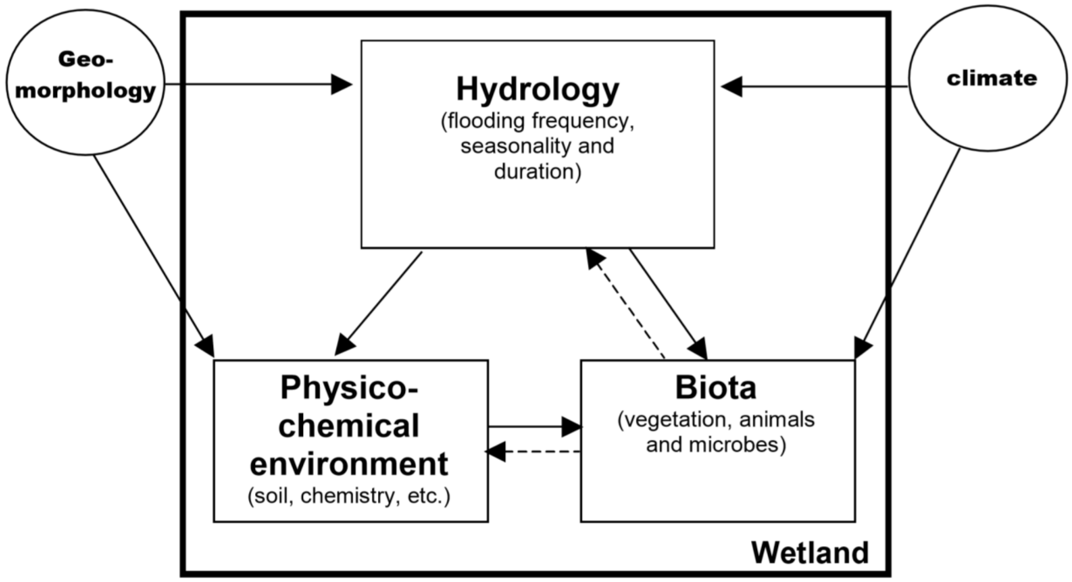


Figure 1.2: Conceptual diagram showing the key characteristics of all wetlands (hydrology, physico-chemical environment and biota), key wetland drivers (geomorphology and climate) and the relationships between them (Victorian Department of Sustainability and Environment, 2005, as adapted from National Research Council, 1995).

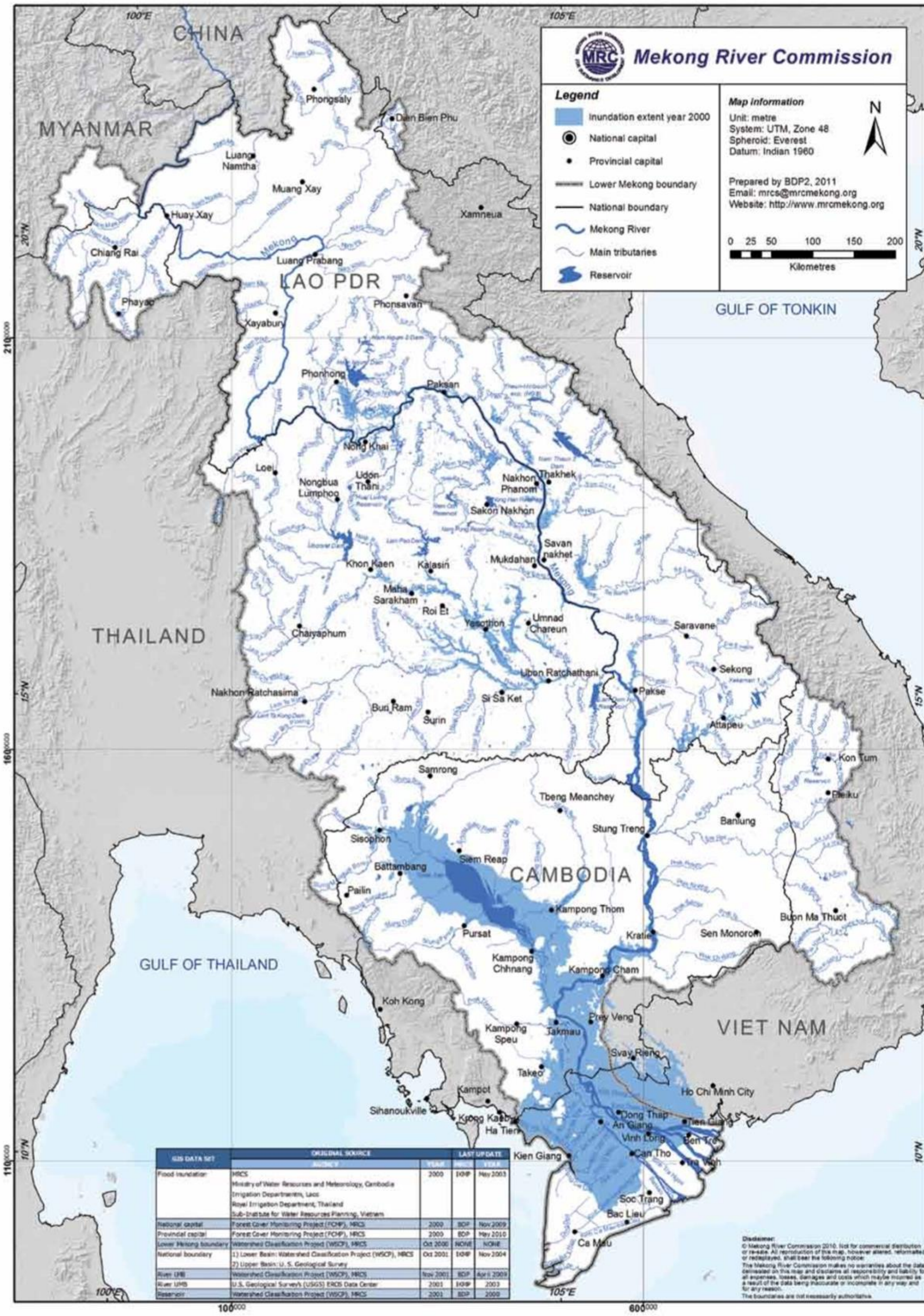


Figure 1.3: Extent of the 2000 flood in the Lower Mekong Basin (MRC, 2011), considered to be the worst flood in the region for 40-50 years (MRC, 2003).

2. State of, and Trend In, Lower Mekong Basin Wetlands

2.1 State and Trend of Pressures on Wetland Health and Functions

The pressures on wetland health and function within the Lower Mekong Basin are well documented. Each of the two most recent *State of the Basin* reports (MRC, 2003; 2010) identifies a wide range of threats to the environment of the Mekong Basin, including its wetlands. Each 2003 country wetland inventory report also identified the range of threats and impacts that are being observed on important wetlands of each of the four member countries (Vathana, 2003; Phittayaphone, 2003; Choowaew, 2003; Thinh, 2003). What is less clear is the magnitude and extent of these threats specifically to different wetland types and the extent to which these may be increasing or decreasing over time.

2.1.1 State and Trend of Pressures due to Anthropogenic Impacts

Reclamation and modification of wetlands (including for agriculture)

The reclamation and conversion of wetlands especially for agriculture is considered to be one of the most significant threats facing natural wetland ecosystems (MRC, 2003 and 2010). There are no statistics available on the amount of wetland area specifically converted to agriculture, but based on the increase in area of irrigated agriculture for each country as a whole over recent years and the forecast increase to 2030 within the LMB (MRC, 2011) it is clear that land-use change to agriculture is an ongoing and significant threat to the viability of natural wetland ecosystems (as shown in ***Table 2-1***).

Table 2-1: Potential indicators of the state and trend of reclamation/modification of wetlands, including for agriculture

Pressure	Indicator	Evidence/data
Reclamation/ modification of wetlands (including for agriculture)	Area of irrigated agricultural	Annual irrigated area across the Basin is 4,002,151 ha in total; of which 504,245 ha is in Cambodia, 166, 476 ha is in Lao PDR, 1,411,807 ha is in Thailand and 1,919,623 ha is in Viet Nam (MRC, 2011). Based on FAO AquaStat (2015) statistics, Cambodia had a 24% increase in area equipped for irrigation between 2001 and 2006 and an 83% increase in non-equipped flood-recession cropping area over the same period; Lao PDR had a 5% increase in area equipped for irrigation between 2000 and 2005 and a 0% increase in non-equipped flood-recession cropping area over the same period; Thailand had a 29% increase in area equipped for irrigation between 2000 and 2007 but no data was provided for non-equipped flood-recession cropping area over the same period; Viet Nam had a 53% increase in area equipped for irrigation between 1994 and 2005 and no data was provided for non-equipped flood-recession cropping area over the same period.

Pressure	Indicator	Evidence/data
		Under the 2030 Basin Development Scenario the area of irrigated agriculture was forecast to increase by 53% in Cambodia, 28% in Lao PDR, and 7% in Viet Nam. The area of increase was not identified for Thailand (MRC, 2011).
	Number of existing and planned irrigation projects	The number of irrigation projects in the Lower Mekong Basin as reported in MRC (2011) was 2,091 for Cambodia; 2,333 for Lao PDR, 6,388 for Thailand, and 608 for Viet Nam. The number of planned irrigation projects was 32 in Cambodia, 2,768 in Lao PDR, 990 in Thailand and 339 in Viet Nam (MRC, 2011).
	Land area used for agricultural activities	Land-use changes in the LMB between 2003 and 2010 for agricultural activities include: a 26% increase in the area used for annual cropping; a 112% increase in the area of orchards; a 423% increase in the area of industrial plantations; a 210% increase in forest plantations; and a 64% increase in the area of aquaculture (IKMP, 2015)

The number of irrigation projects in the LMB is forecast to increase by 36% with an additional 4,129 projects planned (MRC, 2011). However, an indicator based on area is likely to be a better indicator of the actual pressure on wetlands than the number of projects because of the large difference in the size of different projects. For instance, the average area per project is 3,157 ha in Viet Nam and 71 ha in Lao PDR (MRC, 2011). Nevertheless, the planned expansion of irrigated agriculture in the LMB illustrates that this pressure on wetland health and function is only likely to increase.

Of course, not all irrigation expansion is undertaken at the expense of natural wetland areas and not all wetlands are converted to irrigated, rather than dryland, agriculture. An improved indicator would specifically consider the magnitude of land-use change from natural wetland habitat to agriculture use, whether irrigated or not. The land-use data that is available does not explicitly conclude that it is natural wetland areas that are being converted to agriculture. However, as an indicator of the potential pressure on wetlands, it is evident that land-use for agricultural activities has increased considerably between 2003 and 2010 (as shown in ***Table 2-1***), while total wetland area has decreased by approximately 887,787 ha (IKMP, 2015). It has been reported that the area of wetlands reclaimed for cultivation has increased greatly, combined with intensive, often unsustainable, human use of those small wetlands which remain (Parr *et al*. 2009, cited in MRC, 2010a).

Contamination and pollution of wetlands from agriculture, industrial and urban sources

Pollution from agricultural runoff and from industrial and urban discharge is a potentially significant threat to wetland ecological health and function through eutrophication and harm to biota through, for example, toxic substances that can bio-accumulate and negatively impact on reproduction and survival (Bryant, 2002). Although water quality within the river system is generally good (MRC, 2010a), it is not clear that this also extends to off-river wetland and floodplain areas, particularly those in close proximity to agricultural and urban environments. Potential indicators of the threat posed by pollution include the level of fertiliser and pesticide use, the discharge of untreated or inadequately treated wastewater and the presence of POPs, heavy metals and other trace elements in the water column, sediment and biota (as shown in ***Table 2-2***).

Consumption of nutrients increased between 2002-2012, mostly in Cambodia (from 0.021 to 0.065 million tonnes of both Nitrogen and Phosphorus) and Thailand (from 1.4 to 2.1 million tonnes), but decreased in Viet Nam (from 1.7 to 1.4 million tonnes; as shown in ***Figure 2-1***). No figures were available for Lao PDR. Figures on pesticide use are not readily available. However, as most applied pesticides are imported, the total import value of pesticides provides an indication of the growth in use even though not all imported pesticides are used in the agricultural sector (MRC, 2010a). Between 1992 and 2011/2012 the value of imported pesticide increased dramatically in Thailand (from $129 to $626 million), Viet Nam (from $20 to $665 million), Cambodia (from $0.45 to $17 million) and Lao PDR (from $0.3 to $3.8 million)(as shown in ***Figure 2-2***). However, assessments based on total pesticide use (in quantity or value) can be misleading since the nature of pesticides in use changes, in particular the substitution of some pesticides by those with potentially higher toxicity levels meaning smaller amounts can have larger impacts.

An important consideration for the impact of pollution on wetland health is the often localised nature of the most serious problems. Broad-scale statistics therefore do not always provide the most accurate picture of the situation. An improved indicator of this pressure might be based on the extent of polluting activities in proximity to a representative sample of important wetlands.

Table 2-2: Potential indicators of the state of, and trend in, potential wetland contamination and pollution

Pressure	Indicator	Evidence/data
Contamination and pollution	Fertiliser and pesticide use	Since the 1990s commercially produced fertiliser use has increased significantly in the LMB (MRC, 2010a). There are elevated concentrations of phosphorus, nitrogen and COD, and lower dissolved oxygen in the Mekong Delta compared with upstream water quality monitoring stations (Campbell 2007; MRC 2008a). Estimates based on available data suggest that about 225,000 tonnes of nitrogen and 37,000 tonnes of phosphorus are washed into the Mekong River each year (MRC, 2008). More than 40% of this nitrogen and phosphorus is likely to be lost from agriculture in northeast Thailand and the Mekong Delta (MRC, 2008a). Thus, despite fairly low nutrient levels in the Mekong River in general, there may be local risks of elevated levels potentially leading to algal blooms. Since 2002 nitrogen and phosphate consumption has increased primarily in Thailand and Cambodia and decreased in Viet Nam (FAO Stat 2015, as shown in ***Figure 2-1***). Pesticide use is still low compared with western countries, but has sharply increased in Cambodia, Thailand and Viet Nam (MRC, 2010a). Pesticide use in Viet Nam is much higher than in the other LMB countries, especially in the intensively farmed Mekong Delta (MRC, 2005). The use of pesticides in orchards and on vegetables is high, where large quantities are suspected of ending up in the aquatic environment. Many pesticides with high toxicity to aquatic organisms (including crustaceans, fish and amphibians) and humans are still being used (MRC, 2010a).
	Level of treated wastewater discharge	High nutrient levels are also associated with discharge of untreated or inadequately treated domestic and industrial wastes from urban centres (Snidvongs and Teng 2006). In Lao PDR, only 15% of the total industrial effluent from that country is treated (Fengthong and Roger, 2010, country report for UN-Water). In Thailand, 75% of domestic wastewater was estimated to be untreated in 2001 (MoNRE Thailand, 2008). In Viet Nam, of 82 industrial zones recorded in 2003, only 18 had central wastewater treatment facilities and between 1995 and 2003 the Biological Oxygen Demand load in discharges increased from 237,660 to 482,551 tonnes (MoNRE Viet Nam, 2008).
	Presence of POPs, heavy metals and other trace elements	Recent studies conducted in the Mekong Delta reveal the presence of Persistent Organic Pollutants (POPs) in sediment and biota (Minh *et al*. 2006; Minh *et al*. 2007; Carvalho *et al*. 2008; Ikemoto *et al*. 2008). Most of the organisms investigated (phytoplankton, crustaceans and fish) contained POPs, with Dichloro-Diphenyl-Trichloroethane (DDT) being the main contaminant. The concentrations of DDT and Poly-Chlorinated-

Pressure	Indicator	Evidence/data
		Biphenyls (PCBs) were higher in sediment next to urban areas than in sediments from rural and agricultural sites, suggesting that urban areas were important point sources of DDTs and PCBs in the river (Minh *et al*. 2007). Tran *et al*. (2014) also report that while loading of POPs in wetland sediments is generally low there are hotspots. For example, wetlands of the open, dry dipterocarp forest of northern Cambodia and Vietnam as well as wetlands in the Mekong Delta of Vietnam and in the Tonle Sap contained high concentrations of POPs. The use of mercury and cyanide in local gold mining and release of acidic tail water has caused incidents of local pollution with fish kills and elevated environmental levels in certain areas (MRC, 2010a).

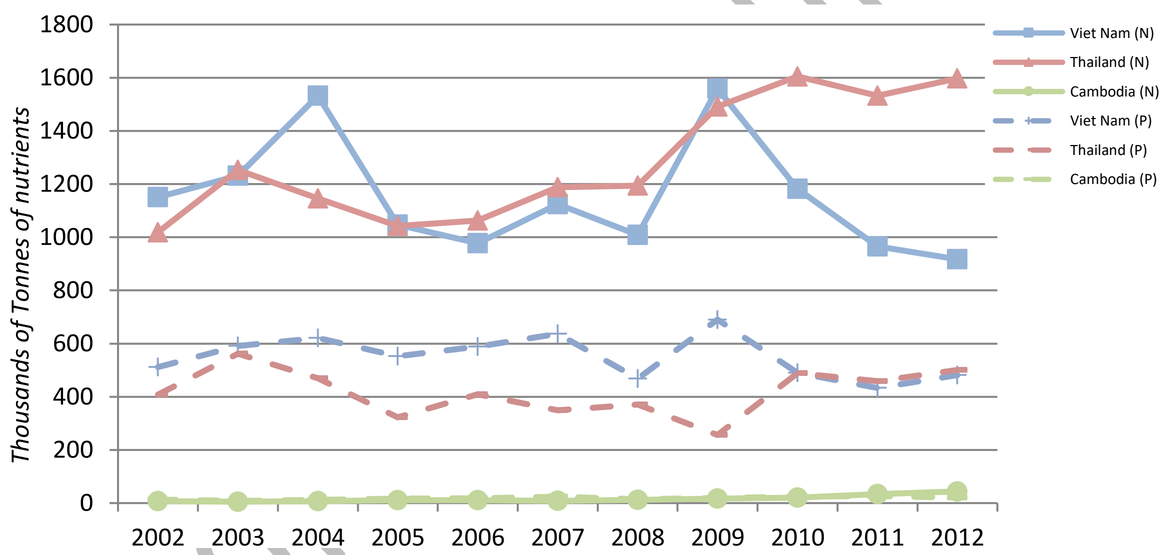


Figure 2-1: Consumption of nitrogen and phosphate in Cambodia, Thailand and Viet Nam between 2002 and 2012. ***Source: FAO Stat 2015. Data not available for Lao PDR.***

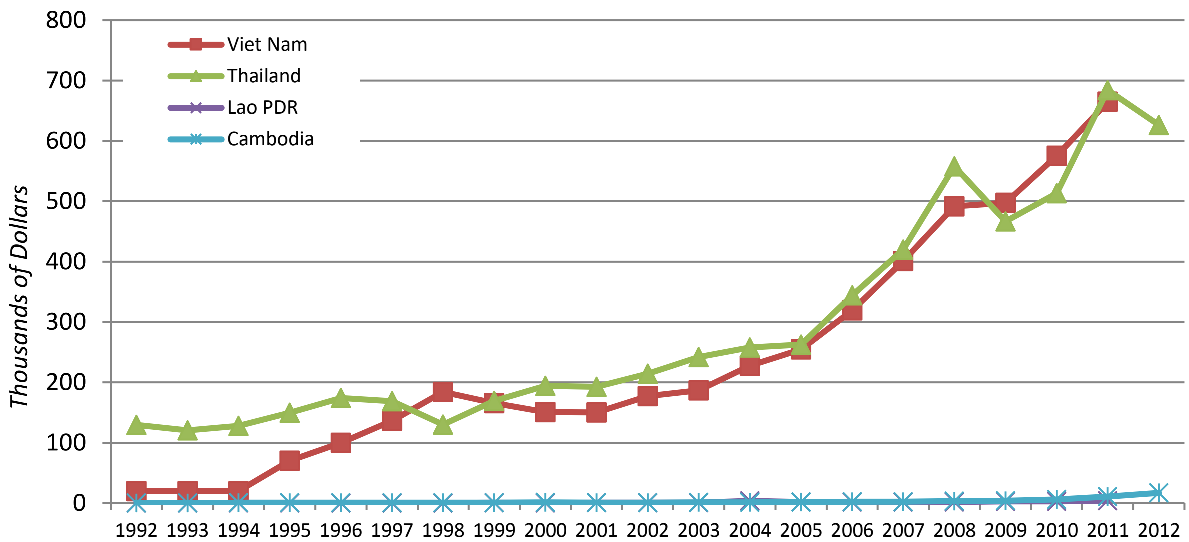


Figure 2-2: Import value of pesticides in Cambodia, Lao PDR, Thailand and Viet Nam between 1992 and 2012. ***Source: FAO Stat 2015.***

Over-exploitation of wetland resources

Wetlands are an important source of food and other products for local people. For instance, two-thirds of LMB households are engaged in fishing, mostly on a part-time basis (MRC, 2015b). Inland fish and Other Aquatic Animals (OAAs) contribute 47-80% of dietary animal protein with average daily intake of 18.3g/day (Hortle, 2007, cited in MRC, 2015b), and fish supplied more than 80% of total protein consumed in Cambodia (MRC, 2006). With such a high reliance of the population on resources from rivers and wetlands, growth in the population is likely to put increasing pressure on the resources provided by wetlands. Potential indicators of the exploitation pressures on wetland resources include population growth, changes in fish and other OAA catch and catch per unit of effort, the level of non-timber forest products exploited and the number of threatened wetland species recorded as being threatened by harvest, hunting or poaching (as shown in ***Table 2-3***).

Table 2-3: Potential indicators of the state of, and trend in, the over-exploitation of wetland resources

Pressure	Indicator	Evidence/data
Over-exploitation of wetland resources	Population growth	The overall population of the Lower Mekong Basin increased by about 12% between 2003 and 2010 from approximately 55 million to 60 million, with a 25% increase in Cambodia, 6% increase in Lao PDR, close to 0% in Thailand and 10% in Viet Nam (MRC, 2010a). About 85% of the LMB population live in rural areas (Landscan data

Pressure	Indicator	Evidence/data
		2007). Most live near rivers, lakes, and wetlands, with 25 million living within a 15 km corridor either side of the Mekong mainstream (Landscan data 2007).
	Fishing and OAA catch	SIMVA data (MRC, 2015b) shows that 66.2% of 2,720 households surveyed reported 'less' fish catch than the last five years. In Cambodia where approximately 50% of fishing occurs in either Tonle Sap or other lakes or swamps/wetlands, the figure was 84.6%. An average of 52.2% of households surveyed reported less food due to declining fish catch. Overall, people surveyed thought that fewer OAAs were being collected than five years ago, with approximately 50% believing this was due either to competition from other OAA collectors or because too many OAAs were being collected (MRC, 2015b). Over the five years to 2010, almost one in six households reported members who have changed occupation because of declining productivity and services of the aquatic ecosystems (MRC, 2010a).
	Catch per unit of effort (CPUE)	In 2008-09 fishing catch per unit of effort was recorded from SIMVA data as an average of 1.23 kilograms of fish per hour of effort (MRC, 2010c). In 2011 catch per unit of effort was recorded as an average of 0.8 kilograms of fish per hour of effort (MRC, 2015b).
	Population dependent on fishing and OAA	15% of households surveyed received some income from fish sales, although only 6.5% of households identified fishing as their most or second most important occupation (MRC, 2015b). If this figure remains stable (or increases) over time and the population increases, this could indicate increased pressure on the resource. A decline in this figure over time could indicate either reduced pressure or a reduced 'state' of the resource.
	Harvest of wildlife and non-timber forest products (NTFPs) – no. of threatened species in decline due to exploitation	Of 64 threatened species of fauna in the LMB (MRC, 2010a), 60 of which are dependent on wetlands at some stage in their life-cycle, 37 identify over-harvesting as a key threat (IUCN Red List; Annex 3). It has also been reported, for example, that the regional trade in turtles has reached alarming rates (Stuart 2004; Stuart and Platt 2004, cited in MRC, 2010a).

Between 2003 and 2010 the total LMB population increased by approximately 12% to 60 million (MRC, 2010a). Based on household survey data there are some indications that catch of fish and OAAs is declining (MRC, 2015b), possibly due to increased competition and a fish population under strain. However, given fish productivity is closely linked to other factors such as the magnitude and duration of flooding in preceding years, and there can be significant variability both within and between years, survey data over short time periods need to be treated with caution.

Another potential indicator of exploitation pressures on wetland resources is the harvest and trade in wetland wildlife including reptiles, amphibians, birds and mammals. Although statistics on this are difficult to come by, one way to consider the potential threat is the number of threatened wetland fauna in the LMB which are identified as having harvest, hunting or poaching as a key threatening process and the extent to which this changes over time. Based on the list of fauna currently identified as threatened on the IUCN Red List (***Annex 3***), that is, having a status of vulnerable, endangered or critically endangered (MRC, 2010a), 37 of 60 wetland species, or 62%, identify exploitation pressure as one of the main reasons for a decline in their population.

Sedimentation and erosion

Sedimentation and erosion impacting on wetlands are natural processes. They can become a problem, however, when the level of sedimentation and erosion due to human activities is beyond the natural variability such that the ecosystem cannot adapt quickly enough to the change or the establishment of a new equilibrium. There are two main causes of sedimentation and erosion problems in the Mekong Basin: (i) the construction of dams that capture sediment, leaving more erosive power in the river as the sediment-depleted flow continues downstream; and (ii) deforestation and land-use change which exposes soil to localised erosion and increases the sediment supply to rivers and wetlands downstream. In general, increases in erosion contribute to deteriorating water quality, including the impacts of sedimentation on wetlands health and increased siltation of reservoirs that reduces storage capacity. However, reduced sediment flows through the system are a significant problem since this undermines wetlands integrity (land formation), notably in the delta. This results in the loss of disaster risk reduction services provided by coastal wetlands and exposes people and infrastructure in the delta region to increased risks from sea-level rise and storm events. Potential indicators of sedimentation and erosion pressures could therefore include the number of dams and their amount of 'non-active' storage, the rate of deforestation within the catchment, or the concentration of total suspended sediments in rivers, streams and other wetlands (as shown in ***Table 2-4***). In addition, trends in the status and extent of coastal wetlands (as influenced by sediments) would be a valuable indication of the scale of pressures/threats.

Table 2-4: Potential indicators of the state of, and trend in, sedimentation and erosion pressures

Pressure	Indicator	Evidence/data
Sedimentation and erosion	Number of dams existing and planned	MRC (2011) reports that in the LMB the numbers of existing, under construction and planned dams with installed capacity of greater than 1 MW on the Mekong mainstream and the tributaries is: 26 existing; 14 under construction and 96 planned (of which 85 are on the tributaries).
	Total volume of live/active and non-live storage	Total live storage volume: 29,913.564 million m^3 out of a total storage volume: 48,669.792 million m^3. Ratio 0.61 with 18,756,228 million m^3 of storage which is not 'live/active'. Ratio of live storage to total storage for dams in China: 0.38; in Laos: 0.67; Thailand: 0.78; Cambodia: 0.80; and Viet Nam: 0.42. There does not appear to be any trend in the ratio of live storage to total storage either geographically or through time (MRC Dam database, 2010) although clearly the total volume of both 'live' and 'non-live' storage is increasing. Modelling indicates that dams will reduce sediment inflow to Cambodia and the Delta region by between 50% and 90%, which is likely to lead to increased coastal erosion (Saarkkula *et al.*, 2010).
	Deforestation rate and harvesting of timber products	MRC study of forest losses between 1993 and 1997 identified that the LMB as a whole lost close to 500,000 ha, or slightly over 2% of its forest cover in only four years (MRC, 2003); while between 2003 and 2010, 21% of broadleaf deciduous and evergreen forest were lost – about 7.4 million ha (IKMP, 2015). The area of flooded forest increased by 39,309 ha between 2003 and 2010 (IKMP, 2015). Between 2000 and 2005 forest area (not necessarily forested wetlands) designated primarily for production declined in Cambodia, remained stable in Thailand and increased in Lao PDR and Viet Nam (MRC, 2010a).
	Concentration of Total Suspended Solids	There has been a decrease over time in TSS monitored in the Mekong river (MRC, 2003). Total suspended solids showed a noticeable decrease between 1985 and 2011, from an average value of 389 mg/L to 82 mg/L and the median value of 244 mg/L to 55 mg/L (Ly and Larsen, 2012).
	Sedimentation rates and sediment flux	Modelling of sediment flux in Tonle Sap demonstrates that around 80 % of the sediment the system receives from the Mekong River and tributaries is stored in the lake and its floodplain (Sarkkula *et al.* 2010). However, sedimentation studies using radioisotope dating (Penny, 2002; Penny *et al.*, 2005; Tsukawaki, 1997; cited in Sarkkula *et al.* 2010) show that net sedimentation within the Tonle

Pressure	Indicator	Evidence/data
		Sap Lake proper has been in the range of 0.1-0.16 mm/year since ca. 5500 years before present. Sediment flux at Chiang Sen averaged 73.3 x 10^6 tonnes/yr from 2000-2007 and only 12.6 x 10^6 tonnes/yr from 2009-2011 based on daily TSS monitoring (Koehnken, 2012).

The construction of dams for hydropower is clearly a significant issue for the Lower Mekong Basin, with 40 projects either existing or under construction and a further 96 planned (MRC, 2011). These figures do not include dams constructed by China on the Lancang (upper Mekong) upstream of the Lao PDR border and a number of studies (Lu and Siew 2006; Fu and He 2007; Kummu and Varis 2007) suggest that sediment delivery from the upper Mekong has decreased as a result of these. They differ, however, on the extent of the change with some suggesting the figure could be as high as 50% since 1993 and the closure of the Manwan dam in China.

The removal of sediment from the system by dams in the upper Mekong is demonstrated by the Manwan dam, which reportedly lost 20% of its storage capacity to sediment deposition during its first 10 years of operation. This is equivalent to a mean annual rate of mainstream sediment loss of 20 x 106m^3. It is estimated that the completed Yunnan cascade in China will trap some 90% of the upper Mekong sediment contribution to the lower basin (Kummu and Varis, 2007).

Dam design is an important consideration in its sediment-trapping effect, with the amount of 'live storage', or the amount of water retained by the dam under normal minimum operating requirements, being a key determinant (MRC, 2011). Up to 2010 the total live storage of existing LMB dams was 29,913.564 million m^3 out of a total storage volume of 48,669.792 million m^3. One indicator of the threat to wetlands caused by erosion could be the quantity of storage in the Basin which is not 'live/active storage', presently 18,756,228 million m^3 and growing.

There are no data specifically on forestry operations in wetland catchments or areas. An indication of overall forestry activity is the amount of land designated specifically for that purpose. Although between 2000 and 2005 this has declined in Cambodia, it has increased or been stable in the other three countries (MRC, 2010a). This indicator does not, of course, pick-up illegal logging which is likely to occur outside of designated areas. Similarly, while there are no statistics on the rates of deforestation for forested wetlands specifically, IKMP (2015) has identified that large areas of forest have recently been lost across the LMB, notwithstanding that the area of flooded forest has increased (as shown in ***Table 2-4***). For this reason, deforestation is considered a better indicator of the erosion and sedimentation pressure than a direct land-use threat to wetlands themselves.

The concentration of total suspended solids in the water column also provides an indication of the potential threats of excessive erosion or sedimentation. As reported in State of the Basin reports (MRC, 2003; 2010) and water quality monitoring reports (Ly and Larsen, 2012), total suspended solids in the water column have been decreasing for some time. This indicates that there is likely to be a greater erosion pressure than sedimentation pressure for aquatic environments in the LMB. Sarkkula *et al*. (2010) reports that although there is a net sediment flux (of approximately 80%) into the Tonle Sap Lake and floodplain, radioisotope dating of sediments has shown that the lake is not filling-up with sediment as is sometimes reported.

Introduction of invasive alien species

There are a number of aquatic species that have been introduced to the LMB for a variety of purposes including aquaculture, stocking of lakes and reservoirs, pest control and the aquarium trade. While non-natives are an identified threat to wetland health, Arthur *et al.* (2010) find that the stocking of non-native fish species (tilapia and carp) did not have any impact on native fish biomass and had no significant impact on species richness or composition in wetlands.

Species that are identified as impacting on the ecology of LMB wetlands are the giant mimosa (*Mimosa pigra*) and the golden apple snail (*Pomacea sp.*)(MRC, 2010a). In addition, the Siam weed (*Chromolaena odorata*) is reported forming dense stands preventing establishment of other species due to aggressive competition (IUCN, 2006). Another major aquatic weed Water Hyacinth (*Eichhornia crassipes*) is reportedly widespread on freshwater wetlands of the Mekong Delta, especially in standing water. It forms dense floating mats, covering the water surface, reducing the abundance of native floating plants and other aquatic organisms by reducing the availability of sunlight and competing for nutrients (Matthews, 2004). Invasion of sand bars and mudflats along the Mekong River in the upper Lao PDR region by *M. pigra* has resulted in the loss of feeding and resting habitats of migratory water birds (Dubeau, 2004). In heavily infested areas, few native plants can grow under the mimosa canopy (Triet *et al.,* 2002).

Potential indicators of the pressure of invasive alien species include the number of species and their range (as shown in ***Table 2-5***). Ideally the area of overlap of the range of each species and wetland areas would be calculated so that the change in extent of invasion and an assessment of the proportion of wetland area and types affected could be ascertained. Without this information, the proposed indicator is a simple presence/absence count of invasive alien species in each LMB country.

Table 2-5: Potential indicators of the state of, and trend in, invasive alien species

Pressure	Indicator	Evidence/data
Introduction of invasive Alien Species (IAS)	Number and extent of IAS recorded in wetlands	IUCN (2006) documents 9, 11, 22, and 13 IAS in each of Cambodia, Lao PDR, Thailand and Viet Nam respectively and notes that IAS have caused significant and often irreversible environmental and socio-economic impacts to ecosystems and livelihoods in the LMB area. Major IAS in the LMB and country distribution (GISP Database[1] and Triet, 2000, cited in IUCN, 2006): • Siam Weed (*Chromolaena odorata*), present in: Cambodia, Lao PDR, Thailand, Viet Nam • Torpedo grass, Victoria grass (*Panicum repens*), present in: Cambodia, Viet Nam • Water hyacinth (*Eichhornia crassipes*), present in: Cambodia, Lao PDR, Thailand, Viet Nam • Mauritius grass (*Brachiaria mutica*), present in: Cambodia, Thailand • Giant Mimosa (*Mimosa pigra*), present in: Cambodia, Lao PDR, Thailand, Viet Nam • Water lettuce (*Pistia stratiotes*), present in: Viet Nam • Golden Apple Snail (*Pomacea canaliculata*), present in: Cambodia, Lao PDR, Thailand, Viet Nam

Changes to the hydrological regime impacting wetlands

There are mixed reports on the extent to which the hydrological regime has already changed as a result of development activities (hydropower and irrigation) within the Basin. Adamson (2006) found no evidence of any monotonic change to the hydrological regime of the Lower Mekong Basin including no evidence of a statistical shift to higher low season flows and lower high season flows as predicted by modelling (MRC, 2010a). Cochrane *et al.* (2014) illustrate that consistent with the modelling, there has been a modest observable increase in low season flows at Chiang Saen but that the effect diminishes downstream until it is negligible at Mukhadan in north-east Thailand.

In 2010, the MRC reported no convincing statistical evidence that the existing tributary dams in Lao PDR, Thailand and Viet Nam have modified the mainstream flow regime (MRC, 2010a). However, Cochrane *et al.* (2014) showed that there has been a statistically significant reduction of 23% and 11% in the water rising and falling rates respectively at Prek Kdam, providing evidence of a diminished Tonle Sap flood pulse in the post-1991 period. At Stung Treng and Prek Kdam, increases in 30-day minimum flows are strongly significant with a mean increase of 13% and 17% respectively. At Pakse, alterations to the number of fluctuations and rise rate

[1] Global Invasive Species Database: http://www.issg.org/database/welcome/.

became strongly significant after 1991. Thirty of 39 Mekong Basin dams on the mainstream and tributaries were constructed after 1991 (MRC dams database, 2010).

These indicators largely consider basin-scale hydrology as manifest on the mainstream of the Mekong or Tonle Sap Rivers. More localised and significant changes to hydrology impacting off-stream wetland and floodplain areas are certain to have occurred as a result of land-use changes, channelization and the building of infrastructure (e.g. levees, roads, urban areas) throughout the region. Improved indicators of the pressures wetlands face might therefore also consider localised changes to hydrological parameters (e.g. area and duration of inundation, depth, timing of inflow and outflow) for a representative set of wetlands in the LMB.

While the evidence of basin-scale hydrological change to-date appears relatively modest, modelling of the potential future impacts of development identifies potentially large impacts, as illustrated by the area of inundation expected for different wetland types. For instance, under the Definite Future Scenario (DFS) defined by MRC (2010b) wetland inundation was predicted to decrease by 0.5% for flooded forests, 2.8% for marshes and seasonal wetlands, 4.1% for seasonally flooded grasslands, and 5.8% for rice fields. The DFS assessed the cumulative impacts of developments that already existed in 2000, were under construction or otherwise firmly committed up to 2015.

Under the Foreseeable Future Scenario (FFS), which assessed the impact of all planned development activities to 2030, the area of wetland decreased by 0.8% for flooded forest, 3.9% for marshes and seasonal wetlands, 5.4% for seasonally flooded grasslands, and 7.2% for rice fields.

Other potential indicators that consider the impact of current and future development on hydrology could include a Catchment River Ecosystem Connectivity Index or a Catchment Degree of Regulation Index, as calculated by Grill *et al*. (2012) as measures of ecosystem fragmentation (as shown in ***Table 2-6***).

Table 2-6: Potential indicators of the state of and trend in, the hydrological regime pressures impacting wetlands

Pressure	Indicator	Evidence/data
Modification of the hydrological regime	Discharge volume and timing; Flood frequency, duration and peak	Mean annual flood peak at Vientiane: 16,200 m^3/s; at Kratie: 50,900 m^3/s. Mean annual dry season flow at Vientiane: 1,235 m^3/s; at Kratie: 2,450 m^3/s (Adamson, 2006). No statistically significant trend evident in the historical record for average flow, maximum or minimum discharge, start and end of flood and dry seasons at Vientiane since 1914 and Kratie since 1925 (Adamson, 2006). There is an observable and statistically

Pressure	Indicator		Evidence/data
			significant increase in dry season flows at Chiang Saen (+21%), an effect which diminishes downstream, but becoming statistically significant again at Pakse (+19%), Stung Treng (+13%) and Prek Kdam (+17%)(Cochrane *et al*., 2014). Hydrological modelling of the impacts of constructed and planned hydropower dams in Yunnan Province describes a significant increase in average discharge during the low-flow season, of about 40% in the upper reaches and about 20% as far downstream as Kratie. The decrease in flood season flows is proportionally far smaller (about 15% in the upper reaches and less than five% at Kratie (MRC 2009a, as cited in MRC, 2010a).
	Rates of water level rise and fall and fluctuation frequency		An increase in fall rates (+42%) and water level fluctuations (+75%) at Chiang Saen. A reduction of 23% and 11% in the water raising and falling rates respectively at Prek Kdam post-1991. At Pakse, alterations to the number of fluctuations and rise rate became strongly significant after 1991 (Cochrane *et al*., 2014)
	Construction of dams and other barriers		30 of 39 mainstream and tributary dams constructed after 1991; 22 of 39 constructed after 2000 (MRC Dams database, 2010).
	Expected impact of planned and foreseeable Basin development	Area of inundation	Definite Future Scenario (DFS): reduction in total flooded area of 248,734 ha (-5.2%) in an average year (MRC, 2010b). Foreseeable Future Scenario (FFS): reduction in total flooded area of 313,671 ha (-6.6%) in an average year or -6.3% without any mainstream dams (MRC, 2010b)
		Inundated area of flooded forest	DFS: reduction in inundated area of 2,287 ha (-0.5%) in an average year (MRC, 2010b) FFS: reduction in inundated area of 4,013 ha (-0.8%) in an average year (MRC, 2010b) In a wet year the changes are very limited; only about 0.1% basin wide. In a dry year, however, the changes are much more pronounced. Cambodia may lose 5 to 6.5% of its flooded forests under the various scenarios, Viet Nam up to 3%. Flood depth and flood duration change as well: areas of shallow flooding increase at the expense of deep flooded areas. Average flood depth decreases with 0.4 to 0.6 m. Average flood duration may decreases with up to one month in a limited area

Pressure	Indicator		Evidence/data
		Inundated area of marsh/ seasonal wetlands	DFS: reduction in inundated area of 15,257 ha (-2.8%) in an average year (MRC, 2010b) with Lao PDR losing 21% and Thailand 16% FFS: reduction in inundated area of 21,077 ha (-3.9%) in an average year (MRC, 2010b)
		Inundated area of flooded grasslands	DFS: reduction in inundated area of 17,660 ha (-4.1%) in an average year (MRC, 2010b) with Lao PDR losing 36% and Thailand 15% FFS: reduction in inundated area of 23,209 ha (-5.4%) in an average year (MRC, 2010b)
		Inundated area of rice fields	DFS: reduction in inundated area of 147,964 ha (-5.8%) in an average year (MRC, 2010b) with Lao PDR losing 17% and Thailand 20% FFS: reduction in inundated area of 184,632 ha (-7.2%) in an average year (MRC, 2010b)
	Water abstractions for urban or agricultural use		Irrigation in the LMB consumes an estimated 41.8 billion m^3 of freshwater (MRC, 2010a). Present demand from urban and industrial uses, mostly in Thailand and Viet Nam is 2.9 billion m^3. More than half of irrigation takes place in the Mekong Delta (26.3 billion m^3), followed by Thailand (9.5 billion m^3), Lao PDR (3.0 billion m^3), Cambodia (2.7 billion m^3) and the highlands of Viet Nam (0.5 billion m^3) (MRC, 2010a). While time-series data on irrigation water use in the LMB is not readily available, given that the area of irrigated agriculture has increased considerably (as shown in ***Table 2-1***) it is expected that water use by irrigation has also increased, notwithstanding any efficiencies which may have been achieved. Overall agricultural water consumption in Thailand rose from 48.2 billion m^3 in 1993 to 61.7 billion m^3 in 2006 (MoNRE Thailand, 2008)

2.1.2 State and trend of pressures due to climate change (whether due to natural or anthropogenic factors)

To date "*there is little if any statistical evidence in the hydro-meteorological record over the period 1925-2005 of climate change in the LMB*" (Adamson, 2006). This finding pertains to 90-day low flow behaviour at Kratie and Vientiane, the dates of onset and cessation of the Northwest monsoon, and the amount of monsoonal rainfall. However, the potential impacts of future climate change on wetlands of the LMB have recently been modelled. MRC (2015a) identifies four direct climate risks to wetland environments. These are changes in precipitation, changes in temperature, modified hydrological regime and sea-level rise (as shown in ***Table 2-7***).

Table 2-7: Potential indicators of the state and trend of climate change impacts on wetlands

Pressure	Indicator		Evidence/data
Climate change	Precipitation	Annual mean	Mean annual precipitation predicted to increase across the Basin with greater increases in the east (MRC, 2015a)
		Wet season mean	Wet season rainfall predicted to increase by 11-14% in the Khorat Plateau, northern Annamites, southeastern Cambodia and the Srepok basin, with the remaining areas experiencing 6-10% increases (MRC, 2015a)
		Dry season mean	Dry season rainfall predicted to decrease by 2-10% south of Pakse, increase by 15-23% in northern Lao PDR and the northern Annamites with negligible change in the northern Khorat Plateau (MRC, 2015a)
	Temperature	Average annual maximum	Average annual maximum temperature predicted to increase by 2-3 degrees with greater increases in southern and eastern regions (MRC, 2015a)
	Modified hydrological regime	Flood magnitude and volume	Predicted increase in flood magnitude and volume across all monitoring stations, with more pronounced increases in average annual flow volume in the lower reaches (MRC, 2015a)
		Flood duration	Predicted increase in the duration of the flood season. For example, at Kratie station the average flood duration is predicted to increase from 134 to 137 days using the average output of all GCMs, while the 1 in 20 year flood is predicted to increase from 119 to 134 days (MRC, 2015a)
		Length of transition season and	The transition period to flood (May/June) and transition to dry (Nov/Dec) is predicted to shorten (MRC, 2015a)

Pressure	Indicator		Evidence/data
		onset of flooding	
		Dry season water levels	Dry season flows are predicted to increase in response to increases in dry season rainfall with the largest proportional increase (20-30%) in water levels in the middle reaches of the Mekong (Vientiane to Pakse)(MRC, 2015a)
	Sea-level rise		Sea levels are predicted to rise resulting in permanent inundation, erosion and salinization of a greater portion of the deltaic environment and an inland migration of coastal wetland environments where this is possible (MRC, 2015a). The 2007 IPCC prediction of sea-level rise (26-59 cm) would lead to a 36-63% inundation of the Ca Mau peninsula; while the MoNRE (Viet Nam) predictions (65-100 cm rise) would lead to a 67-83% inundation of the Ca Mau peninsula. With tidal effects super-imposed on top of this, a predicted 95-100% of the peninsula would be inundated with up to 0.7m of water(MRC, 2015a)

The MRC (2015a) study evaluated the vulnerabilities of habitats at six case study LMB wetlands as a result of these risks. When these were scaled-up to a basin-scale, MRC (2015a) then identified the following habitat vulnerabilities resulting from these risks:

- Flooded forests are the most exposed wetland type to climate change, experiencing the largest increases in precipitation with large temperature increases in Cambodia and Lao PDR;
- Riverine, freshwater, mangrove and peat wetlands are all moderately exposed to climate change and are more exposed to temperature increases than to precipitation increases. Changes in temperature are most important for peat lands, freshwater and riverine wetlands, while changes in precipitation are most important for riverine wetlands and mudflats;
- Grasslands, scrub and lakes/ponds are the least exposed to climate change;
- The vast majority of ponds and deltaic/estuarine wetlands together with 70% of flooded forest; 31% of grasslands and marshes, 20% of rivers and streams are highly vulnerable;
- The vast majority of peatlands, lakes (saline and fresh) and un-vegetated mudflats, together with 30% of flooded forests, 60% of rivers and streams and 40-45% of grasslands, swamps, marshes and wood scrub would be moderately vulnerable;
- All estuarine watercourses, together with 45% of swamps and wood scrub, 30% of grasslands and marshes, 20% of rivers and streams and a small fraction of lakes would experience low vulnerability;
- 34 of 97 high priority wetland sites across the LMB (***Annex 6***) are considered to be highly vulnerable to climate change, two-thirds of which are in Thailand and Cambodia.

2.2 State of, and Trend in, Wetland Health and Function

2.2.1 State of, and trend in, wetland health and function by wetland type

The total area of wetlands in the Lower Mekong Basin is subject to some uncertainty due partly to different definitions and different delineations of wetland type, and partly due to a lack of up-to-date and available data. Ringler (2001) reported that wetlands are estimated to cover 6–12 M ha of the entire lower basin. Since then, MRC reports have used a wetland database compiled in 2003 from country data and re-classified in 2009. MRC (2009a) reported that there were an estimated 5.25 M ha of flood-affected wetlands in the LMB. MRC (2015a) identified 25.4 M ha, of which 5.5 M ha were considered natural and the rest artificial, while analysis by IKMP of data used to prepare MRC (2011) indicates that there was 16.5 M ha of wetland area in the LMB in 2009. If it is considered that all area covered by aquaculture and rice fields is largely artificial wetlands, then the remaining natural wetland resource, according to this 2009 IKMP data, would be 2.3 M ha. This is less than half of the area of natural wetland described in MRC (2015a), which considered artificial wetlands to include rice paddy, recession agriculture and other wet agricultural crops, lakes and ponds from irrigation and hydropower reservoirs and in urban areas, and man-made artificial channels.

Clearly it is not possible to determine the state of the overall wetland resource within the LMB without a definitive understanding of the extent of wetland area and the different habitats associated with different wetland types. Nevertheless, from the available evidence it appears clear that overall wetland area is in decline. For instance, each of the 2003 wetland country reports identify wetland habitats being degraded with changes in wetland area and significant declines in wetland biota (Vathana, 2003; Phittayaphone, 2003; Choowaew, 2003; Thinh, 2003). MRC (2010a) estimate that less than 2% of the original wetland area in the Mekong Delta remains. Talk Viet Nam (2014) reports that there are 60% less Mangrove forests than in the 1940s.

It is also likely that significant conversion from natural to artificial wetlands is occurring such that the area of natural wetland is declining more rapidly than wetlands as a whole. For example, it is reported that the area of wetlands reclaimed for cultivation has increased greatly, combined with intensive, often unsustainable, human use of those small wetlands which remain (Parr *et al*. 2009, cited in MRC, 2010a). Natural Melaleuca forests and seasonally flooded grasslands in the Plain of Reeds have been disappearing and are being replaced by rice fields and planted Melaleuca forests (Viet Nam EPA, 2005). Tidal wetlands in estuarine areas of the Mekong Delta have decreased in area from 1,473,889 ha in 1995 to 1,409,289 ha in 1999 (Viet Nam EPA, 2005). In addition, the recent growth in aquaculture production in Viet Nam has seen total production in 2008 estimated at about 1.9 million tonnes, more than five times the level in 2000. Of this, about 1.6 Mt originates from within the LMB portion of the Mekong Delta (MRC, 2010a). The total area of coastal wetlands in 1982 was 494,000 ha, and has increased up to 606,792 ha in 2000 due to an expansion of shrimp ponds (Do Dinh Sam *et al*., 2005, cited in Viet Nam EPA, 2005).

Based on land cover data between 2003 and 2010 (***Annex 4***), the area of flooded forest has increased by 8%, the area of grassland has decreased by 60% (although this is not all necessarily seasonally inundated grassland), the area of mangrove has declined by 33%, the area of marsh and swamp area has increased by 169%, the area of aquaculture has increased by 64% and the area of water bodies has increased by 30%.

Table 2-8: Potential indicators of the state of, and trend in, the overall wetland resource.

Resource/ function	Indicator	Evidence/data
Overall wetland resource	Total wetland area	The total wetland area in the LMB has declined from 17,474,874 ha in 2003 to 16,589,088 ha in 2009 (IKMP, 2015; ***Annex 4***), a decline of 5%. In the Mekong Delta, less than 2% of the area's original inland wetlands remain (MRC, 2010a)
	Area of seasonally inundated forest	Seasonally inundated forests made up 3.3% of LMB wetland area, predominantly surrounding Tonle Sap and Delta region (MRC, 2011 based on 2003 data). The area of flooded forest increased by 8% between 2003-2010 (IKMP, 2015; ***Annex 4***)
	Area of seasonally inundated grasslands	Seasonally inundated grasslands made up 3.6% of LMB wetland area, predominantly surrounding Tonle Sap and Delta region (MRC, 2011 based on 2003 data). The total area of grasslands decreased by about 60% between 2003-2010 (IKMP, 2015; ***Annex 4***), although this data does not distinguish between permanently dry and seasonally flooded grasslands.
	Area of marshes, swamps, lakes and ponds	Areas of marshes and swamp increased by 169% and area of water body increased by 30% between 2003-2010 (IKMP, 2015; ***Annex 4***). Tidal wetlands in estuarine areas of the Mekong Delta have decreased in area from 1,473,889 ha in 1995 to 1,409,289 ha in 1999 (Viet Nam EPA, 2005)
	Area of mangroves	Areas of Mangrove declined by 33% between 2003-2010 (IKMP, 2015). In the past, mangrove cover was extensive along the coast, but mangroves have since been degraded and reduced substantially in terms of both quantity and quality (Viet Nam EPA, 2005). Mangrove forests are being severely degraded due to their conversion into agricultural and aquacultural land and due to sea reclamation and coastal erosion. More than 200,000 ha of mangrove forests have been destroyed over the last two decades for the purpose of shrimp farming (Viet Nam EPA, 2005). In southwestern Ca Mau, after one year of conversion of mangrove forests into shrimp ponds, approximately 20 zoobenthos species were lost while bird species from Bac Lieu and Dam Doi colonies migrated to other areas. In Tien Hai (Thai Binh Province), the conversion of 2,500 ha

Resource/ function	Indicator	Evidence/data
		mangrove forests to shrimp ponds has caused substantial damage to the environment (e.g. H_2S and COD concentrations exceed standards, leading to acidification and salinisation of the soil and water environment over a vast area (Viet Nam EPA, 2005). Data reported by the Southern Institute of Water Resources have shown that more than 50% of the total area of the Mekong Delta (approximately two million ha) is currently affected by salinisation. One of the reasons for this phenomenon is the loss of mangrove forests along the coast (Viet Nam EPA, 2005)
	Area of rice fields	Rice fields made up 84% of LMB wetland area in 2003 with the large portion being in northeast Thailand and the Delta region. In 1976, the area of rice paddies in the Mekong Delta was 2,062,000 ha, and had risen to 3,815,000 ha by 2004 (Nguyen Sinh Cuc, 2005, cited in Viet Nam EPA (2005)). Overall, areas of rice field in the LMB have declined from 14,244,611 ha in 2003 to 13,920,505 ha in 2009 (IKMP, 2015)
	Area of aquaculture	Aquaculture made up 2.1% of total LMB wetland area in 2003, mainly in the southwest of the Delta and coastal areas to the east (MRC, 2011 based on 2003 data). Area of aquiculture increased by 64% between 2003-2010 (IKMP, 2015). The area devoted to aquaculture in Thailand has increased more than three-fold since 1995 (MRC, 2010a)

2.2.2 State of, and trend in, wetland health and function by provisioning service

As wetlands are identified as providing resources and livelihoods for people throughout the region, one way to evaluate the extent of any change in health and function of wetlands is by the ongoing availability of the wetland resources upon which people depend. Possible indicators include the change in fish and OAA catch over time and the consumption of fish by local communities (taking into account sources and imports/exports to the area), the change in harvest of other biota used for food or trade, the change in harvest of non-timber forest products, particularly fuel wood, and the change in the accessibility of medicine from natural products (as shown in ***Table 2-9***). With both rice paddies and aquaculture ponds falling under the definition of wetlands, yields of rice and aquaculture production should also be a consideration in developing indicators of the provisioning capacity of the overall wetland resource. In both cases, ideally the better indicator would be trends in rice and aquaculture production based on sustainable criteria (e.g. production per unit of input – water, fertiliser, chemicals and, for aquaculture, feedstocks). Data for aquaculture production in Thailand and Viet Nam are shown in ***Figure 2-3***.

Despite survey results from SIMVA data which indicate a reduction in catch per unit of effort and reduced quantity of fish and OAA caught, an integrated review of fish catch data from the Tonle Sap *dai* fishery and the *li* fishery at Khone Falls illustrated that there was no significant reduction in species abundance, richness or biomass between 1997 and 2010 (Halls *et al*., 2013). Baran and Myschowoda (2008) in their examination of the Tonle Sap fishery suggest that although overall fisheries production has increased over the years, rather than declined as many people assume, the amount of fish caught per fisher has declined due to increasingly intense competition. Baran *et al*. (2005) highlight some of the challenges of discovering inter-annual trends in such species diverse fisheries with so many different catch methods used.

Information on the harvest of other wetland biota is difficult to come by, although it is often reported that many species that are hunted and harvested are in decline (e.g. Birdlife International, 2003). Much more attention needs to be given to the harvest of OOA from rice fields since this can be significant and is often under reported. This would also be a useful indicator of the sustainability of rice production (since unsustainable rice farming practices reduce or eliminated this important co-benefit of rice paddy systems). Of 60 wetland species in the LMB that are threatened 37 identify hunting or harvesting pressure as a key reason for population decline (***Annex 3***). The harvest of timber and fuel wood products, the latter which is more relevant specifically to wetlands, is said to be declining across the Basin. The reduction in fuel wood consumption may be a reason for the increase in the area of flooded forest in recent years (as shown in ***Table 2-9***).

The decline in rattan availability due to its importance as a non-timber forest product is also a potential indicator of the reduction in provisioning services of wetlands. However, as rattan grows in non-wetland forested areas as well the health of this resource in forested wetland areas relative to other forested areas is not clear.

The decline in many of the species that provide traditional medicines (e.g. giant water bugs, otters, turtles and tortoises) indicates that the capacity of wetlands to continue to provide this service is reducing.

Hydropower, technically, is also a provisioning service provided by wetlands (which includes rivers). Trends in installed hydropower capacity would be an indicator of increases in this service but also an indicator of the potential negative impacts of hydropower on other ecosystem services.

Table 2-9: Potential indicators of the state and trend of some provisioning services provided by wetlands

Resource/ function	Indicator	Evidence/data
Food from fish and other aquatic biota	Fish and OAA catch levels Species abundance, biomass and richness	Comparisons with earlier data [for the Tonle Sap *dai* fishery] suggest a reduced proportion of larger species in recent catches (Halls and Paxton 2010, cited in MRC, 2010a). However, there was no apparent trend in species richness, abundance or biomass between 1997 and 2010 for Tonle Sap *dai* fishery, and no significant trend in fish biomass migrating upstream at Khone falls between 1997 and 2009 (Halls *et al*. 2013)
	Catch per unit of effort	No long-term trend is evident in the catch per unit effort data for the *li* trap fishery or the gill net fishery near Khone falls in Laos, despite the general opinion expressed by many fishers that catches are declining (MRC, 2010a) In the Thai part of the LMB commercial catches show an increase of about 45% over the period 1995–2007, which may be a result of an increasing number of large waterbodies, increasing fishing pressure and improvements in data collection (MRC, 2010a). The data do not support the view that there is a general decline in catches [riverine capture fisheries], but for any definitive conclusion on trends a much longer period of record is required (MRC, 2010a). Hong and San (1993) report a decline in mud crabs, shrimp post-larvae abundance, and shrimp yields due to acidification of ponds associated with mangrove removal.
Agriculture/rice /aquaculture	Rice yields	Rice yields in the LMB range from 1.0 to more than 5.0 t/ha, with the highest yields in the delta region of Viet Nam, moderate yields in some parts of Lao PDR and the Viet Nam highlands and the lowest yields in Cambodia and northeast Thailand (MRC, 2010a); In all regions, productivity increased from 1993 to 2004, with the increase being more prominent in Lao PDR and Viet Nam. For Cambodia and Thailand, the yield has been more or less consistent since 2000 with slight variations from year to year (MRC, 2010a)
	Aquaculture production	In Viet Nam, 1.9 million tonnes in 2008 – five-times the production in 2000 (MRC, 2010a). Aquaculture production has increased significantly in both Thailand and Viet Nam (MRC, 2010a). In Lao PDR, FAO statistics indicate a steady increase in total national aquaculture production from 12,900 tonnes in 1995 to 78,000 tonnes in 2005. Aquaculture in Cambodia was officially estimated as 35,000

Resource/ function	Indicator	Evidence/data
		tonnes in 2007 (MRC, 2011) although field surveys found production in 2004 was about 60–80,000 tonnes, about twice as much as official estimates (So and Haing, 2007, cited in MRC, 2010a).
Non-timber forest products (including for construction, tools and handicrafts)	Populations and harvest rates of other biota used for food or trade	Populations of all large species of open habitats (e.g. the fishing cat, several species of otter) have declined (Birdlife International, 2003). As a result of extensive habitat degradation and high exploitation, a number of mammal species within the basin are considered rare (MRC, 2010a)
	Availability and harvest of non-timber forest products	MRC (2010a) reports that rattan is the most important internationally traded NTFP, although Asian rattan resources are diminishing due to overexploitation and forest loss and few countries still have significant stocks. In Thailand, Viet Nam, Lao PDR and Cambodia, the long-term sustainability of rattan-processing industries has been undermined by unsustainable harvesting. Due to diminishing supply, Thailand has banned harvesting of rattan in natural forest and export of rattan in its raw form (DNP 2009, cited in MRC, 2010a). Based on field surveys, declines in the availability of wild NTFP resources including wildlife, fish and rattan products in Lao PDR are reported in Foppes and Ketphanh (2000).
Fuel wood and timber	Area of seasonally inundated forest Remaining natural forest Rate if timber extraction and fuel wood consumption	Area of seasonally inundated forest has increased significantly between 2003 and 2009 (IKMP, 2015) despite overall reductions in forested area between 2000 and 2005 in Cambodia (-2%); Lao PDR (-0.5%); and Thailand (-0.4%); offset by an increase in Viet Nam (2%) (FAO, 2005a, cited in MRC 2010). Only 17% of natural forest remaining is 'primary forest' as defined by FAO (2005a). Commercial logging and fuel wood consumption is declining across the LMB countries with fuel wood consumption forecast to continue to decline to 2020 (MRC, 2010a). Overharvesting of high value [timber] species and breaking of cutting cycles to extract newly marketable species have left stocking densities low and ecosystem composition greatly altered. High impact and excessively heavy logging has also damaged remaining stands and reduced the commercial viability of production forests (MRC, 2010a).
Medicines	Availability of medicines and biota from which medicines are derived	Huge demand for wildlife for ….medicine,… particularly from China, has led to increased trafficking and many wildlife species with high commercial value are now rare, endangered or locally extinct – including the tiger, Asian elephant, freshwater turtles and tortoises, agarwood and numerous wild orchid species (MRC, 2010a) All otter species are under heavy threat by the local demand for skins and for use in traditional medicine (Campbell *et al*. 2006, cited in MRC, 2010a)

Resource/ function	Indicator	Evidence/data
		The giant water bug is also used as traditional medicine; mixed with alcohol it is given to women after birth (Balzer *et al*. 2005). Due to high levels of pesticides and fertilisers used in agriculture in Thailand giant water bug catches have greatly declined and so they are imported from Cambodia, where they are still common (Balzer *et al*. 2005, cited in MRC, 2010a)

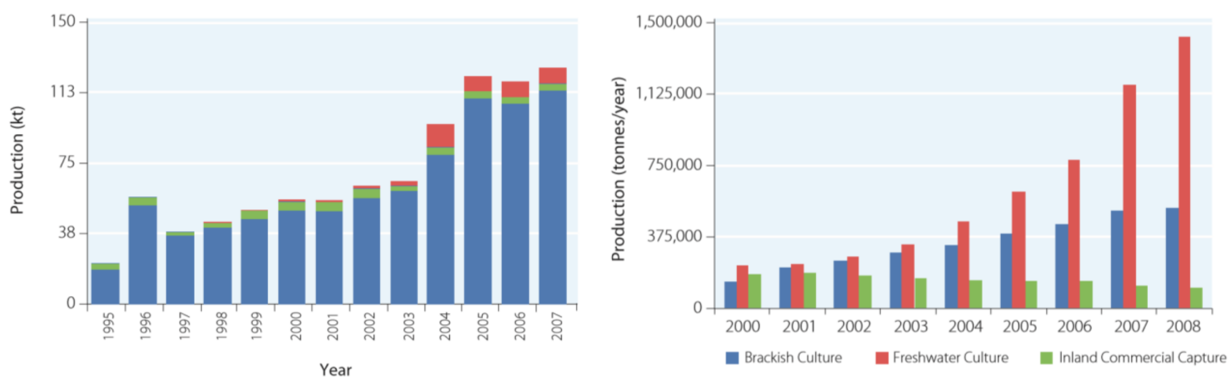


Figure: 2-3: Aquaculture production in Thailand and Viet Nam. (*Source: MRC, 2010a)*

2.2.3 State of, and trend, in wetland health and function as indicated by regulating services

Regulating services are a particularly important ecosystem service provided by wetlands in the Mekong, whether this is groundwater recharge ensuring availability of supply through the dry season, flood regulation by absorbing and controlling the release of the annual flood, or the removal of pollutants through natural wastewater treatment, particularly in wetlands close to urban areas (e.g. That Luang Marsh in Vientiane). However, systematic quantified indicators of these functions are for the most part not available.

There are no comprehensive data or evidence available across the whole of the Basin on rates of groundwater recharge or the state of the groundwater resource itself. However, it has been reported that groundwater recharge in the delta region has declined (IUCN, 2011) due to the conversion of wetlands for agricultural production, and the removal of mangroves has exposed many areas to increased erosion. It has not been possible to identify how widespread these impacts on groundwater are. However, there are reports of increased coastal erosion in the Mekong Delta (Cat *et al*., 2006).

In terms of pollutant removal, while there is no data specifically on the extent of improved water quality in the LMB due to wetlands, water quality overall remains relatively good (MRC, 2010a) despite some signs that some measures are deteriorating (MRC, 2011). Total phosphorus and Ammonium levels, and to a lesser extent Chemical Oxygen Demand (COD), increased between 1985 and 2011, while Nitrate-Nitrite remained relatively constant (Ly and Larsen, 2012). The level of pollutants in off-river wetlands needs further examination.

The regulating of floods by wetlands is a difficult parameter to measure because flood behaviour in particular locations can be so variable from one year to the next, depending on the major drivers of flooding in that year (MRC, 2010a). The cost impact of floods is a very imprecise indicator because of the interaction of complex socio-economic factors in different locations. The overall capacity of wetlands to regulate floods is perhaps best indicated by the overall wetland area available for that purpose (as shown in ***Table 2-10***).

Table 2-10: Potential indicators of the state of, and trend in, some regulating services provided by wetlands

Resource/ function	Indicator	Evidence/data
Water regulation (e.g. flood control)	Flood magnitude, frequency and extent	As noted earlier, changes in overall flood hydrology of the Basin have not been definitively determined. However, it has been reported that floodwater storage in the delta region has been reduced by the reduction in wetlands (Van Ni *et al*. 2003). Storm or flood damage has been very severe since 1996 (Voice of Viet Nam, 1998; Van Ni *et al*. 2003).
	Annual cost of flooding	The average annual cost of flooding in the LMB is $60-70 million (MRC, 2010a). However, changes in this figure will be strongly affected by changes in socio-economic circumstances.
		Large-scale conversion of wetlands for agricultural production has led to a dramatically altered hydrology (Hashimoto, 2001; Hung *et al*., 2000; White, 2002), which has altered the recharge pattern of the delta's aquifers (the amount of water entering the aquifer).Winter *et al*. (1998) explains how draining wetlands increases the volume of runoff, reducing the amount of groundwater recharge and increasing the frequency of downstream flooding. Water resources management since the 1990s has further affected supply through the construction of dykes and creation of polders that have blocked the natural water flow and reduced groundwater recharge. This is especially significant for the Vietnamese section of the Plain of Reeds where important recharge areas exist for the heavily used Pleistocene aquifers (IUCN, 2011).
Groundwater recharge	Groundwater level and quality	Decline in groundwater levels in parts of the delta caused by a reduction in the volume of water in the aquifer system from extensive drainage, exploitation, and the interception of recharge waters; and decline in groundwater quality caused by urban, industrial, and rural pollutants, and the concentration of natural

Resource/ function	Indicator	Evidence/data
		contaminants and salt water intrusion caused by excessive pumping of groundwater reserves (IUCN, 2011) Groundwater levels in Ca Mau have fallen by as much as 10 m since 1995 (Phuc, 2008, cited in IUCN, 2011)
Removal of pollutants/ Waste treatment	Water quality (Nitrates, Phosphates, Ammonium, DO, COD)	No data for the impact or capacity of wetlands specifically. However, Human Impact on water quality scores based on monitoring in the Mekong River mainstream shows a deterioration in water quality. In 2003 four sites were classed as A – 'No impact' while in 2008 only one site was classed as A. In 2003 no sites were classed as D – 'Severe Impact' while in 2008 4 sites were classed as D (MRC, 2011). Ecological Health monitoring in the Mekong and Bassac Rivers suggests that water quality to support biodiversity and aquatic life is still very good. Of 22 stations sampled, all but four were rated as good or excellent (Ly and Larsen, 2012). It is not clear that this situation extends to off-river wetlands. Despite 17 stations being rated as either "impacted" or "severely impacted" by human activities in 2011, all but 2 stations are rated as "excellent" for the protection of aquatic life. My Tho and Can Tho are the last monitoring stations on the Mekong River and the Bassac River, respectively. These two stations were still rated as "good" for the protection of aquatic life. The slight impairment at these two stations was attributed to both the elevated total phosphorus concentrations and salinity intrusion, causing elevated electrical conductivity levels (Ly and Larsen, 2012). Compared to previous years, nutrient levels increased slightly in 2011 with total phosphorus (from a mean of 0.09 to 0.12 mg/L) and ammonium levels (from a mean of 0.05 to 0.06 mg/L) showing increasing trends in the Mekong River from 1985 to 2011 while the nitrate-nitrite levels remain relatively constant. While dissolved oxygen levels remained relatively constant from 1985 to 2011, chemical oxygen demand increased slightly during the same time frame (Ly and Larsen, 2012). Fluxes of total inorganic nitrogen and total phosphorus have increased between 1985 and 2005, nitrogen more so than phorphorus (Liljeström *et al.*, 2012).

Resource/ function	Indicator	Evidence/data
Erosion and natural hazard protection	Rate and extent of coastal erosion	Mangrove removal and degradation exposes the delta to increased erosion impacts from sea-level of rise and storm surges (MRC, 2015a). Area of mangroves has declined significantly (as shown in ***Table 2-8***). There has been an increase in coastal erosion in the southern region of Viet Nam around the Mekong Delta. Between 1992 and 2002 the number of areas experiencing coastal erosion increased by 10 (Cat *et al*., 2006).

2.2.4 State of, and trend in, wetland health and function as indicated by cultural services

Cultural services provided by wetlands include spiritual, religious and cultural values and educational, training and recreational opportunities. These services are potentially indicated by the amount of remnant natural landscapes available, including the presence of 'iconic species' such as the Mekong Giant Catfish, the Irrawaddy Dolphin, the Siamese Crocodile and the Sarus Crane. As these species and the availability and accessibility of natural landscapes declines, the connection that people have with these places is likely to be diminished.

To the extent that the protected area estate is likely to encompass areas that maintain relatively intact wetland values this is also a potential indicator of the potential for cultural services from wetlands. At the time of writing it was not clear how much of the total wetland area was included in the protected estate in 2003. Approximately 22% of wetland area in the LMB is natural wetland. However, this is a relatively imperfect measure of cultural services due to the cultural significance of many artificial landscapes (e.g. rice paddies).

Table 2-11: Potential indicators of the state of, and trend in, some cultural services provided by wetlands

Resource/ function	Indicator	Evidence/data
Spiritual, religious, cultural and historical values	Area of remnant natural landscape	No information available, although clearly natural landscapes are in decline, as is the habitat for many iconic species. For instance the number of Siamese crocodiles, Sarus crane, soft turtle and others are decreasing in large part due to habitat destruction.
Aesthetic appreciation of natural features	Proportion of natural versus artificial wetland	22% of LMB wetlands are natural, compared to 78% artificial (MRC, 2015a).

Resource/ function	Indicator	Evidence/data
Educational, training and recreational opportunities	Habitat loss for iconic species	Of 60 threatened wetland species, 47 identify habitat loss as a key threat implicated in their decline (IUCN Red List). Of four iconic species (Irrawaddy Dolphin, Sarus Crane, Siamese crocodile and Mekong Giant Catfish), three were heavily impacted by habitat loss and degradation (Annex 3).
	Area of wetland within protected areas	To be confirmed from national data of MRC Indicator Framework (MRC IF)

2.2.5 State of, and trend in, wetland health and function as indicated by supporting services

Supporting services are those that are necessary for the production of all other ecosystem services (MEA, 2005). They differ from other services in that they do not always impact on people directly. Potential indicators include the availability of habitat in good condition and the level of wetland biodiversity (as shown in ***Table 2-12***). Indicators based on biodiversity though could be problematic because the full biological diversity of the region has not yet been completely documented (MRC, 2010a).

The overall wetland area in the LMB is in decline, indicating a reduced capacity for supporting services. There is also evidence that the habitat which remains is not in a very favourable condition, at least for birds (Birdlife International). Of 64 threatened species in the basin (IUCN Red List, ***Annex 2***), including fish, birds, mammals, amphibians and reptiles, 60 could be considered wetland species (***Annex 3***) and habitat loss is implicated in the population decline of all of them. 12 are critically endangered.

Table 2-12: Potential indicators of the state of, and trend in, supporting services provided by wetlands

Resource/ function	Indicator	Evidence/data
Habitat *Spawning and nursery grounds* *Store of genetic material*	Availability of habitat in good condition	See area of overall wetland resource by wetland type in ***Table 2-8***. 73% of Important Bird Areas that contain wetlands within the Mekong Basin were considered to have habitat condition which was very unfavourable or unfavourable, based on monitoring between 2007 and 2013. See table below. 47 of 60 threatened wetland species identified habitat loss or

Resource/ function	Indicator	Evidence/data	
		degradation as a key reason for population decline (***Annex 3***).	
	Biodiversity – No. of threatened species	Fish	• 1,500 fish species in the Basin (MRC, 2003) • 5 critically endangered, 6 endangered and 2 vulnerable species (MRC, 2010a); • No apparent decline in fish species identified on IUCN Red List (Halls *et al*., 2013)
		Birds	• 2,800 bird species in the Basin (MRC, 2003); • Wetland birds declined over last 50 years (24 wetland birds seriously declined) (MRC, 2003); • Reduction in bird population and extinction of some species in the region (MRC, 2010a); • 3 Critically endangered, 6 Endangered and 10 vulnerable species (MRC, 2010a); • Surveys by RJ Safford between 1996 and 1998 failed to locate several rare waterbird species such as Giant Ibis, Milky Stork, and Greater Adjutant previously known in the Delta (Duc, 1989), (Van Ni *et al*. 2003)
		Amphibians	• 250 amphibian species in the Basin (MRC, 2003); • 0 critically endangered, 1 endangered, and 10 vulnerable species (MRC, 2010a); • 91 new species of amphibian have been described within the Greater Mekong region since 1997 (Thompson 2008, cited in MRC, 2010a)
		Reptiles	• 650 reptile species in the Basin (MRC, 2003); • 5 critically endangered, 4 endangered and 5 vulnerable species (MRC, 2010a); • some previously-abundant species such as box turtles are now considered vulnerable (MRC, 2003) • Sophisticated hunting and trading practices have destroyed local populations and removed species from large areas of the Mekong Basin (Bezuijen et. al. 2008, cited in MRC, 2010a); • 46 lizards join the ranks of the Greater Mekong's known reptile species. In 2007, four new gekko species were recorded in forests in southern Viet Nam (Grismer and Van 2007); • 19 species of freshwater turtles, tortoises, and marine turtles collected in Lao PDR, Cambodia, and

Resource/ function	Indicator	Evidence/data
		Viet Nam (Stuart and Platt, 2004, cited in MRC, 2010a).
	Plants	• Total vascular plant diversity may be as high as 20,000 species, with conservative estimates suggesting that about 50% of flowering and seed-bearing plants are endemic to the region (MRC, 2010a); • Thirty-five species of wetland plants used for medicinal purposes were recorded in the community of Prek Sramaoch on Tonle Sap Great Lake (Mcdonald and Veasna 1997, cited in MRC, 2010a); • Decline in habitat areas (Nhan, 1997) has caused declines in valuable species such as Wild Rice, such that valuable genotypes have almost certainly been lost (Van Ni *et al*. 2003)
	Mammals	• 830 mammal species in the Basin (MRC, 2003); • Mammal populations kept low by hunting pressure; 70 endemic mammal species (MRC, 2010a); • 1 Critically endangered, 4 endangered and 2 vulnerable (MRC, 2010a) with one species changing category since 2003 (Irrawaddy Dolphin previously considered endangered); • the fishing cat (*Prionailurus viverrinus*), is considered globally endangered due to its dependence on wetlands, also due to human overexploitation of local fish stocks (MRC, 2010a)
	Invertebrates	Due to high levels of pesticides and fertilisers used in agriculture in Thailand giant water bug catches have greatly declined and so they are imported from Cambodia, where they are still common (Balzer *et al*. 2005, cited in MRC, 2010a) Bio monitoring using invertebrates based on paramaters such as species richness, abundance and an average tolerance score per taxa shows some declines and some improvements in ecological health at different monitoring sites with no geographic trend across the basin. The number of sites that improved from 2008 to 2011 was greater than the number that declined (Cheng *et al.*, 2014).

2.2.6 State of, and trend in, wetland health and function as indicated by condition and extent of environmental hotspots

About 32 environmental hotspots covering wetland areas have been identified in the LMB (MRC 2010b; National Environment Administration of Viet Nam, 2011). These are ecologically sensitive areas of national, regional or international significance containing rich biodiversity, a large number of important species at risk and areas important for migrating species or supporting key ecological processes (MRC 2010b). They include 10 Ramsar sites, 3 Biosphere Reserves, 12 Protected Areas, 29 Important Bird Areas (IBAs) and 4 Greater Mekong Region Sub-region (GMS) hotspots (as shown in ***Figure 2-4*** and ***Table 2-13***).

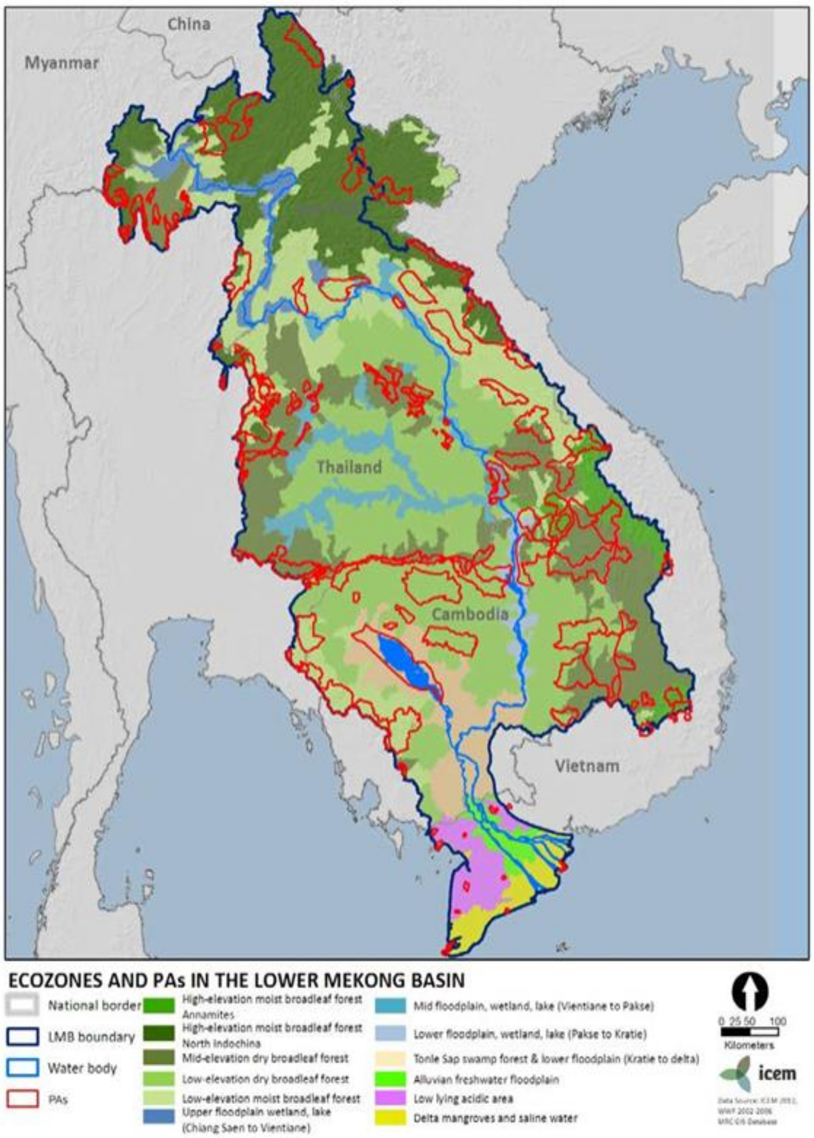


Figure 2-4: Location of protected areas in the LMB. (*Source: MRC, 2010b*)

Table 2-13: Location and status of the 32 identified environmental hotspots

Country	Number	Status				
		RS	BR	PA	IBA	GMS
Shared by >1 country[1/]	4			1	2	1
Lao PDR[1/]	5			1	5	
Thailand[1/]	4	3		3	3	
Cambodia[1/]	13	3	1	5	13	3
Viet Nam[1/, 2/]	6	4	2	2	6	
TOTAL	**32**	**10**	**3**	**12**	**29**	**4**

Remark: ***RS = Ramsar Site, BR = Biosphere Reserve, PA = Protected Area, IBA = Important Bird Area, GMS = Greater Mekong Sub-region Hotspots***

Source: [1/] ***MRC, 2010b***
[2/] ***National Environment Administration of Viet Nam, 2011***

Ramsar sites

Based on 2012-2015 national reporting to the Ramsar Convention (as shown in ***Table 2-15***), the condition of Ramsar sites is not reported to have changed significantly for any country. Only Thailand and Viet Nam though have undertaken a survey in recent years. Lao PDR reported that wetlands generally are in decline.

Based on a review of Ramsar Information Sheets for listed wetlands, only Cambodia has reported significant environmental deterioration, when it updated its RIS for its two Ramsar sites in 2009 (as shown in ***Table 2-16***). No other country has provided an update since the time of listing.

Table 2-15: Reported change in condition of Ramsar sites and wetlands generally

Country	Reported change in condition of Ramsar sites & wetlands generally
Cambodia	No change reported. Land use conversion for agriculture and residential developments continuing.
Lao PDR	No change to Ramsar sites, but wetlands generally reported as being in decline due to infrastructure development & agriculture
Thailand	No change reported. Results of 2014 survey of Ramsar sites not yet available.
Viet Nam	No major changes of Ramsar sites reported, based on a 2013 survey.

Table 2-16: Evidence of change as reported by countries updating Ramsar Information sheets for designated Ramsar wetlands.

Ramsar Site	Comments on change in condition or existing threats
Boeng Chhmar and Associated River System and Floodplain (Cambodia)	A decline in fish populations and increased pressure on resources including wildlife collection and wood collection. More frequent dry season fires, generally deliberately lit for hunting or land clearing, caused a precipitous decline in the site's ecological character, revealed by gradual landscape modification from tall forest to grasslands and shrublands. However no detailed survey about this impact has been done in this Ramsar Site so far (RIS, 2012).
Middle stretches of the Mekong River north of Stoeng Treng (Cambodia)	High loss rate of gallery and semi- evergreen forest is continuing. Riverbanks in poor condition. Algal blooms increased in some locations. Fire and exploitation of wildlife are continuing issues. The RIS also notes that the ecosystems of the Mekong and its tributaries will undoubtedly be seriously affected by upstream dams (already existing ones and such being in the planning phase). The change of the rivers hydrological system through dams will dramatically damage the still existing fish populations with very disastrous effects for the livelihood situation of the human communities along the rivers which depend to a very large degree on the protein and income generated through fishing those rivers (RIS, 2012).
Xe Champhone (Lao PDR)	No update available. Pressures reported include: conversion to agriculture, pollution from fertilizers and pesticides, changed hydrological regime, poaching of important species, grazing pressures (RIS, 2009).
Beung Kiat Ngong Wetlands (Lao PDR)	No update available. Pressures reported include: peat extraction, over-exploitation of aquatic resources, grazing pressure, conversion to rice paddies (RIS, 2009).
Nong Bong Kai non-hunting area (Thailand)	No update available. Pressures reported include: residential and tourist developments in the surrounding area (RIS, 2001).
Kut Ting Marshland (Thailand)	No update available. Pressures reported include: overfishing, fertiliser and pesticide pollution, grazing pressures, hunting (RIS, 2007).
Bung Khong Long non-hunting area (Thailand)	No update available. Pressures reported include: fishing, hunting, burning of habitat (RIS, 2001).
Lang Sen Wetland Reserve (Viet Nam)	No update available. Pressures reported include: infrastructure development, invasive species, and overexploitation of resources (RIS, 2015)
Tram Chim National Park (Viet Nam)	No update available. Pressures reported include: hunting, poisoning and disturbance of birds, invasion of exotic plant species, fire, changes to hydrology, encroachment and overexploitation of aquatic resources (RIS, 2012).

Ramsar Site	Comments on change in condition or existing threats
Mui Ca Mau National Park (Viet Nam)	No update available. Pressures include: encroachment and conversion of mangrove to aquaculture, afforestation of disused agricultural areas by trees, illegal fishing, mangrove cutting, over-exploitation of wetland resources (RIS, 2012).

Important Bird Areas

Based on a review of the Important Bird Areas in the LMB that are likely to contain wetland areas (i.e. wetland habitat was specifically identified in the descriptor in the Birdlife International database), 73% of sites assessed were identified by Birdlife International monitoring between 2007 and 2013 as having habitat condition that was either 'very unfavourable' or 'unfavourable'. Only 14% had habitat which was considered favourable (as shown in ***Table 2-17***).

Table 2-17: Numbers of Important Bird Areas that are likely to contain wetland areas within the Lower Mekong Basin, as assessed by Birdlife International for level of threats, condition of habitat and extent of response measures. Sites included are listed in *Annex 5*.

Threats			Condition			Response		
Very high	7	18%	**Very unfavourable**	9	41%	**Negligible**	14	36%
High	19	49%	**Unfavourable**	7	32%	**Low**	15	38%
Medium	12	31%	**Near favourable**	3	14%	**Medium**	6	15%
low	1	3%	**Favourable**	3	14%	**High**	4	10%
Not assessed	16		**Not assessed**	33		**Not assessed**	16	

Source: Birdlife International database (http://www.birdlife.org/datazone/site)

2.3 State of, and trend in, Responses to changes in wetland health and function

Evaluating the state and trend of country responses to changes in wetland health and function has been done based on a review of the overall policy and management framework for wetlands within the respective LMB countries (as shown in ***Table 2-18***).

Following the entry into force of the Ramsar Convention in Lao PDR in 2010, all countries have now signed and ratified all four of the key international conventions related to wetland issues: the Ramsar Convention, the Convention on Biological Diversity (CBD), the United Nations

Framework Convention on Climate Change (UNFCCC) and the World Heritage Convention. Each country has at least two Ramsar sites of international importance listed.

Table 2-18: Overview of key policy and management context for wetlands within LMB countries

	Cambodia	**Lao PDR**	**Thailand**	**Viet Nam**
Relevant International Agreements signed and ratified				
Ramsar Convention	1999	2010	1998	1999
Convention on Biological Diversity	1995	1996	2004	1995
United Nations Framework Convention on Climate Change	1996	1995	1995	1995
World Heritage Convention	1991	1987	1987	1987
Legislation and overall policy authority[2]	No specific legislative authority National Wetlands Policy planned but not yet in place	No specific legislative authority National Wetlands Policy planned but not yet in place	No specific legislative authority Cabinet decision (2000) on the designation of internationally and nationally important wetlands and conservation Cabinet decision (2009) on improved measures for wetland conservation at all levels	Water Resources Law No. 17 (2012) Law on Land No. 45 (amended 2013) Decree on wetlands conservation and sustainable development (2003)
Related legislation/policy	Law on Environmental Protection and Natural Resource Management (1996) and Sub-decree on Environmental Impact Assessment Process (1999) and Draft Law on Environmental Impact Assessment	National Law on Water Management (under revision to include consideration of Ramsar Convention)	Enhancement and Conservation of National Environmental Quality Act (1992)	Law on Environmental Protection (2005) and Decree providing Strategic Environmental Impact Assessment, Environmental Impact Assessment and Environmental Protection Commitment (2011)
Ministries primarily responsible for wetland issues	Ministry of Environment Ministry of Agriculture, Forestry and Fishery Ministry of Water Resources and Meteorology	Ministry of Natural Resources and Environment	Ministry of Natural Resources and Environment	Ministry of Natural Resources and Environment Ministry of Agriculture and Rural Development
Lead agency on wetland issues	Department of Wetlands and Coastal Zones	Department of Environmental Quality Promotion	Office of Natural Resources and Environmental Policy and Planning	Viet Nam Environment Administration
Cross-sectoral governance	National committee planned but not yet in place	National Ramsar Steering Committee	National Committee on Wetland Management (1993)	No national Ramsar committee
System of development approvals considering environmental impacts	Yes. EIAs required to consider impacts on the environment	Yes. 2010 Prime Minister's decree on EIA	Yes. Both EIA and SEIA for potential impacts on wetlands of national or international importance (2009 Cabinet Decision)	Yes. Law on EIA amended in 2014 to include SEIA
System of protected areas/conservation **Categories of protected area relevant to LMB wetlands**	National Parks Wildlife Sanctuaries Multiple-use areas Fish Sanctuaries Protected Forests	National Biodiversity Conservation Areas including: - Protection Forest - Conservation Forest	National Parks Wildlife Sanctuaries Non-hunting areas Biosphere Reserves Class I Watersheds National Environmental Conservation Areas	Special-use forests covering: - National Parks (since 1962) - Nature Reserves - Cultural, Historical and Environmental Sites
Major planning instruments that consider the wise use and sustainable development of wetlands	Cambodia Wetlands National Action Plan 2005 [for coastal wetlands] Cambodia National Strategy and Action Plan 2014-16 – Mangroves for the Future [for coastal wetlands]	None identified	Wetland Management Plan included in NBSAP (2008-2012) under CBD Draft Master Plan on integration of biological diversity management (2013-2021) under CBD included wetland issues Draft Action Plan on Biodiversity Management (2016-2020)	National Environmental Protection Strategy to 2020 (vision to 2030) National Action Plan on Environmental Protection Strategy to 2020 (vision to 2030) National Biodiversity Strategy to 2020 (vision to 2030)

[2] Meaning there is a specific instrument of government (e.g. a law, a decree, a policy statement) that provides the overall policy direction and mandate for the sustainable management of wetlands in the country

	Cambodia	Lao PDR	Thailand	Viet Nam
			National Strategy on Climate Change Management (2008-2013) Draft Master Plan on Climate Change (2013-2050) National Economic and Social Development Plan (2012-2016) Measures on the Prevention, Control and Eradication of Invasive Alien Species (2009 Cabinet Decision) Draft National Action Plan on Wetland Management in the Gulf of Thailand under the UNEP/GEF SCS project 2004	Master Plan on Biodiversity Conservation to 2020 (vision to 2030) Management Strategy on System of Special-use forests, marine and inland waters protected areas to 2020 (vision to 2030) Poverty Reduction Strategy 2012-2015 Decision of the Prime Minister No. 182 (2014) approving national action plan to enhance management efficiency and protection using integrated water resources management (2014 to 2020) Decision of the Prime Minister No. 1896 (2012) approving the scheme on the prevention and control of invasive alien species to 2020
Key national/regional-scale conservation programmes /projects implemented	'Lower Mekong Basin Wetland Management and Conservation' (proposed KfW funded project)	'Lower Mekong Basin Wetland Management and Conservation' (proposed KfW funded project) 'Climate Change Adaptation in Wetland Areas' (proposed project with FAO/IUCN)	'Maximising Carbon Sink and Conserving Biodiversity through Sustainable Conservation, Restoration, and Management of Peat-Swamps Ecosystem' (GEF funded project) 'Lower Mekong Basin Wetland Management and Conservation' (proposed MRC-KfW funded project)	'Lower Mekong Basin Wetland Management and Conservation' (proposed MRC-KfW funded project)
Communication, Education, Participation Action (CEPA) plans that include wetland issues	No plans in place Two sites have visitor centres for ecotourism	No plans in place Plan for information/ education centre at one site	The Implementation Guidelines on CEPA in response to the United Nations Decade on Biodiversity (2011-2020) Learning or information centres established at 14 Ramsar sites and 15 other wetland sites	Yes. A range of activities implemented Learning or information centres established at 8 sites

No country has legislation specifically targeted at wetlands. However, wetland issues are identified in both Viet Nam's Water Resources Law and Land Law, which are supported by a decree on wetlands conservation and sustainable development. Thailand has a national policy elicited in cabinet decisions from 2000 and 2009. Neither Cambodia nor Lao PDR has a specific national wetlands policy, although various regional policies and strategies exist. For example, Cambodia has a Wetlands National Action Plan to address issues associated with its coastal wetlands developed under the UNEP/GEF South China Sea Project, as well as a National Strategy and Action Plan 2014-16 to address the decline in Mangroves. Neither of these is targeted at wetlands in the LMB.

All countries have a system of Environmental Impact Assessments in place in order to assess the potential impacts of development projects on the environment including wetlands; and all countries have a system of protected areas within which areas of wetland are included.

Thailand and Viet Nam appear to more advanced in the implementation of planning instruments and projects that include consideration of the sustainable development of wetlands. These include biodiversity strategies and action plans, climate change adaptation strategies and plans, plans for the control and eradication of invasive species and poverty reduction plans.

Based on national reporting to the Ramsar Convention five potential response indicators were selected to illustrate the trend in country action to conserve and sustainably manage wetlands. These are, whether or not the country claimed to have:

(i) a comprehensive wetland inventory;
(ii) a national wetland policy;
(iii) incorporated wetland issues into other national strategies and planning processes;
(iv) whether or not it claimed to have environmental impact assessment or strategic environmental impact assessment processes in place that consider wetlands;
(v) policies or strategies that enhanced the role of wetlands in mitigating or adapting to climate change;
(vi) a national strategy for further designation of Ramsar sites.

As is evident in ***Tables 2-19*** to ***Table 2-23***, over time countries are gradually implementing more and more of these response measures. In 1999 Viet Nam had met one of these indicators fully (ii) and one partially (iv), Thailand had met four fully (i, ii, iii, iv) while Lao PDR and Cambodia had not met any. By 2015 (or 2012 in the case of Cambodia), Thailand and Viet Nam had met all of these indicators, Lao had met two (i, iii) and Cambodia had met three fully (iii, iv, vi) and one partially (v). Note that this information is based on country self-reporting to the Ramsar Convention and is not necessarily up-to-date and complete. It is known for instance the Lao PDR does have a system of EIA which includes consideration of potential impacts on wetland areas, despite its national report not identifying this. In addition, Cambodia's national climate change strategy 2014-2023 identifies a key objective being to ensure climate resilience of critical ecosystems including Tonle Sap and the Mekong River.

Table 2-19: Response indicators from national reporting to the Ramsar Convention by Cambodia

2015 Question No.	Indicator	1999	2002	2005	2008	2012	2015
1.1.1	Existence of comprehensive wetland inventory		x		x	x	
1.3.1	Existence of national wetland policy		x		x	x	
1.3.3	Wetland issues incorporated into other national strategies and planning processes		☑		-	☑	
1.3.4; 1.3.5	Strategic Environmental Impact Assessments or Environmental Impact Assessments consider impacts on wetlands		☑		x	☑	
1.7.5	Existence of policies or strategies to enhance the role of wetlands in mitigating or adapting to climate change		-		-	∞[3]	
2.1.1	National strategy for further designation of Ramsar sites		-		☑	☑	

☑ = fully met; ∞ = partially met; x = not met

Table 2-20: Response indicators from national reporting to the Ramsar Convention by Lao PDR

2015 Question No.	Indicator	1999	2002	2005	2008	2012	2015
1.1.1	Existence of comprehensive wetland inventory					☑	☑
1.3.1	Existence of national wetland policy					x	x
1.3.3	Wetland issues incorporated into other national strategies and planning processes					x	☑
1.3.4; 1.3.5	Strategic Environmental Impact Assessments or Environmental Impact Assessments consider impacts on wetlands					x[4]	x

[3] Cambodia's climate change strategy 2014-2023 has an objective to ensure climate resilience of critical ecosystems including Tonle Sap and the Mekong River

[4] Although not identified in Ramsar country reports and not specifically identifying impacts on wetlands, Lao PDR does have a system of EIA, based on a 2010 Prime Minister's decree.

2015 Question No.	Indicator	1999	2002	2005	2008	2012	2015
1.7.5	Existence of policies or strategies to enhance the role of wetlands in mitigating or adapting to climate change					x	x
2.1.1	National strategy for further designation of Ramsar sites					x	x

☑ = fully met; ∞ = partially met; x = not met

Table 2-21: Response indicators from national reporting to the Ramsar Convention by Thailand

2015 Question No.	Indicator	1999	2002	2005	2008	2012	2015
1.1.1	Existence of comprehensive wetland inventory	☑	☑	☑	☑	☑	☑
1.3.1	Existence of national wetland policy	☑	☑	☑	☑	☑	☑
1.3.3	Wetland issues incorporated into other national strategies and planning processes	☑	☑	☑	∞	☑	☑
1.3.4; 1.3.5	Strategic Environmental Impact Assessments or Environmental Impact Assessments consider impacts on wetlands	☑	☑	☑	x	☑	☑
1.7.5	Existence of policies or strategies to enhance the role of wetlands in mitigating or adapting to climate change	-	-	x	-	x	☑
2.1.1	National strategy for further designation of Ramsar sites	-	☑	☑	☑	☑	☑

☑ = fully met; ∞ = partially met; x = not met

Table 2-22: Response indicators from national reporting to the Ramsar Convention by Viet Nam

2015 Question No.	Indicator	1999	2002	2005	2008	2012	2015
1.1.1	Existence of comprehensive wetland inventory	x	X		x	x	☑
1.3.1	Existence of national wetland policy	☑	☑		☑	☑	☑
1.3.3	Wetland issues incorporated into other national strategies and planning processes	x	☑		∞	☑	☑
1.3.4; 1.3.5	Strategic Environmental Impact	∞	☑		∞	☑	☑

2015 Question No.	Indicator	1999	2002	2005	2008	2012	2015
	Assessments or Environmental Impact Assessments consider impacts on wetlands						
1.7.5	Existence of policies or strategies to enhance the role of wetlands in mitigating or adapting to climate change	-	-		-	∞	☑
2.1.1	National strategy for further designation of Ramsar sites	-	☑		☑	☑	☑

☑ = fully met; ∞ = partially met; x = not met

Table 2-23: 2012/2015 Ramsar Convention reporting by country in relation to Ramsar sites

	Reported change in condition of Ramsar sites & wetlands generally	Wetland restoration: (a) sites identified; (b) projects implemented	Ramsar sites within the Mekong Basin	Number of Ramsar sites with management plan: (a) in place; (b) being implemented	Ramsar site management effectiveness	New Ramsar sites planned
Cambodia[1]	No change reported. Land use conversion for agriculture and residential developments continuing.	(a) Planned (b) No	Number: 2 (i) Middle stretches of the Mekong River north of Stoeng Treng (ii) Boeng Chhmar and Associated River System and Floodplain	(a) 2 (b) 1	Assessment carried out. No further information provided.	(i) Prek Toal (ii) Stung Sen (both in Tonle Sap biosphere reserve)
Laos PDR[2]	No change to Ramsar sites, but wetlands generally reported as being in decline due to infrastructure development & agriculture	(a) No (b) No	Number 2 (i) Xe Champhone (ii) Beung Kiat Ngong Wetlands	(a) 1 (b) 1	No assessment carried out, but planning underway	None

	Reported change in condition of Ramsar sites & wetlands generally	Wetland restoration: (a) sites identified; (b) projects implemented	Ramsar sites within the Mekong Basin	Number of Ramsar sites with management plan: (a) in place; (b) being implemented	Ramsar site management effectiveness	New Ramsar sites planned
Thailand[2]	No change reported. Results of 2014 survey of Ramsar sites not yet available.	(a) Yes (2009 Cabinet list of important sites) (b) Planned	Number 3 (i) Nong Bong Kai Non-hunting area (ii) Kut Ting Marshland (iii) Bung Khong Long non-hunting area	(a) 3 (b) Unclear	Assessment carried out. Management standards drafted as a result.	None
Viet Nam[2]	No major changes of Ramsar sites reported, based on 2013 survey.	(a) Yes (b) Yes (mangrove restoration projects)	Number: 2 (i) Tram Chim National Park (ii) Mui Ca Mau National Park	(a) 2 (b) 2	Assessment carried out. No further information provided.	(i) Lang Sen protected area

Remark: [1] ***2012 Country report***
[2] ***2015 Country report***

Oh *et al*. (2005) undertook a review of wetland governance in the Mekong region. While some of this is now out-of-date it is expected that the main conclusions are at least in part still relevant. For instance, they identify key areas to address to improve wetland governance across all countries; in particular, the lack of clear definitions for wetlands, poor interagency coordination, the lack of a coherent national legal framework, and the need to incorporate non-use and indirect-use values in governance and management decisions.

3. Further details of the Methodology and Tool for Wetland Ecosystem Functions, Assets and Services Assessment and Management (WEFASAM) and the assessment, identification and development of indicators of wetlands importance and value

3.1 The purpose of wetlands inventory in the Lower Mekong Basin and role of the Methodology and Tool for Wetland Ecosystem Functions, Assets and Services Assessment and Management (WEFASAM)

The Wetland Inventory for the Lower Mekong River Basin is being continually developed with multiple purposes in mind. These take into account the need for information at multiple scales (local to basin-wide). A fundamental principle of the wetlands inventory activities supported by the MRCS is that improved wetlands relevant information is required from local through to national and to regional (basin) scale levels. Improved information is primarily of benefit to national governments (Member Countries of the MRC - MCs). There are considerable opportunities for MCs to pool resources and share information and experiences. In addition, a better standardized wetlands inventory system, one sensitive to the differing needs and capacities among the MCs, will enable wetlands information to be compiled at basin scale in order to better inform basin scale policies and management – to the benefit of all MCs.

The objectives of this process are to provide improved information including to:

i. provide core data/information on wetlands to support national level planning and management up-scalable to basin level including for:
    a. assessing the stock of wetland natural capital;
    b. assessing the importance of that capital for supporting local, national and regional sustainable development;
    c. analysis of long-term trends in wetlands and their natural resources;
    d. enabling the identification and regular revisions and updates of information on wetlands of national and international importance; and
    e. disseminating these analyses for wider consideration and use in sustainable development, including basin scale planning; and

ii. provide improved capacity for national level reporting to international conventions and treaties on wetlands, climate change, biodiversity, etc.

The Methodology and Tool for Wetland Ecosystem Functions, Assets and Services Assessment and Management (WEFASAM) is being developed to assist the generation of improved and standardised wetlands information in the Lower Mekong Basin (LMB). Document 2/2017 (*Technical Note on the Conceptual Framework for the Updated Methodology and Tool of Wetland Inventory (WI)*) further describes why an updated Wetlands Inventory for the LMB is needed and further outlines the needs for the updated Methodology and Tool. The same report also provides: an overview of previous wetland inventories and results in the LMB countries; an introduction to applying an inventory methodology in the LMB countries; and, an introduction to the conceptual framework for the updated Methodology and Tool of Wetland Inventory, including guiding principles, an integrated approach and key steps in the Wetland Inventory process.

This section provides further details of the concept of the Methodology and Tool for Wetland Ecosystem Functions, Assets and Services Assessment and Management (WEFASAM). This is to, in part, better inform indicator development so that indicators can be fit for purpose. It focuses in particular on approaches for providing improved assessments of wetlands based on their relative importance or values and introduces the topic of indicators for this. The next section (section 4) of this report outlines the framework for assessing and developing indicators related to the wetland inventory process.

3.2 Multiple approaches for wetlands inventory

There are many types of wetland assessment that can and should be used for different purposes and at different scales in support of assessments of wetlands as shown in ***Figure 3.1***. These, their purposes and the relationships between them have been summarised in the Ramsar Convention's Integrated Framework for Wetland Inventory, Assessment and Monitoring (IF-WIAM) available in Ramsar Resolution IX.1 Annex E. This resolution, and further guidance from the Ramsar Convention (Ramsar Convention Secretariat 2010) was used as a starting point for further developing the updated Methodology and Tool for Wetland Ecosystem Functions, Assets and Services Assessment and Management (WEFASAM) for the LMB. A key point being that the LMB Wetlands Inventory is ultimately designed to cover all wetlands in the LMB, not just those that might qualify under Ramsar Site Designation Criteria.

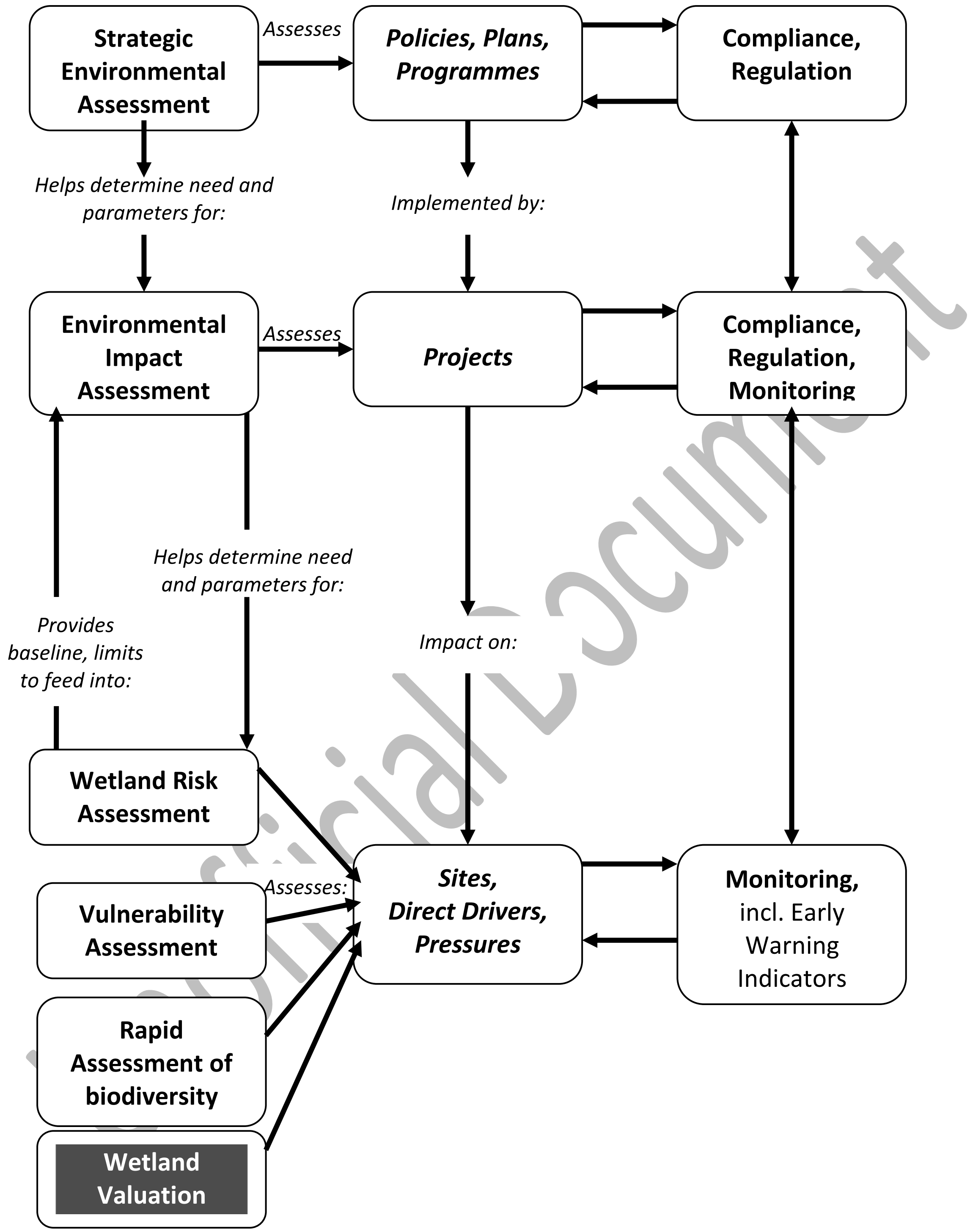


Figure 3-1: The relationships between various wetland assessment tools. (from Ramsar Resolution IX.1 Annex E).

3.3 Wetlands Inventory, Assessment and Monitoring

It is important to recognise the relationships between wetlands inventory, assessment and monitoring and these have particular implications for indicators. Using the Ramsar Convention definitions these are:

- *Wetland Inventory*: is the collection and/or collation of core information for wetland management, including the provision of an information base for specific assessment and monitoring activities.

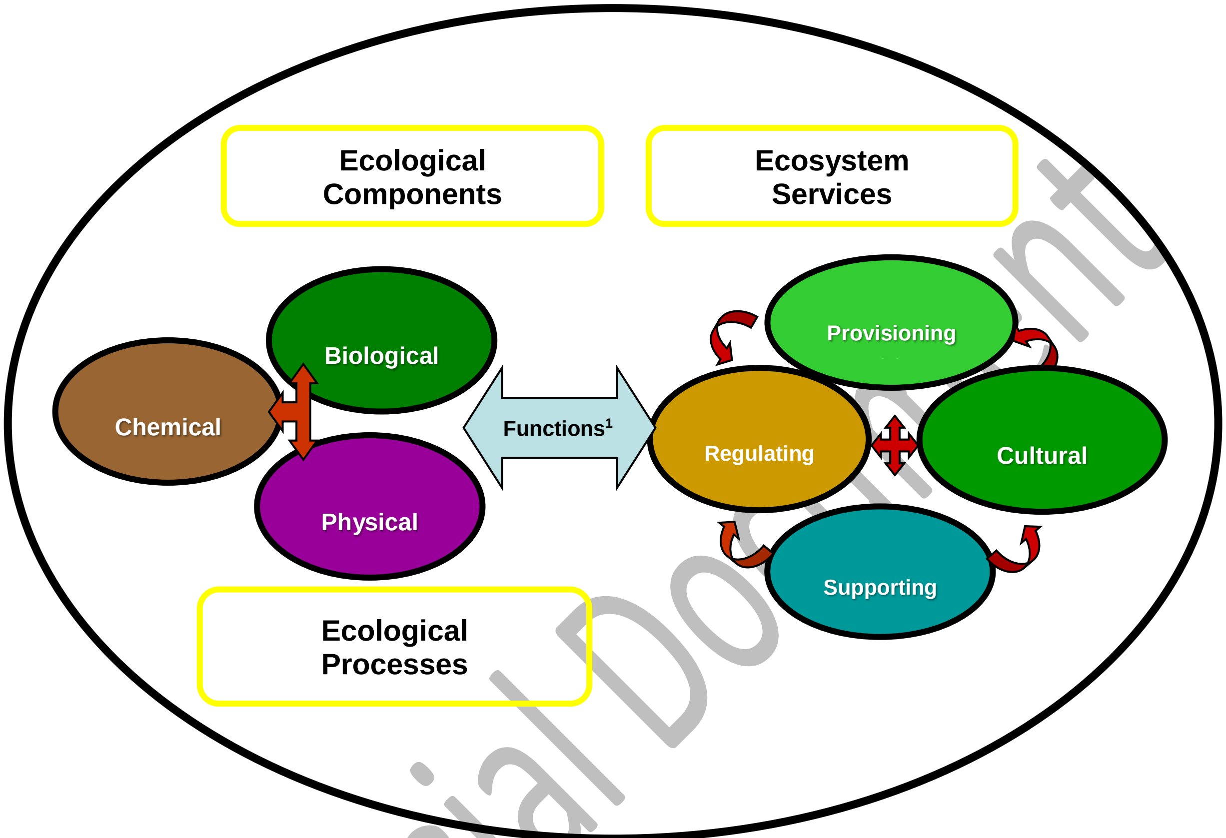
- *Wetland Assessment:* is the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities. For this some indicators or metrics to measure status or threats are required but it is not necessary to be able to record such indicators over time.

- *Wetland Monitoring:* is the collection of specific information for management purposes in response to hypotheses derived from assessment activities, and the use of these monitoring results for implementing management. For this, indicators capable of tracking changes over time are required. The collection of time-series information that is not hypothesis-driven from wetland assessment is usually termed *surveillance* rather than monitoring.

Wetland inventory provides the basis for guiding the development of appropriate assessment and monitoring. Wetland inventory is used to collect information to describe the ecological character of wetlands; assessment considers the pressures and associated values and risks of adverse change in ecological character; and monitoring, which can include both survey and surveillance, provides information on the extent of any change. Taken together, they provide the information needed for establishing strategies, policies and management interventions to maintain the ecological character of a wetland and its value and benefits, including incorporation of the outcomes of economic valuations. Pooling together such information across a broad suite of wetlands enables wetlands to be inventoried, assessed, monitored and managed through to national scales and onwards to basin scale.

3.4 Wetlands Biodiversity, Processes, Functions and Services

Wetlands are composed of a number of physical, biological and chemical components such as soils, water, plant and animal species and nutrients. Interactions among and within these components allow certain processes to occur which make the wetland to perform certain *functions*. Ecosystem functions refer to the capacity of ecosystem process and components to provide goods and services that satisfy human needs, directly or indirectly. These benefits are ecosystem services that are "the benefits people obtain from ecosystems" (Millennium Ecosystem Assessment 2003). Wetland characteristics (ecological processes and components) can be translated into a comprehensive list of services that can then be quantified in appropriate units (biophysical or otherwise) to determine their value (importance) to human society (***Figure 3.2***).



The degree to which Ecological Components and Processes provide Ecosystem Services depends on the functional properties of the ecosystem (*e.g.* biomass production, nutrient cycling, food-chain dynamics and other properties of species and abiotic components)

Figure 3.2: Relationships between ecological components, processes and functions that comprise a wetland and the ecosystem services they deliver. (***Source: de Groot et al. 2006***).

In practical terms, the distinction and relationships between processes, functions and services need not be assessed in great detail. Although they are inter-related, what we are principally interested in regarding wetlands in the LMB is essentially the services (benefits/value) they provide – because that is one basis of assessing its importance (its value). Hence the primary focus of indicators should be on services.

Biodiversity is relevant to the inventory, assessment and monitoring of wetlands in two ways. First: biodiversity underpins the ecological functioning of wetlands and therefore is required in order to sustain the delivery of ecosystem services. It can be challenging to establish the exact relationship between biodiversity and some ecosystem services but, fortunately, it is rarely necessary to consider this in technical detail because it is the services that are usually the focus of assessment. Second: biodiversity as specifically referring to the existence of certain species, or range of animals and plants, or certain communities of animals or plants present in a wetland – which can be important even where its relationship to underpinning ecosystem services is obscure (or even absent). For example, a wetland can be determined to be "important" because of the biodiversity it supports – such as being the last remaining habitat for an endangered species. It is, therefore, possible for a wetland to have high (conservation) value but deliver minimal ecosystem services. The Methodology and Tool for WEFASAM includes facility for considering both of these aspects in a wetlands inventory (that is, biodiversity conservation values and ecosystem services values).

Document 1/2017 (*Technical Note on Criteria and Process of Wetland Site Selection for Implementation of Testing and Improvement of WI and WEFASAM (including WBIA)*) includes further explanation of criteria for establishing the importance of a wetland for biodiversity conservation purposes and in terms of the benefits it delivers to people (ecosystem services).

3.5 Assessing the importance (values) of wetland ecosystem services

This section provides some introductory guidance for identifying and determining the value of the ecosystem services (ecological, socio-cultural and economic) provided by wetlands, and discusses the advantages and disadvantages of different valuation methods. This essentially is the foundation of indicators for wetland ecosystem services. It is beyond the scope of this report to review in detail the different methods available, their pros and cons, and how they might be used to value ecosystem services provided by wetlands in the LMB. For a more fulsome review of the economic valuation as applied to wetlands see Barbier *et al.* (1997), De Groot et al. (2006) and Russi et al. 2012. The use of all methods is subject to a number of challenges; in particular, determining how different ecosystem services inter-relate, and addressing issues of irreversibility and uncertainty about how ecosystem services function (DEFRA, 2007). Nevertheless, valuing ecosystem services provides decision-makers with additional information on the costs and benefits associated with particular actions so that the net impacts of policy interventions and development activities can be more fully considered. It is important to recognise, however, that any valuation based only on indicators will, of course, only be indicative. For an assessment of the Total Economic Value (TEEB, 2010) provided by ecosystem services it is necessary to undertake a comprehensive evaluation of the total use (both direct and indirect) and non-use values that people derive from wetlands.

3.5.1 What is value and why is it important in wetland inventory?

In order to develop and improve wetlands inventory in the LMB, compilation of lists of wetlands must go well beyond their physical (geographic) location and ecological characteristics/descriptions. In order to make better decisions regarding the use and management of LMB wetland ecosystem services, their importance to people of the LMB must be assessed.

However, the importance or "value" of ecosystems is viewed and expressed differently by different disciplines, cultural conceptions, philosophical views, and schools of thought. The Millennium Ecosystem Assessment (2003) defined *value* as "The contribution of an action or object to user-specified goals, objectives, or conditions". According to the *Oxford English Dictionary* the term "value" is used in three main ways:

i. **Exchange value:** the price of a good or service in the market (= market price);
ii. **Utility:** the use value of a good or service, which can be very different from the market price (e.g. the market price of water is very low, but its use value very high; the reverse is the case, for example, for diamonds or other luxury goods);
iii. **Importance:** the appreciation or emotional value we attach to a given good or service (*e.g.* the emotional or spiritual experience some people have when viewing wildlife or natural scenery or our ethical considerations regarding the existence value of wildlife).

These three definitions of value roughly coincide with the interpretation of the term *value* by the three main scientific disciplines involved in ecosystem valuation:

a) **Economics**, which is mainly concerned with measuring the exchange value or price to maintain a system or its attributes;
b) **Ecology**, which measures the role (importance) of attributes or functions of a system to maintain ecosystem resilience and health, and
c) **Sociology**, which tries to find measures for moral assessments.

Because of the many services and multiple values of wetlands, many different stakeholders are involved in wetland use (and mis-use), often leading to conflicting interests and the over-exploitation of some services (*e.g.* fisheries or waste disposal) at the expense of others (*e.g.* biodiversity conservation and flood-control). There are also many shortcomings in economic accounting and decision-making procedures (see ***Box 3-1***) leading to incomplete cost-benefit analysis of planned interventions in wetland systems. As a result, wetlands in the LMB (as elsewhere) continue to be undervalued and consequently over-used, degraded and lost.

Box 3-1: Reasons why wetlands are still under-valued and over-used.

Wetland values are often not taken into account properly of fully, or are only partially valued, in decision making, often leading to degradation or even destruction of a wetland.

Reasons for under-valuation include:

- **Market failure: public goods.** Many of the ecological services, biological resources and amenity values provided by wetlands have the qualities of a public good; *i.e.* many wetland services are seen as "free" and are thus not accounted for in the market (*e.g.* water-purification or flood-prevention).
- **Market failures: externalities.** Another type of market failure occurs when markets do not reflect the full social costs or benefits of a change in the availability of a good or service (so-called externalities). For example, the price of agricultural products obtained from drained wetlands does not fully reflect the costs, in terms of pollution and lost wetland-services, which are imposed on society by the production process.
- **Perverse Incentives (e.g. taxes/subsidies stimulating wetland over-use).** Many policies and government decisions provide incentives for economic activity that often unintentionally work against wise-use of wetlands, leading to resource degradation and destruction rather than sustainable management. For example, subsidies for shrimp-farmers leading to mangrove destruction.
- **Unequal distribution of costs and benefits.** Usually, those stakeholders who benefit from an ecosystem service, or its over-use, are not the same as the stakeholders who bear the cost. For example, when a wetland is affected by pollution of the upper catchment by runoff from agricultural land, the people living downstream of the wetland could suffer from this. The resulting loss of value (*e.g.* health, income) is not accounted and the downstream stakeholders are generally not compensated for the damages they suffer.
- **No Clear Ownership.** Ownership of wetlands can be difficult to establish. Wetland ecosystems often do not have clear natural boundaries and even when natural boundaries can be defined, these may not correspond with an administrative boundary. Therefore, the bounds of responsibility of a government organisation cannot be easily allocated and user values are not immediately apparent to decision-makers.
- **Devolution of decision-making away from local users and managers**. Failure of decision-makers and planners to recognize the importance of wetlands to those who rely on them, either directly or indirectly.

Source: de Groot et al. 2006

3.5.2 When should valuation be undertaken?

The purpose of improving the wetlands inventory of the LMB is to improve the management of wetlands. Valuation of wetlands in the LMB is an important component of wetlands inventory because it is one factor relating to the "importance" of wetland systems and therefore a key factor in policies for, and management of, wetlands. An ultimate objective of improving the Wetlands Inventory system for the LMB is to be able to track changes in the value (importance/benefits) of LMB wetlands over time in order to manage them better.

Whenever decisions are made, and at all decision-making levels (including personal, corporate and government decisions), judgements are made, often implicitly rather than explicitly, about the values (ecological as well as social, economic and monetary) that will be affected by the decision. Often the changes in these values are not made explicit, leading to decisions that have unwanted, and avoidable side-effects. Since most development decisions are based on (market) economic considerations, it is especially important to make a proper assessment of **all** the monetary consequences of these decisions. However, monetary valuation should always be seen in addition to, and not as a replacement of ecological, social and cultural values under consideration in the decision-making process.

Undertaking a full and comprehensive valuation of a wetland can require considerable effort and resources. For this reason the WEFASAM will develop simple, practical, approaches for assessing the value/importance of a wetland. Some further guidance for this is provided in documents 1/20017 and 2/2017. This will provide an overview of values for wetland sites that is sufficient to further develop the LMB wetlands inventory. However, it is critically important that the data in the wetlands inventory is used for only general purposes and not as the basis of site specific management decisions resulting in the conversion or degradation of any particular wetland. Before such steps are taken a full wetlands valuation must be carried out.

There are three situations in which it is particularly important to carry out more detailed valuation studies. These are:

1) Assessment of Total Economic Value (TEV): *i.e.* to determine the total contribution of wetlands to the local or national economy and human well-being. As most wetlands play a crucial role in maintaining local livelihoods and significantly contribute to the local regional and national economy in the LMB it is important that information about the Total Economic Value of wetlands is properly assessed, explained and communicated to all stakeholders and to create the boundary conditions for policy making that stimulates the conservation and sustainable use of wetlands as "Natural capital", and prevents their further degradation or destruction.

2) Trade-off Analysis: *i.e.* to evaluate effects (costs and benefits) of alternative development options for a given wetland in order to make informed decisions about possibilities (and impossibilities) for sustainable, multi-functional use of wetland services. Proper inclusion of all values in trade-off analysis and decision-support systems is essential for achieving "wise use" of wetlands (*i.e.* outcomes that are ecologically sustainable, socially acceptable and economically sound).

3) Impact Assessment: *i.e.* to analyse the effects of (proposed) wetland conversion or drainage, or other destructive practices, on wetland services and their value (including ecological, socio-cultural, economic and monetary values). In cases where there will be good reasons for converting wetlands into another use, results from studies on the (total) value of ecosystems can help to compensate those people who suffered losses.

3.5.3 How can assessments of LMB wetland values be used?

More and better information on the socio-cultural and economic benefits of ecosystem services is needed to:

i. demonstrate the contribution of wetlands to the local, regional and national economies of the LMB (and thus build local and political support for their conservation and sustainable use);

ii. convince decision-makers that the benefits of conservation and sustainable use of wetlands in the LMB usually outweigh the costs and explain the need to better factor wetlands into development planning (through more balanced cost-benefit analysis);

iii. identify the users and beneficiaries of wetland-services to attract investments and secure sustainable financial streams and incentives for the maintenance, or restoration, of these services (*i.e.* make users pay and ensure that local people receive a proper share of the benefits); and

iv. increase awareness about the many benefits of wetlands to human well-being and ensure that wetlands are better taken into account in economic welfare indicators for the LMB.

Valuation studies can also help to improve local institutions in the LMB that manage resources; identify better markets and resource management options for wetlands and their products in the LMB; and investigate people's livelihood strategies in the LMB and how these determine the constraints and options for making wise use of wetlands. Wetland valuation can also help in sizing the amount of damage done by an accident, natural disaster or illegal use, thereby helping in legal proceedings and decisions on suitable restoration options.

3.6 A framework for wetland valuation in the WEFASAM

In general there are two ways in which ecosystem services contribute to human welfare – by contributing to the generation of income and wellbeing, and by reducing damage that imposes costs on society (DEFRA, 2007). Both mechanisms are relevant to the role that wetlands play in the Lower Mekong Basin, and there are a range of methods available to assess the economic value of ecosystem services provided through each of them depending on the particular type of ecosystem service and the availability of data. The two main categories of approaches are:

1) Revealed preference techniques, which rely on individuals' preferences for marketable goods. These approaches require the actual presence of markets and methods include: market prices, avoided cost, hedonic pricing, travel cost and random utility modelling (DEFRA, 2007). Some categorisations split-out techniques which use data from 'direct markets' (e.g. market prices, avoided cost, production function) from those which rely on 'related market' data (e.g. travel cost) (Chee, 2004; TEEB, 2010); and

2) Stated preference techniques, or contingent valuation approaches, which rely on what individuals state their preferences to be for changes to the environment in hypothetical markets through carefully constructed questionnaires and interviews (see further below). These are the only methods that can be used to determine 'non-use' values and include: contingent valuation and choice modelling (DEFRA, 2007).

The following general framework is adapted mainly from de Groot et al. (2006) and Russi et al. (2012).

A framework for wetland valuation is illustrated in ***Figure 3-3.*** The four main steps described in this concept note are: 1. Policy Analysis; 2. Stakeholder Analysis; 3. Function Analysis (inventory: identification and quantification of services); 4. Valuation of services; and 5. communicating the value of wetlands to all stakeholders and decision-makers. Some additional activities are needed for a complete integrated assessment of the role of wetland ecosystems in development planning. These include analysis of pressures, trade-offs and management implications. These are included in Figure 3-3 but are not discussed further here.

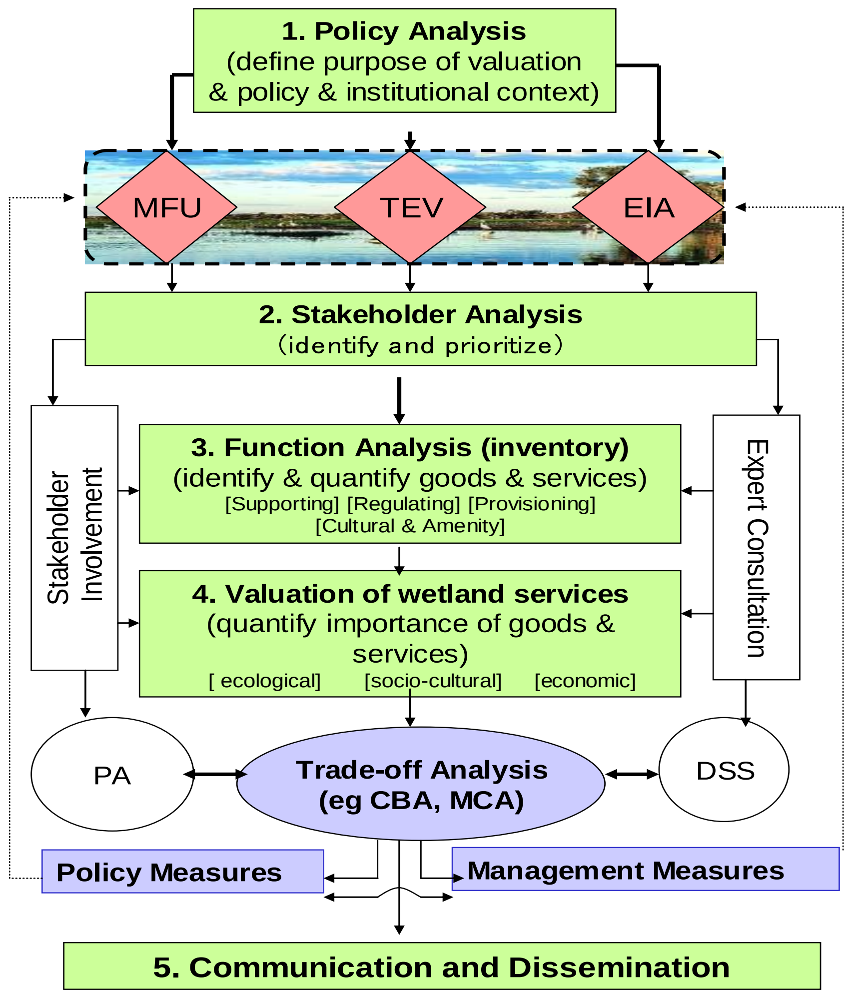


Figure 3-3: A framework for integrated assessment and valuation of wetland services for the WEFASAM. (*Source: de Groot et al. 2006*)

Explanation of symbols, colours and abbreviations:

Green: the five steps described in these guidelines; *White:* additional tools and activities which are needed for a full Integrated Assessment, but which are not covered in these guidelines; *Mauve:* areas of application (*i.e.* in trade-off analysis to determine policy and management measures); *Red:* the three situations in which Valuation is used: MFU - assessment of options and trade-offs for multi-functional use of wetlands, TEV - assessment of the total contribution (value) of wetlands to the economy at different scale levels (local, national or even global), EIA - assessments of the effects/impacts (ecological and socio-economic) of wetland conversion or proposed conversion. *Other abbreviations*: PA – Participatory Approach; DSS - Decision Support System; CBA - Cost Benefit Analysis; MCA – Multi-Criteria Analysis.

3.6.1 Steps for undertaking wetland valuation

The main steps in an assessment of the valuation of a wetland are:

Step 1: Analysis of policy processes and management objectives *(**why** undertake the valuation)*

Step 2: Stakeholder analysis and involvement *(**who** should do the valuation, and for whom?)*

Step 3: Function analysis (identification & quantification of services) *(**what** should be valued?)*

Step 4 Valuation of services *(**how** to undertake the valuation?)*

Step 5 Communicating wetland values *(to **whom** to provide the assessment results)* (see Section 7)

Step 1: Policy Analysis - Analysis of policy processes and management objectives

Policies, institutions and governance aspects influence the kind of values that will be taken into account in decision making and management measures. The aim of policy analysis is to:

i. identify the types of information (and kinds of values) required and by whom;
ii. understand the policy making process and stakeholder interests, both in current practice and the desirable state, and how they influence the kind of information that is required;
iii. enable key stakeholders to assign their own values and incorporate that into decision making, and to be able to compare different kinds of values;
iv. describe the objective of the valuation within the policy and stakeholder context;
v. identify the main valuation questions in relation to the current and 'desired' policies; and
vi. ensure that valuation reflects policy-goals and aspirations for wetlands and those who use them.

The following five main elements should be included in Policy Analysis (based on the DFID Sustainable Livelihoods website http://www.livelihoods.org and the IFAD Sustainable Livelihoods workshop on Methods for Institutional and Policy Analysis http://www.ifad.org/sla/background/english/institution.ppt):

i. ***Social capital and actors***: to involve the appropriate stakeholder groups in the valuation process, the main actors and 'social capital' need to be identified (see also Step 2 *Stakeholder analysis*). Questions to be asked include: What is the available knowledge on the current situation? What force is available to harness the problems? Who are the players? Who is affected? What techniques are available to elicit values from under-represented groups?

ii. ***Policy context, statements and measure:*** the current policy context needs to be analysed to see how policies interrelate, how they work together or against each other, and to be aware of opportunities and constraints.

iii. ***Policy process and priorities*:** through analysing existing policies and policy gaps, policy priorities can be identified.

iv. ***Institutions and organisations*; i**nstitutions (rules, procedures and norms of society) and organizations (government, private sector and civil society) form the interface between policy and people. Questions to keep in mind while mapping the relevant institutions (and considered stakeholders) for a particular analysis or valuation: **"**Why do policy statements often say one thing, but quite another is observed in the field?", "How do the realities of the micro-level situation get fed into the policy making process?"

v. ***Livelihood Strategies***: An analysis of policies for sustainable livelihoods (and ecosystems) requires an understanding of the livelihood priorities, the policy sectors that are relevant, and whether or not appropriate policies exist in those sectors.

Table 3-1 gives an overview of the main policy analysis methods and the different elements of policy to which they can be applied. There are some methodological issues that must be kept in mind when conducting policy analysis. Policy is highly political; policy can shift when local, regional or national governing bodies change their political stance after elections. This means policy has the potential of being only temporary. The Institutions and organizations involved in policy and policy making in the LMB are not uniform. Each organization has its own culture and language, which may not always bring the message across clearly to stakeholders or to other organizations and institutions. Policy also affects different (stakeholder) groups in different ways.

In situations where a policy analysis shows that a valuation cannot be conducted in the best way possible due to constraints in institutional or human capacity or social capital, measures of capacity-building and training could be considered as well as support for related research and cooperation with partners.

Table 3-1.: Methods for analysing different elements of policy and policy process. (Adapted from: http://www.livelihoods.org)

Methods	*Policy elements to which each method can be applied*				
	Social capital & actors	*Policy context, statements & measures*	*Policy process and priorities*	*Institutions and organisations*	*Livelihood Strategies*
Document analysis	✓	✓	✓	✓	✓
Interviews	✓	✓	✓	✓	✓
Policy mapping		✓	✓		
Policy ranking			✓		
Visioning			✓		
Power analysis	✓			✓	
Social maps	✓			✓	
Strategy flow diagrams	✓				✓
Institutional analysis	✓			✓	
Stakeholder analysis	✓		✓		
Actor network analysis	✓		✓		
Livelihood analysis					✓
Preference ranking					✓
Time lines		✓	✓		✓

Step 2: Stakeholder analysis and involvement

Early in the assessment and inventory process, the main stakeholders regarding particular wetlands should be identified. This is particularly important because in almost all steps of the valuation procedure, stakeholder-involvement is essential, so as to determine the main policy and management objectives, to identify the main relevant services and assess their value, and to discuss trade-offs involved in wetland use – and hence to properly characterise the wetland, its setting and its importance/values as part of the inventory process.

Methods that can and should, as appropriate, be used in stakeholder analyses of wetland valuation are listed in ***Table 3-2***. A particularly important tool is the use of questionnaires that can be used in all stages of the stakeholder analysis. It is important to have expert advice and input to the design of such questionnaires, otherwise there is a high risk that ambiguous, confusing or un-interpretable answers will be collected.

Table 3-2: Methods used in stakeholder analysis

Method	Can be used for:		
	Selecting Stakeholders	Prioritising Stakeholders	Involving Stakeholders
Data Review	✓	✓	
Observation	✓	✓	
Interviews, Questionnaires	✓	✓	✓
Resource tenure & ownership maps	✓	✓	✓
Diagrams, Maps	✓		✓
Ranking		✓	
Stories, Portraits		✓	✓
Workshops		✓	✓

Questionnaire design

Questionnaires are an inexpensive way to gather data from a potentially large number of respondents. They are particularly useful for undertaking rapid assessments of wetlands, particularly at site level. A well-designed questionnaire that is used effectively can gather information on both the overall topic at hand as well as information on specific components of the issue. Although questionnaires may be 'cheap' to administer compared to other data collection methods, they require investments in terms of design time and interpretation.

Six Principles for drafting a Questionnaire are:

1. **Content**: include the minimum number of topics to meet your objectives: What does the survey want to find out, why is the information needed, from whom and where can it be obtained and how the topics are to be questioned.
2. **Time**: must be kept reasonable (not more than 60 minutes to complete). If necessary, limit the number of questions.
3. **Ease to use**: the questionnaire should be easy to use as an interview guide for the researcher and as an instrument for recording answers.
4. **Self-contained**: include appropriate detail/identification for the researcher, respondent, date of interview and any other reference information such as field details.
5. **Coding**: coding for analysis should be done directly on the form, preferably alongside the verbal response for each question. Coding should be consistent with codings used in the WEFASAM.
6. **Smart presentation**: give thought to quality of paper, size of sheets used, clarity of printing and presentation and spaces provided for recording answers.

The first step in stakeholder assessment is to identify people, groups and organizations who are important to involve in a valuation or who might be affected by the outcome (see ***Table 3-3***).

Table 3-3: Main methods used in the identification and selection of stakeholders

Methods	Description	Sources
Data Review	Review of existing data on potential stakeholders, and/or the issue at hand that the stakeholder analysis is needed for.	Local municipalities, local NGO's, involved organisations and institutions
Observation	Observation of potential stakeholders, interaction of stakeholders	
Interviews, Questionnaires	For accurate determination for the selection of stakeholders. Method to gauge level of involvement, power structure, level of influence, etc.	See MacNamara (1999). *General guidelines for conducting interviews* http://www.managementhelp.org/evaluatn/intrview.htm
Resource tenure & ownership maps and other diagrams and maps	Previous information and actual step-by-step mapping based on site visits	See also guidance on relevant sections of the LMB wetland inventory data sheets in document 2/2017 Annex 3.

There are different ways to identify stakeholders, and it is up to the selector to use his common sense and prudence in selection. Methods for selection include a top-down approach (macro to micro level), and questionnaires to large groups for mutual identification. Stakeholders can also identify each other by asking already involved stakeholders who else they think are relevant and need to be considered. This identification process will unearth a range of individuals, groups, NGOs, other organisations and government departments.

A distinction should be made between stakeholders who identify themselves as a cohesive group (*e.g.* companies and NGO's) and unorganized 'groups' such as small businesses and households.
There is no 'standard set' of stakeholders relevant to wetland valuations. Stakeholders identified for one valuation project are not necessarily important for another project. In addition, stakeholders change over time, so stakeholders previously identified must be reconsidered rather than immediately assumed to still be relevant to the process.

Stakeholders can be categorized according to their level of influence and their importance (***Figure 3-4***). The relative levels of influence and importance determines whether a stakeholder is a primary, secondary or external stakeholder. *Importance* refers to the degree to which the stakeholder is considered a focus of a decision to be made. *Influence* refers to the level of power a stakeholder has to control the outcome of a decision. Influence is dictated by stakeholders' control of, or access to, power and resources. Influential stakeholders, (lobbying groups, wealthy landowners etc) often are already engaged in the process or have access to it.

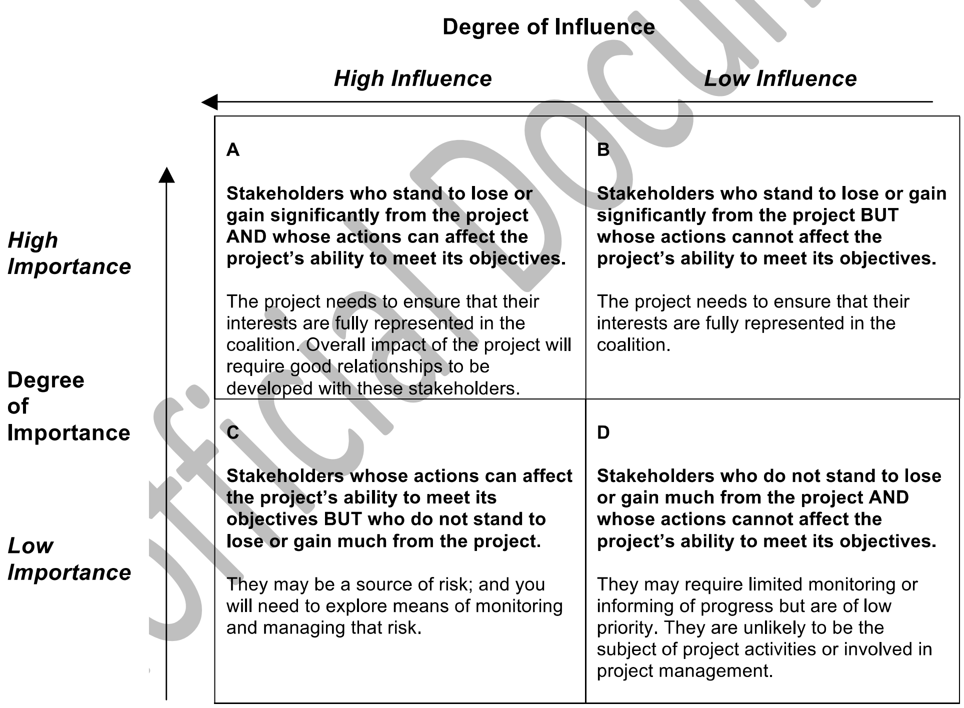


Figure 3-4.: Prioritizing stakeholders based on their influence and importance (to a wetland) (***Source: de Groot et al. 2006***).

Based on this categorisation, three types of stakeholders can be distinguished:

1. *Primary stakeholders* (Figure 3.4, cells A & B) – those who have high importance to the process. Note that such stakeholders may frequently perceive themselves as having low influence, despite being important;

2. *Secondary stakeholders* (Figure 3.4, cells A & C) – those who can be both important and influential, they may be directly involved in the process, and are integral to success. They can in some circumstances be highly influential (for example governmental implementing agencies);

3. *External stakeholders* (Figure 3.4, cells C & D) can also be influential but they tend to have low importance for particular activities. External stakeholders can, however, be influential to outcomes.

It is essential to identify what form of participation is both desirable and feasible for the different actors in each stage and activity of the valuation process. This will depend largely on the objectives of the valuation which have implications for the assessment design. For the LMB wetland inventory using the WEFASAM this will usually be a data gathering exercise and rapidity will probably usually win over pursuit of local analytical processes. If it is to be an exercise leading to local action, then building local analysis and competence will need to be prioritised over quick research outcomes.

Participatory methods imply certain obligations, and it is important to be aware of the following issues (IIED 1997):

i. Active involvement of people in research and analysis means that all participants should have ownership of the results. This implies a requirement for effective and timely feedback, the sharing of reports and the recognition of contributions.

ii. The use of interactive, participatory methods may generate enthusiasm and excitement and raise expectations. This implies that plans for follow-up must always be part of these activities. Rooting research work within local structures, seeking alliances with development actors on the ground and finding a means to pursue findings all require prior planning and a commitment that stretches both before and beyond the research study.

iii. Open and frank discussions about research use can raise latent resource-related conflicts that then need to be addressed. Do researchers have the skills to deal with some of these conflicts?

iv. Finally, active local involvement in research has costs as well as its well-recognized benefits. These costs include the real costs of time out of busy lives and material costs in terms of accommodation and food provided, as well as the potential costs political and social disputes generated by the intervention. These costs must be recognized and compensated in locally appropriate ways.

Step 3: Inventory of wetland services

The first step in producing an inventory of wetland services for a particular site is to use a pre-prepared checklist of the main services that might apply to the wetland being assessed. Table 3-4 provides a list of the main services provided by different types of wetland (both inland and coastal), and their general relative magnitude. Depending on the complexity of the wetland being valued, the services should be described for each of the main ecosystem components (e.g. constituent river, lake, marsh etc.) and if possible be supported by maps to show the spatial distribution of each service.

The assessment selection of services to be included in the valuation process should be done in close consultation with the main stakeholders. It is beyond the scope of this report to describe each of these services in any detail.

Table 3-4: Services provided by a) inland and b) coastal wetlands. (***Source: Finlayson et al., 2005***).

a. Inland wetlands

Services (Comments and Examples)	**Permanent & Temporary Rivers & Streams**	**Perma-nent Lakes. Reser-voirs**	**Seasonal Lakes, Marshes & Swamps incl Floodplains**	**Forested Wetlands, Marshes & Swamps incl. Floodplains**	**Alpine & Tundra Wet-lands**	**Springs & Oases**	**Geothermal Wet-lands**	**Under-Ground Wetlands, incl. Caves & Groundwater Systems**
Provisioning								
Food: Production of fish, wild game, fruits, grains, etc.	●	●	●	●	•	•		
Fresh Water: Storage and retention of water; provision of water for irrigation and for drinking.	●	●	●	•	•	•		●
Fiber, Fuel & other raw materials: Production of timber, fuel wood, peat, fodder, aggregates	●	●	•	●	●	•		
Biochemical products and medicinal resources	•	•	?	?	?	?	?	?
Genetic Materials: genes for resistance to plant pathogens	•	•	?	•	?	?	?	?
Ornamental species (eg. aquarium fish)	•	•	?	•	?			
Regulating								
Air quality regulation (eg. capturing dust			•	●				

Services (Comments and Examples)	Permanent & Temporary Rivers & Streams	Perma-nent Lakes. Reser-voirs	Seasonal Lakes, Marshes & Swamps incl Floodplains	Forested Wetlands, Marshes & Swamps incl. Floodplains	Alpine & Tundra Wet-lands	Springs & Oases	Geothermal Wet-lands	Under-Ground Wetlands, incl. Caves & Groundwater. Systems
particles)								
Climate Regulation: Regulation of greenhouse gases, temperature, precipitation and other climatic processes	•	●	•	●	•		•	•
Hydrological regimes: Groundwater recharge/discharge; storage of water for agriculture or industry	●	●	●	●	•	•		•
Pollution Control & Detoxification: Retention, and removal of excess nutrients and pollutants	●	●	•	●	•	•		●
Erosion protection: Retention of soils and prevention of structural change (e.g. coastal erosion, bank slumping etc.)	●	•	•	●	?	•		•
Natural Hazard mitigation: Flood control, storm protection.	●	●	●	●	●	•		•
Biological regulation: eg. control of pest species and pollination	•	•	•	●	•	•		
Cultural & Amenity								
Cultural heritage and identity (sense of place and belonging)	●	●	●	●	•	●		
Spiritual & artistic Inspiration: Personal feelings and well-being, religious significance	●	●	●	●	•	●	•	•
Recreational: Opportunities for tourism and recreational activities.	●	●	●	•	•	•	•	•
Aesthetic: Appreciation of natural features.	●	●	•	●	•	•	•	•
Educational:	●	●	●	●	•	•	•	•

Services (Comments and Examples)	Permanent & Temporary Rivers & Streams	Perma-nent Lakes. Reser-voirs	Seasonal Lakes, Marshes & Swamps incl Floodplains	Forested Wetlands, Marshes & Swamps incl. Floodplains	Alpine & Tundra Wet-ands	Springs & Oases	Geothermal Wet-lands	Under-Ground Wetlands, incl. Caves & Groundwater Systems
Opportunities for formal & informal education & training.								
Supporting								
Biodiversity & nursery: Habitats for resident or transient species.	●	●	●	●	•	•	•	•
Soil Formation: Sediment retention and accumulation of organic matter.	●	•	●	●	•	?	?	
Nutrient Cycling: Storage, recycling, processing and acquisition of nutrients.	●	●	●	●	•	•	?	•

Remark: ***The symbols indicate the relative magnitude (per unit area) of each ecosystem service derived from different types of wetland ecosystem, with a scale from low •, medium ● to high: ● ; not known = ?; blank cells indicate that the service is not considered applicable to the wetland type. The information in the table represents expert opinion for a global average pattern for wetlands; there will be local and regional differences in relative magnitudes.***

b. coastal wetlands

Services (comments and examples)	Estuaries & marshes	Mangroves	Lagoons (incl. salt ponds)	Inter-tidal flats, beaches and dunes	Kelp	Rock and shell reefs	Sea-grass beds	Coral reefs
Provisioning								
Food: Production of fish, algae and invertebrates	●	●	•	●	•	•	•	●
Fresh Water: Storage and retention of water; provision of water for irrigation and for drinking	•		•					
Fiber & Fuel & other raw materials: Production of timber, fuel wood, peat, fodder, aggregates	●	●	●				•	
Biochemical products and medicinal resources	•	•			•			•

Services (comments and examples)	Estuaries & marshes	Mangroves	Lagoons (incl. salt ponds)	Inter-tidal flats, beaches and dunes	Kelp	Rock and shell reefs	Sea-grass beds	Coral reefs
Genetic Materials: Medicine, genes for resistance to plant pathogens	•	•	•		●			•
Ornamental species (eg. aquarium fish)	•	•	•					●
Regulating								
Air quality regulation (eg. capturing dust particles)	•	●	•					
Climate Regulation: Regulation of greenhouse gases, temperature, precipiptation and other climatic processes	●	●	●	•		•	•	●
Hydrological regimes: Ground-water recharge/discharge; storage of water for agriculture or industry	•		•					
Pollution Control & Detoxification: Retention, recovery and removal of excess nutrients/ pollutants	●	●	•		?	•	•	•
Erosion protection: Retention of soils	●	●	•				•	•
Natural Hazard mitigation: Flood control, storm protection	●	●	•	•	•	●	●	●
Biological Regulation: eg. control of pest-species and pollination	●	●	●	•		•		•
Cultural & Amenity								
Cultural heritage and identity (sense of place and belonging)	●	•	●	●	•	•	•	●
Spiritual & artistic Inspiration: Personal feelings and well-being, religious significance	●	•	●	●	•	•	•	●
Recreational: Opportunities for tourism and recreational	●	•	•	●	•			●

Services (comments and examples)	Estuaries & marshes	Mangrove s	Lagoons (incl. salt ponds)	Inter-tidal flats, beaches and dunes	Kelp	Rock and shell reefs	Sea-grass beds	Coral reefs
activities								
Aesthetic: Appreciation of natural features	●	•	●	●				●
Educational: Opportunities for formal and informal education & training	•	•	•	•		•		•
Supporting								
Biodiversity & nursery: Habitats for resident or transient species	●	●	•	●	•	●	•	●
Soil Formation: Sediment retention and accumulation of organic matter	●	●	•	•				
Nutrient Cycling: Storage, recycling, processing and acquisition of nutrients	●	●	●	•	•	•		●

Remark: ***The symbols indicate the relative magnitude (per unit area) of each ecosystem service derived from different types of wetland ecosystem, with a scale from low •, medium ● to high: ● ; not known = ?; blank cells indicate that the service is not considered applicable to the wetland type. The information in the table represents expert opinion for a global average pattern for wetlands; there will be local and regional differences in relative magnitudes.***

Once the main services delivered by the wetland have been identified, the magnitude of the (actual and potential) availability of these main services should be determined, based on sustainable use levels. Preferably these should be quantified but in practice usually an indication of their relative importance (not applicable to high) will need to be used for site based field visits (see ***Documents 1/2017 and 2/2017 for suggested approaches***).

Table 3-5 provides a list of example metrics or indicators suitable for quantifying wetland services.

Table 3-5: Potential metrics or indicators for quantifying wetland services

Services Comments and Examples	Ecological process and/or component providing the service (or influencing its availability) = Functions	State indicator (how much of the service is present)	Performance indicator (how much can be used/ provided in sustainable way)
Provisioning			
Food: production of fish, algae and invertebrates	Presence of edible plants and animals	Total or average stock in kg	Net Productivity (in Kcal/year or other unit)
Fresh Water: storage and retention of water; provision of water for irrigation and for drinking.	1) Precipitation or surface water inflow 2) biotic and abiotic processes that influence water quality (see water purification)	-Water quantity (in m3) -Water quality related to the use (conc. of nutrients, metals etc.)	Net water inflow (m3/year) (i.e. water-inflow minus water used by the ecosystem and other water needs)
Fiber & Fuel & other raw materials: production of timber, fuel wood, peat, fodder, aggregates	Presence of species or abiotic components with potential use for fuel or raw material	Total biomass (kg/ha)	Net productivity (kg/year)
Biochemical products and medicinal resources:	Presence of species or abiotic components with potentially useful chemicals and/or medicenal use	Total amount of useful substances that can be extracted (kg/ha)	Maximum sustainable harvest
Genetic Materials: genes for resistance to plant pathogens	Presence of species with (pot.ential) useful genetic material	Total "gene bank" value (e.g. number of species & sub-species)	Maximum sustainable harvest
Ornamental species: e.g. aquarium fish and plants	Presence of species or abiotic resources with ornamental use	Total biomass (kg/ha)	Maximum sustainable harvest
Regulating			
Air quality regulation: (e.g. capturing dust particles	Capacity of ecosystems to extract aerosols & chemicals from the atmosphere	Leaf area index NOx-fixation, etc.	Amount of aerosols or chemicals "extracted" - effect on air quality
Climate Regulation:	Influence of ecosystems on local and global	Greenhouse gas-balance (esp. C-	Quantity of Greenhouse gases etc. fixed and/or

Services Comments and Examples	Ecological process and/or component providing the service (or influencing its availability) = Functions	State indicator (how much of the service is present)	Performance indicator (how much can be used/ provided in sustainable way)
regulation of greenhouse gases, temperature, precipitation, and other climatic processes	climate through land-cover and biologically-mediated processes	fix) DMS production Land cover characteristics. etc	emitted -> effect on climate parameters
Hydrological regimes: ground-water recharge/ discharge; storage of water for agriculture or industry	Role of ecosystems (especially forests and wetlands) in capturing and gradual release of water	Water storage capacity in vegetation, soil, etc. or at the surface	Quantity of water stored and influence of hydrological regime (eg. irrigation)
Pollution Control & Detoxificat.ion : retention, recovery and removal of excess nutrients / pollutants	Role of biota and abiotic processes in removal or breakdown of organic matter, xenic nutrients and compounds	Denitrification (kg N/ha/y) Accumulation In plants - Kg –BOD /ha/y Chelation (metal-binding)	Max amount of waste that can be recycled or immobilized on a sustainable basis Influence on water or soil quality
Erosion protection: retention of soils	Role of vegetation and biota in soil retention	Vegetation cover Root-matirx etc	Amount of soil retained or sediment captured
Natural Hazard mitigation: flood control, storm & coastal protection	Role of ecosystems in dampening extreme events (e.g. protection by mangroves and coral reefs against damage from hurricanes)	Water-storage (buffer) capacity in m3 Ecosystem structure characteristic	Reduction of flood-danger and prevented damage to infrastructure
Biological Regulation: eg. control of pest-species and pollination	Population control through trophic relation Role of biota in distribution, abundance and effectiveness of pollinators	Number & impact of pest-control species Number & impact of pollinating species	Reduction of human diseases, live-stock pests, etc Dependence of crops on natural pollination
Cultural & Amenity			
Cultural heritage and identity: sense of place and belonging	Culturally important landscape features or species	Presence of culturally important landscape features or species	Number of people “using” ecosystems for cultural heritage and identity

Services Comments and Examples	Ecological process and/or component providing the service (or influencing its availability) = Functions	State indicator (how much of the service is present)	Performance indicator (how much can be used/ provided in sustainable way)
		(e.g. No. of WHS)	
Spiritual & artistic Inspiration: nature as a source of inspiration for art and religion	Landscape features or species with inspirational value to human arts and religious expressions	Presence of Landscape features or species with inspirational value	Number of people who attach religious significance to ecosystems # books, paintings, etc. using ecosystems as inspiration
Recreational: opportunities for tourism and recreational activities	Landscape-features Attractive wildlife	Presence of landscape & wildlife features with stated recreational value	Maximum Sustainable number of people & facilities Actual use
Aesthetic: appreciation of natural scenery (other than through deliberate recreational activities)	Aesthetic quality of the landscape, based on e.g. structural diversity, “greenness”, tranquility.	Presence of landscape features with stated appreciation	Expressed aesthetic value, e.g.: Number of houses bordering natural areas # users of “scenic routes”
Educational: opportunities for formal and informal education & training	Features with special educational and scientific value/interest	Presence of features with special educational and scientific value/interest	Number of classes visiting Number of scientific studies etc
Supporting			
Biodiversity & nursery: Habitats for resident or transient species.	Importance of ecosystems to provide breeding, feeding or resting habitat to resident or migratory species (and thus maintain a certain ecological balance and evolutionary processes	Number of resident, endemic sp. Habitat integrity Minimum critical surface area -etc	“Ecological Value” (i.e. difference between actual and potential biodiversity value) Dependence of species or other ecosystems on the study area
Soil Formation: sediment retention and accumulation of organic matter	Role of species or ecosystem in soil formation	Amount of topsoil formed (e.g. per ha per year)	*These services cannot be used directly but provide the basis for most other services, especially erosion protection and waste treatment*
Nutrient Cycling: storage, recycling, processing and	Role of species, ecosystem or landscape	Amount of nutrients (re-) cycled (e.g. per	

Services Comments and Examples	Ecological process and/or component providing the service (or influencing its availability) = Functions	State indicator (how much of the service is present)	Performance indicator (how much can be used/ provided in sustainable way)
acquisition of nutrients	in biogeochemical cycles	ha/year)	

Step 4: Valuation of wetland services

Three main types of values can be defined which together determine the Total Value (or importance) of wetlands. These are: ecological, socio-cultural and economic values (see ***Figure 3-5***).

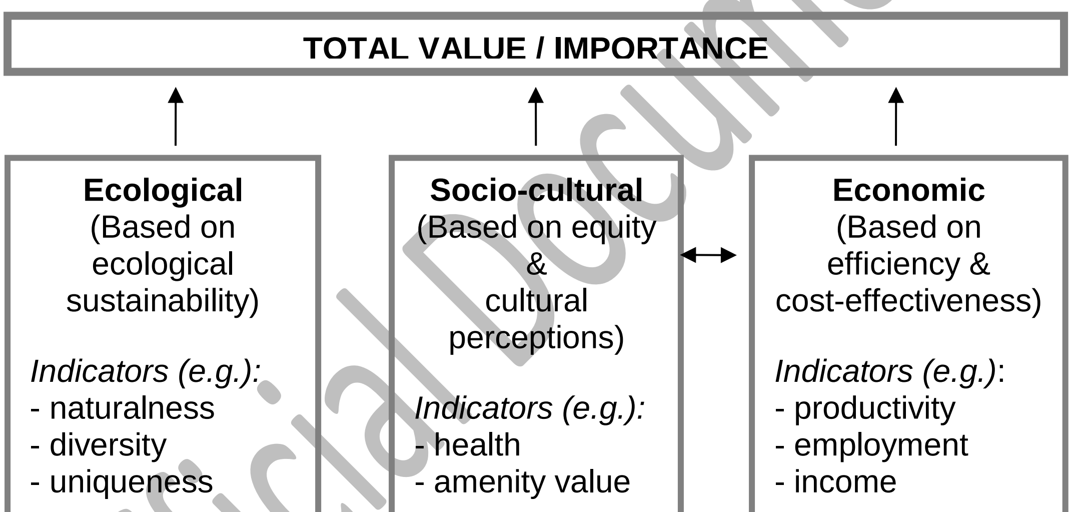


Figure 3.5: The components of the Total Value of a wetland. *(Source: de Groot et al. 2006)*.

As each wetland in the LMB is unique, data on these values should as much as possible be obtained through original research on the ecological, socio-cultural and economic indicators based on research and in particular site visits. Regardless of the methods used (field research, desk studies, internet-searches, benefit transfer), the involvement of stakeholders is important in the collection and/or the verification of the data.

An overview of the main criteria and measurement units (indicators) needed to quantify the ecological, socio-cultural, economic and monetary importance of wetland services is provided in the following sections.

Ecological Value (importance) or Biodiversity Value of wetlands

The magnitude of this ecological value is expressed through indicators such as species diversity, rarity, ecosystem integrity (health), and resilience, which mainly relate to the Supporting and Regulating Services. ***Table 3-6*** lists the main ecological valuation criteria and their associated indicators.

Table 3-6: Ecological valuation criteria and measurement indicators (after de Groot *et al.* 2003)

Criteria	Short description	Measurement units/indicators
Naturalness/Integrity (representativeness)	Degree of human presence in terms of physical, chemical or biological disturbance.	- Quality of air, water, and soil - % key species present - % of min. critical ecosystem size
Diversity	Variety of life in all its forms, including ecosystems, species & genetic diversity.	- number of ecosystems/ geographical unit - number of species/surface area
Uniqueness/rarity	Local, national or global rarity of ecosystems and species	- number of endemic species & sub-species
Fragility/vulnerability (resilience/resistance)	Sensitivity of ecosystems to human disturbance	- energy budget (GPP/NPP[1]) - carrying capacity
Renewability/recreatability	The possibility for (spontaneous) renewability or human aided restoration of ecosystems	- complexity & diversity - succession stage/-time/NPP - (restoration costs)

Remark:* [1] *GPP – Gross Primary Production; NPP = Net Primary Production

Socio-cultural Value (importance) of wetland services

For many people in the LMB wetlands are a crucial source of non-material well-being through their influence on physical and mental health, and historical, national, ethical, religious, and spiritual values. A particular wetland may, for example, have been the site of an important event in their past, the home or shrine of a deity, the place of a moment of moral transformation, or the embodiment of national ideals. These are some of the values that the Millennium Assessment recognizes as the cultural services of ecosystems (Millennium Ecosystem Assessment 2003). The main types of socio-cultural values described in the literature are therapeutic value, amenity value, heritage value, spiritual value and existence value.

Table 3-7 lists the main criteria that determine the socio-cultural importance of wetlands which are mainly related to the Cultural and Amenity services.

Table 3-7: Socio-cultural valuation criteria and measurement indicators (after De Groot *et al*. 2003).

Socio-cultural Criteria	Short description	Measurement units/indicators
Therapeutic Value	The provision of medicines, clean air, water & soil, space for recreation and outdoor sports, and general therapeutic effects of nature on peoples' *mental and physical well-being.*	- Suitability and capacity of natural systems to provide "health services" - Restorative and regenerative effects on peoples' performance. - Socio-economic benefits from reduced health costs & conditions.
Amenity Value	Importance of nature for *cognitive development,* mental relaxation artistic inspiration, aesthetic enjoyment and recreational benefits.	- Aesthetic quality of landscapes. - Recreational features and use - Artistic features and use - Preference studies.
Heritage Value	Importance of nature as reference to personal or collective *history and cultural identity.*	- Historic sites, features and artefacts - Designated cultural landscapes - Cultural traditions and knowledge
Spiritual Value	Importance of nature in symbols and elements with *sacred, religious and spiritual significance*.	- Presence of sacred sites or features - Role of ecosystems and/or species in religious ceremonies & sacred texts.
Existence Value	Importance people attach to nature for *ethical* reasons (*intrinsic* value) and inter-generational equity *(bequest* value). Also referred to as "warm glow-value"	- Expressed (through, for example, donations and voluntary work) or stated preference for nature protection for ethical reasons.

To some extent, these values can be captured by economic valuation methods (see further below), but to the extent that some ecosystem services are essential to a peoples' very identity and existence, they are not fully captured by such techniques. To obtain a certain measure of importance, this may be approximated by using participatory assessment techniques. ***Table 3-8*** gives an overview of approaches for socio-cultural valuation.

Table 3-8: Methods for quantification of the importance people attach to socio-cultural values of wetlands (*Source: de Groot et al. 2006*).

Assessment Method	Measuring the importance people attach to therapeutic value, amenity value, heritage value, spiritual value and/or existence value provided by wetlands, based on:			
	Judgement	***Attitude***	***Well-being***	***Perception***
Checklist (of issues & stakeholders)	✓	✓	✓	✓
Questionnaires (& Interviews)	✓	✓	✓	✓
Visual Media (preferences)	✓	✓	✓	✓
(Expert) Jurors/Referees	✓			
Animation Technologies for Group Interaction		✓		
Judgement (Personal & Groups)			✓	
Measurement of Environmental Variables			✓	
Behavioural Observations			✓	
Interviews with Key Persons				✓
Desk-research (e.g. of Media Attention)				✓

Economic Value (importance) of wetland services

The Total Economic Value (TEV) of a wetland is usually divided into two categories: *use values* and *non-use values* (***Figure 3-6***)

Use values are composed of three elements: direct use, indirect use and option values. *Direct use value* is also known as extractive, consumptive or structural use value and mainly derives from *goods* which can be extracted, consumed or enjoyed directly. *Indirect use value* is also known as non-extractive use value, or functional value and mainly derives from the *services* the environment provides. *Option value* is the value attached to maintaining the option to take advantage of something's use value at a later date.

Non-use values derive from the benefits the environment may provide which do not involve using it in any way, whether directly or indirectly. In many cases, the most important such benefit is *existence value*: the value that people derive from the knowledge that something exists, even if they never plan to use it. *Bequest value* is the value derived from the desire to pass on values to future generations (i.e. our children and grand-children).

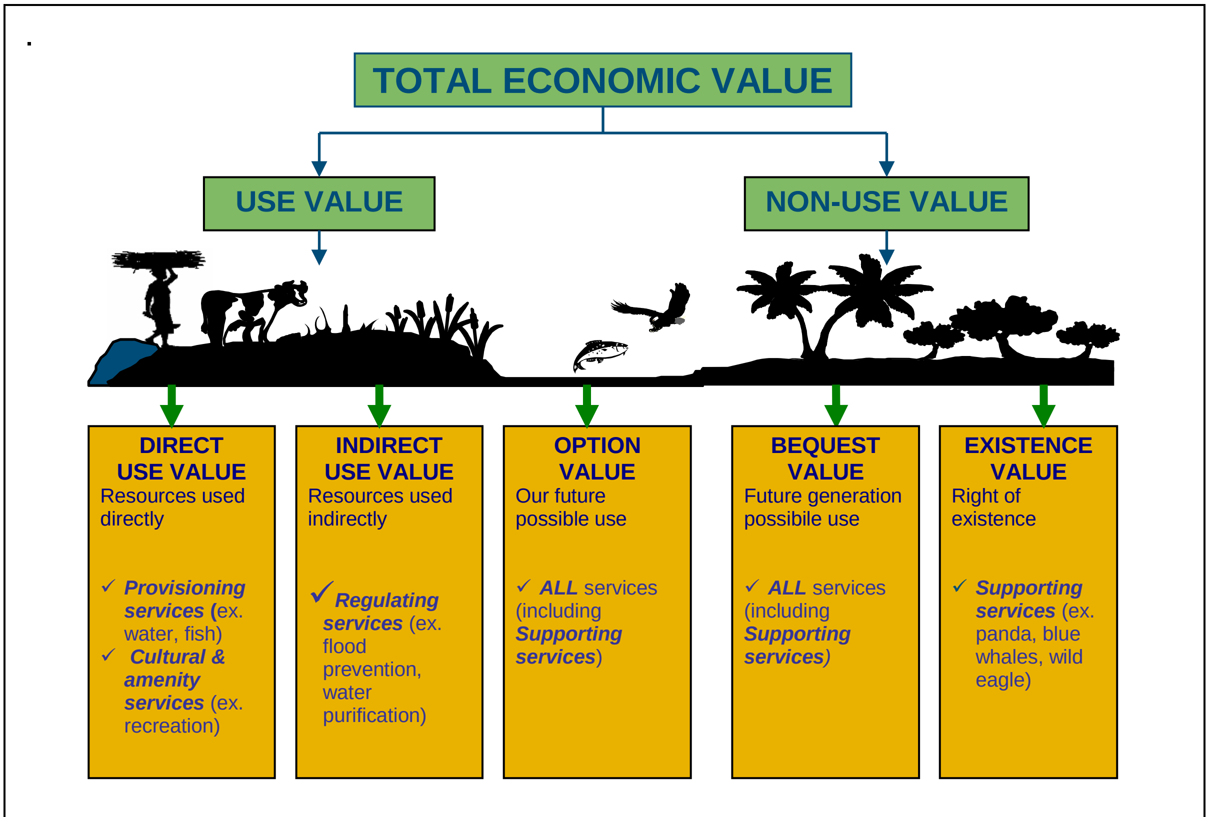


Figure 3-6: The Total Economic Value Framework. Adapted from Millennium Ecosystem Assessment (2003).

The economic importance of ecosystem services can be measured not only in monetary units, but also by their contribution to employment, livelihoods and productivity, e.g. in terms of number of people whose jobs or livelihood are related to the use or conservation of wetland services, or the number of production units which depend on wetland services. Since employment and productivity can be relatively easily measured through the market, this is usually part of the monetary valuation method.

Monetary Valuation of wetland services

The (relative) importance people attach to many of the wetland services can be measured using money as a common denominator. Monetary or financial valuation methods fall into three basic types, each with its own repertoire of associated measurement issues (***Table 3-9***):

1) direct market valuation;
2) indirect market valuation; and
3) survey-based valuation (i.e. contingent valuation and group valuation).

If no site-specific data can be obtained (due to lack of data, resources or time) *benefit transfer* can be applied (*i.e.* using results from other, similar areas, to approximate the value of a given service in the study site). This method is rather problematic because, strictly speaking, each decision-making situation is unique, but the more data that becomes available from new case studies, the more reliable benefit transfer becomes. As the LMB Wetland Inventory becomes more comprehensive, opportunities for using benefit transfer approaches will increase. Thus, short-term investments in more detailed site-specific economic assessments will yield dividends in terms of the ability to expand assessments to future sites.

Table 3-9: Monetary Valuation Methods, Constraints and Examples. ***(Source: de Groot et al. 2006)***

	METHOD	DESCRIPTION	CONSTRAINTS	EXAMPLES
1. Direct Market Valuation	Market Price	The exchange value (based on marginal productivity cost) that ecosystem services have in trade	Market imperfections and policy failures distort market prices.	Mainly applicable to the "goods" (*e.g.* fish) but also some cultural (*e.g.* recreation) and regulating services (*e.g.* pollination).
	Factor Income or Prod. Factor method	Measures effect of ecosystem services on loss (or gains) in earnings and/or productivity)	Care needs to be taken not to double count values	Nnatural water quality improvements which increase commercial fisheries catch and thereby incomes of fishermen.
	Public pricing	Public investments, eg land purchase, or monetary incentives (taxes/subsidies)	Property rights some-times difficult to establish; care must be taken to avoid perverse incentives	Investments in watershed-protection to provide drinking water, or conservation measures
2. Indirect Market Valuation	Avoided (Damage) Cost Method	Services that allow society to avoid costs that would have been incurred in the absence of those services	It is assumed that the costs of avoided damage or substitutes match the original benefit. However, this match may not be accurate, which can lead to underestimates as well as overestimates.	The value of the flood control service can be derived from the estimated damage if flooding would occur
	Replacement Cost & Substitution Cost	Some services could be replaced with human-made systems		The value of groundwater recharge can be estimated from the costs of obtaining water from another source (substitute costs)
	Mitigation or restoration cost	Cost of moderating effects of lost functions (or of their restoration)		E.g. cost of preventive expenditures in absence of wetland service (e.g. flood barriers) or relocation

METHOD		DESCRIPTION	CONSTRAINTS	EXAMPLES
	Travel Cost Method	Use of ecosystem services may require travel and the associated costs can be seen as a reflection of the implied value	Over-estimates are easily made. The technique is data intensive.	E.g. part of the recreational value of a site is reflected in the amount of time and money that people spend while traveling to the site.
	Hedonic Pricing Method	Reflection of service demand in the prices people pay for associa-ted marketed goods	The method only captures people's willingness to pay for perceived benefits. Very data intensive.	For example: clean air, presence of water and aesthetic views will increase the price of surrounding real estate.
3. Surveys	Contingent Valuation Method (CVM)	This method asks people how much they would be willing to pay (or accept as compensation) for specific services through questionnaires or interviews	There are various sources of bias in the interview techniques. Also there is controversy over whether people would actually pay the amounts they state in the interviews	It is often the only way to estimate non-use values. For example, a survey questionnaire might ask respondents to express their willingness to increase the level of water quality in a stream, lake or river so that they might enjoy activities like swimming, boating, or fishing
	Group valuation	Same as Contingent Valuation (CV) but then as an interactive group process	The bias in a group CV is supposed to be less than in individual CV	
4. Benefit Transfer		*Uses results from other, similar areas, to estimate the value of a given service in the study site*	*Values are site and context dependent and therefore in principle not transferable*	*When time to carry out original research is scarce and/or data is unavailable, Benefit Transfers can be use (but with caution)*

The relationship between ecosystem functions and services and monetary valuation is illustrated in ***Table 3-10***.

Table 3-10.: **The relationship between ecosystem functions and services and monetary valuation technique.** (***Source: de Groot et al., 2002***). In the columns, the most used method on which the calculation was based is indicated with +++, the second most with ++, etc.; open circles indicate that that method was not used in the Costanza *et al.* (1997) study but could potentially also be applied to that service.

ECOSYSTEM FUNCTIONS (and associated services - see ***Table 6***)	**Maximum monetary values (US$/ha Year)** [1]	**Direct Market Pricing** [2]	**Indirect Market Pricing**					**Contingent Valuation**	**Group Valuation**
			Avoided Cost	**Replacement cost**	**Factor Income**	**Travel cost**	**Hedonic pricing**		
Regulating services									
1. Gas regulation	265		+++	o	o			o	O
2. Climate regulation	223		+++	o	o		o	o	O
3. Disturbance Regulation	7,240		+++	++	o		o	+	O
4. Water regulation	5,445	+	++	o	+++		o	o	O
5. Water Supply	7,600	+++	o	++	o	o	o	o	O
6. Soil retention	245		+++	++	o		o	o	O
9. Waste treatment	6,696		o	+++	o		o	++	O
10. Pollination	25	o	+	+++	++			o	O
11. Biological control	78	+	o	+++	++			o	O
Supporting services									
12. Refugium function	1,523	+++		o	o		o	++	O
13. Nursery Function	195	+++	o	o	o		o	o	O
7. Soil formation	10		+++	o	o			o	O
8. Nutrient cycling	21,100		o	+++	o			o	O
Provisioning services									
14. Food	2,761	+++		o	++			+	O
15. Raw Materials	1,014	+++		o	++			+	O
16. Genetic Resources	112	+++		o	++			o	O

ECOSYSTEM FUNCTIONS (and associated services - see ***Table 6***)	**Maximum monetary values (US$/ha Year)** [1]	**Direct Market Pricing** [2]	**Indirect Market Pricing**					**Contingent Valuation**	**Group Valuation**
			Avoided Cost	**Replacement cost**	**Factor Income**	**Travel cost**	**Hedonic pricing**		
17. Medicinal Resources		+++	o	o	++			o	O
18. Ornamental Resures	145	+++		o	++		o	o	O
Cultural services									
19 Aesthetic information	1,760			o		o	+++	o	O
20 Recreation & tourism	6,000	+++		o	++	++	+	+++	
21 Cultural & artistic	25	o			o	o	o	+++	O
22 Spiritual & historic						o	o	+++	O
23 Science & education		+++			o	o		o	O

Remark: ***[1] Dollar values are based on Costanza et al. (1997) and apply to different ecosystems (e.g. waste treatment is mainly provided by coastal wetlands and recreational benefits are, on a per hectare basis, highest in coral reefs). These are examples for illustrative purposes only: actual values will vary from location to location.***

[2] Based on Added Value only (i.e. market price minus capital and labour costs (typically about 80%).

Based on a large number of case studies world-wide, ***Figure 3-7*** gives an overview of the monetary value of the main services provided by wetlands. As the LMB wetland inventory develops and becomes populated by case studies and data it will become increasingly valuable and useful for assisting wetlands valuations based on locally appropriate, Mekong specific, knowledge.

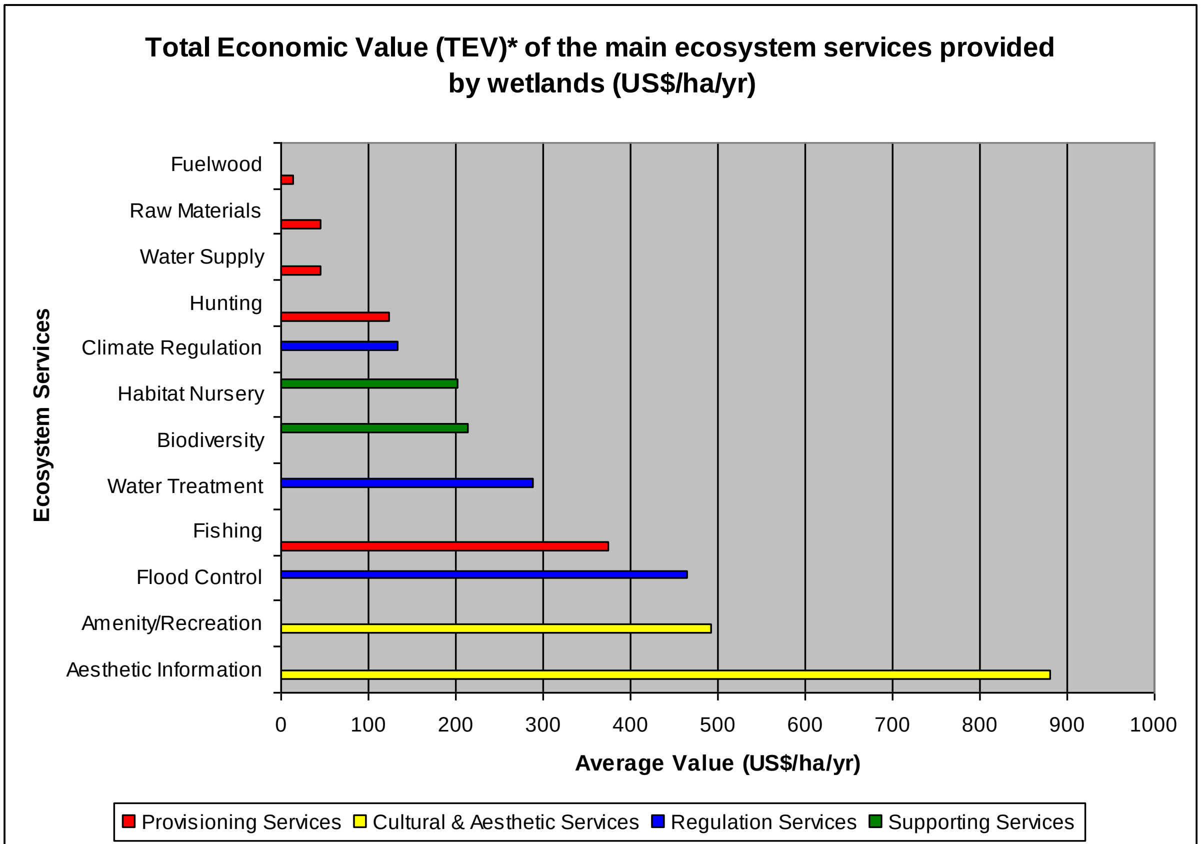


Figure 3-7: The Total Economic Value (TEV) of the main ecosystem services provided by wetlands (US$/ha/year). All figures are average global values based on sustainable use levels and taken from various synthesis studies covering over 200 case studies. These figures do not include services such as ornamental and medicinal resources, historic and spiritual values, sediment control and several others and so are certainly an under-estimation. ***(Source: de Groot et al. 2006)***.

3.7 Undertaking assessments of wetland value in practice in the Lower Mekong Basin

The valuation of a wetland can at first sight appear to be an overwhelmingly complex task. However, good progress can be made with modest resources – provided that thought is given to assessment design and field survey implementation. ***Box 3-2*** provides an example of how rapid assessments can provide valuable information to better inform a wetlands inventory process in the Lower Mekong Basin.

Box 3-2.: Rapid Participatory Assessment of Wetland Valuation in Veun Sean Village, Stoeng Treng Ramsar Site, Cambodia

Site Description

The Ramsar site in Stoeng Treng Province, Cambodia, is about 14600 hectares and extends 37 kilometers in length along the Mekong River, from 5 km North of Stoeng Treng town to the Lao PDR border. The Ramsar site is characterized by rocky streams, small islands, sandy inlets, deep pools and seasonally inundated riverine forests. Veun Sean village, the smallest village in the Ramsar site, has a population of about 150 people. The village is situated on Khorn Hang Island, although the land use practices such as cultivation, non-timber forest products (NTFP), collection and wildlife hunting extends beyond the island to the mainland. Veun Sean is relatively poor in built and human capital – there is only one well, no electricity, no latrines and poor access to health services (as of 2005). Almost 75% of people from Veun Sean cannot read or write.

Valuation Methods Used

This case study describes an application of participatory approaches to assess the importance of wetland resources to people from Veun Sean. The study goes beyond quantitative assessment to understand the context in which resource-use decisions are made – and the linkages between poverty and the importance of wetland resources.

Resource Mapping

This is an effective tool for gaining an understanding of the spatial distribution of wetland resources. It is also an interactive activity, which can be a good 'ice-breaker' between community and researchers. The resource map of Veun Sean identified deep pools as important fishing grounds, and areas of cultivation and hunting some distance from the village.

Web diagrams of social networks

In this activity, groups were invited to identify institutions, which were illustrated on paper circles. Institutions from within the village were placed inside a large circle, and external institutions were placed outside the circle. Lines were drawn between different institutions to describe the strength of influence between these organizations.

Flow diagram of wetland values

The wetland was represented by drawing the Mekong River with flooded forests in the centre of a sheet. An arrow was drawn from the wetland to a fish to illustrate a wetland use. The group then identified and described various benefit flows and market linkages, including: fishing, fish spawning, waterbird hunting, water for cooking and drinking, irrigating cash crops and transport. The group agreed that fish, a valuable resource of nutrition and income was the 'most important' wetland resource.

Seasonal Calendar of activities

Each group was invited to identify the main activities, which they conducted. These were then rated across seasons, wet, dry cold and dry hot. It was evident that the key factor which influences the timing of activities across the seasons is rice growing, which is driven by seasonal differences in weather. The wet season, when most rice cultivation occurs, is the busiest time of year for both men and women.

Wealth ranking

A measure of wealth consistently identified by all members of the group was a household's ability to grow rice sufficient to meet the needs of the family throughout the year. Rich families were identified as growing sufficient or excess rice, medium families as facing 'rice shortage' for six months, and poor and very poor families for nine or ten months. During this activity, the group noted that in response to rice shortages, poorer households generated income to purchase rice by selling fish and wildlife.

Relative ratings

This approach reflected the experiences drawn from the previous activities. Ratings were conducted using piles of 1 to 5 beans. A variety of wetland values from the flow diagram of wetland values were identified. The group unanimously rated fish as '5' representing the highest level of relative importance.

Problem ratings were undertaken to identify some of the key problems faced by the households. Lack of access to hospital services was described as a major factor contributing to health problems. The impact of recent droughts and the lack of buffalo to prepare land were described as major underlying causes of rice shortage. Declining fish stocks were also identified as a significant problem.

Ratings of sources of income revealed that poorer households have fewer options for generating income – although it appears that they may be more dependent on generating income to purchase the staple food, rice. Fish (mostly sold to middlemen) and cash crops are relatively important income sources for all households.

Household surveys

Targeted household surveys were also conducted to complement and verify the participatory activities. A key aim of the household survey was to provide additional quantitative information about the wetland values described in the participatory activities. The quantitative assessment confirmed the fisheries resource is more valuable to poorer households, because of its importance as a source of income.

Results

The value of other wetland uses was estimated using the relative ratings of different wetland uses. Using this method, the average value of the wetland to a household in Veun Sean was calculated as approximately US$3200 per year per household (See Table below).

Table Box 3-2: Wetland Values: Riel per household per year (4,000 Riel = 1 US$; 2005 figures):

Rating	Value	Wetland Uses
• • • • •	1,700,000	Fishing, washing, cooking/drinking
• • • •	1,360,000	Transportation
• • •	1,020,000	Construction material, firewood
• •	680,000	Aquatic animals, waterbirds, reptiles, irrigation, traditional medicines
•	340,000	Floodplain rice, recreation, dolphins
Total	**12,900,000**	

On average, the value of fisheries resource is $425 per household per year. However, for a poorer household, fisheries are worth about $650 per year. Much of this value is derived from income earned from selling fish, which is mainly used to purchase the food staple, rice.

Discussion
It is critical to consider access to these fisheries and other wetland resources. The poorest households have limited access to land, labour, transport to markets, health care or alternative sources of income. They are particularly dependent on fisheries resources on an 'as-needs' basis to generate income to purchase rice.

In the Stoeng Treng Ramsar site, strategies to conserve and protect the fisheries resource must consider the biological importance of the habitats in the region as spawning and dry season refuges – these benefits would extend beyond the site itself and the local community. However, it is critical that this information be considered in light of local-level dependencies on access to the resources.

In this context, participatory research methods for economic assessment could be a key tool used in the planning process – to gain an understanding in the importance of wetlands resource to local communities.

Source: Case Studies in Wetland Valuation # 11, Feb. 2005. IUCN Water and Nature Initiative (WANI), Integrating Wetland Economic Values into River Basin Management

3.8 Further guidance

In addition to de Groot *et al.* (2006), Ramsar Convention Secretariat (2010) and Russi *et al.* (2012), ***Annex 9*** provides further sources of information an guidance on assessing the importance and value of wetlands ecosystem services and wetlands as natural capital.

4. Methodology and Tool for Wetland Biodiversity, Health and Function Indicator Assessment

4.1 Conceptual framework for the development of wetland biodiversity, health, function and services indicator assessment

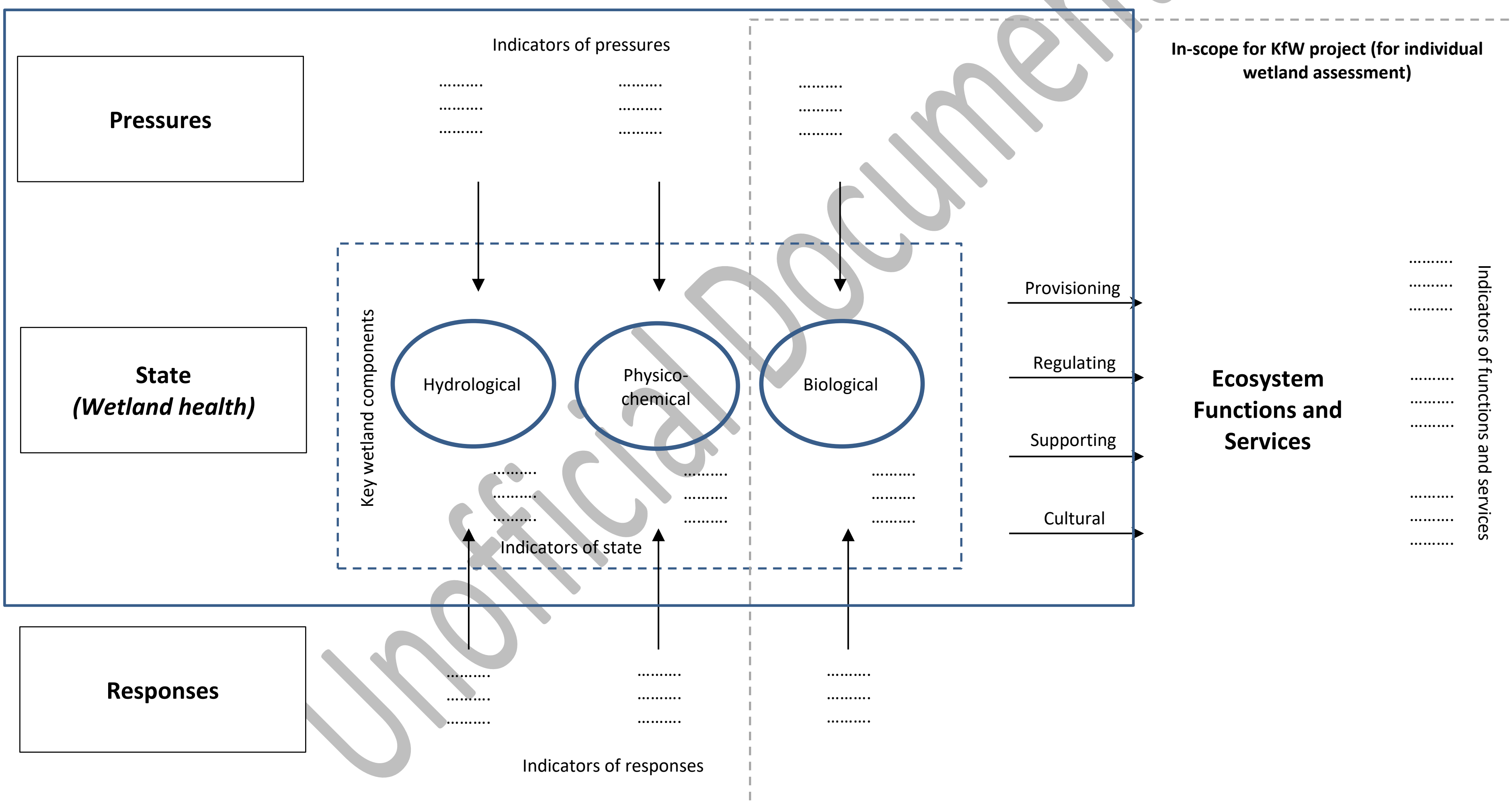
4.1.1 Indicator requirements

The selection of indicators of wetland biodiversity, health, function and services in the LMB should be undertaken, so that indicators of individual wetlands are aligned with, and could help inform, a regional-scale assessment in addition to wetland-specific management requirements. It is expected that a regional assessment would largely be based on existing national and regional datasets supported by GIS analysis, while the wetland assessment would be based on new data collected from field surveys undertaken using the updated Wetland Inventory (WI) and Wetland Ecosystem Functions Assets and Services Assessment and Management (WEFASAM) methodology and tool.

As noted above, MRC (2011) described six broad wetland types drawn from the MRC 2003 wetland database. While there are any number of ways by which to classify and delineate wetland types from the database, it would be useful to have indicators that are relevant to at least each of these six broad types. This would help ensure that change in biodiversity, health, function and services is identifiable across the wetland resource and that response actions are better targeted at ecosystems where impacts occur. Different ecosystems are more or less relevant to different ecosystem services. For instance flooded forest offers more resources for fish than flooded grassland, and the latter is richer than barren land, with the diversity and abundance of species in a floodplain usually related to the diversity of habitats (Baran *et al*., 2001).

Indicators can be developed for different elements of wetland ecosystems. These include the specific biophysical components (i.e. hydrological, physicochemical, and biological), or the ecosystem functions and services that result from the interaction of these components (as shown in ***Figure 4-1***). Under the KfW-funded *Sustainable Use and Management of Wetland in the Lower Mekong Basin Project* the focus is on the assessment of biodiversity indicators and indicators of ecosystem function and services at a wetland-scale. While this is likely to be sufficient for informing conservation investment and management actions at individual wetland sites, consideration should also be given to the use of a broader range of ecological indicators from across the various wetland components, in particular with regard to changes in physicochemical and hydrological parameters that will impact significantly on the quantity and quality of ecosystem services provided by different wetlands.

Figure 4-1: Different elements for which the selection of indicators could be applied: Pressures, State and Responses for wetland components (hydrological, physicochemical and biological) and wetland ecosystem functions and services (provisioning, regulating, cultural and supporting.



Indicators that are derived directly from the core hydrological and physicochemical components will be more sensitive to changes that are more directly attributable to human pressures and can to a large extent also be useful for indicating trends in ecosystem functions and services. However, the latter are particularly important as an aid to decision-making being more closely aligned with societal values and benefits. A mix of indicators for components, functions and services is likely to be most useful. That said, it is important that the number of indicators is kept relatively small. Too many indicators can be confusing and difficult to convey to decision-makers, while also increasing the monitoring effort required.

4.2 Proposed framework for the development and use of LMB wetland health indicators

To support the selection of indicators by MRC Member Countries it is important to be clear about the framework in which these indicators might be applied to support monitoring and reporting efforts. This framework needs to be aligned with the overall objectives for the development of indicators and should support reporting at both a national level, for example, to the Ramsar Convention and the Convention on Biological Diversity, and at a regional level, for example, state of the basin reports to support deliberations amongst MRC member countries on different basin development scenarios as described in periodic Basin Development Strategies.

To do this it is proposed that a conceptual framework of a Pressure, State, Response (PSR) model as initially devised by the Organisation for Economic Cooperation and Development (OECD, 1993; 2003) and supported by the Convention on Biological Diversity (CBD, 2003) is used as the basis for the selection of indicators. Under this framework, causality is recognised whereby human activities exert pressures on the environment, which causes changes in the state of the environment, leading to institutional responses which seek to mitigate or reverse those changes by acting either directly on the environment or on the human activities which are causing the impacts (OECD, 1993; 2003). ***Figure 4-2*** illustrates the potential application of this model to wetlands of the LMB.

Using this framework, indicators would be selected for each category (*Pressure, State and Response)* to help provide a more complete picture of the state of, and trends in, wetlands. This is the same model as used by the Greater Mekong Sub-regional Environmental Performance Assessments and is valuable in that those indicators in different categories can be mutually reinforcing, supporting an overall assessment of wetland health even if data across categories is limited. For example, an indicator which identifies increasing prevalence of a known pressure on wetland health would suggest that wetland health is likely to be impacted, even if there is no specific data available to indicate wetland health itself. The model also helps guide decision-makers on potential actions that can be taken to address threats and a decline in the state of wetland health and function.

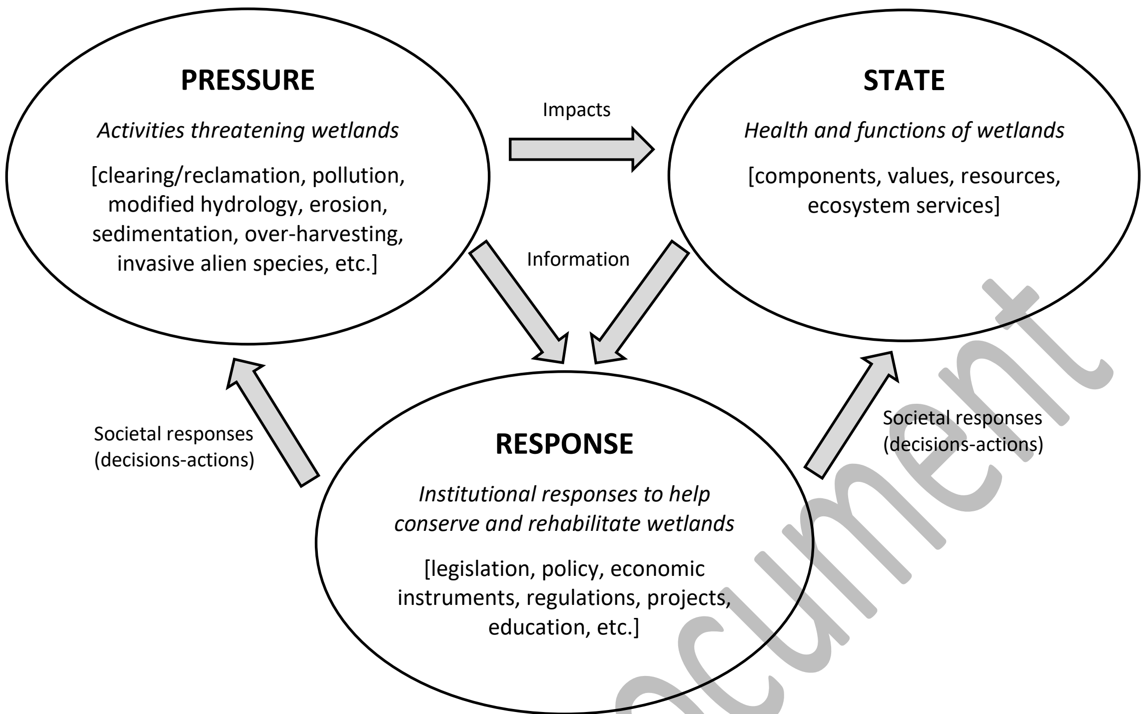


Figure 4-2: Pressure-State-Response Framework as applied to wetlands in the LMB. *(Source: Adapted from OECD, 2003)*

When selecting pressure indicators, consideration should be given both to indicators of the underlying driving force (e.g. agricultural expansion), as well as the change associated with the exertion of the pressure (e.g. decline in water quality). Often data on the former are more readily available, even if they do not necessarily provide information on the extent to which the pressure is actually causing change to wetlands. For instance, agricultural expansion may not necessarily be putting direct pressure on wetlands if it is occurring in areas other than where wetlands are located.

It is also proposed that indicators for the state of wetland health, functions and services be chosen with regard to both the health of key wetland components (hydrological, physicochemical and biological) and the quantity and quality of ecosystem services they provide or have capacity to provide in future (please see ***Box 1-1***). The reason for this is due to the very high dependence of the population of the LMB on wetland resources (MRC, 2010b). Understanding the health and function of wetlands in this environment is essentially about understanding the extent to which these ecosystems have the capacity to continue to provide the services on which peoples' livelihoods depend. The ecosystem services approach is also important as a mechanism to understand trade-offs between different development approaches. For example, as natural wetlands are converted to artificial wetlands there may be an increase in one ecosystem service (e.g. food from aquaculture) but a decrease in others (e.g. erosion protection from mangroves, habitat for biodiversity etc.). Using indicators based on ecosystem services can also aid decision making in relation to these types of trade-offs by supporting future consideration of economic valuation and cost-benefit analysis of alternatives.

Adopting this approach would lead to a logical indicator pathway from the exertion of a driving force to the impact on wetland components and ecological function created as a result of this force and then its impact(s) on the capacity of the wetland to provide one or more ecosystem services. For example, the driving force of hydropower development might be indicated by the number of existing and planned projects and the overall level of non-active storage of these projects. An indication of the pressures on wetlands and a change in state created as a result of this activity includes changes in hydrological regime and in sediment supply. These impacts have the potential to affect the supply of ecosystem services as indicated, for example, by the population (resource stock) and catch (flow of services) of fish and Other Aquatic Organisms (OAA) used for food, as well as the capacity to retain sediment and contribute to soil formation downstream as indicated by wetland sediment flux. Response indicators of actions that seek to address these impacts, however imperfectly, might include the legislative requirement for strategic environmental impact assessment, or for operational regulations for the provision of fish flows and/or sediment discharge from storages (as shown in ***Table 4-1***).

Table 4-1: Example of the logical indicator pathway from driving force to pressures on the condition of wetland components and function to impacts on ecosystem services and policy responses to the driving forces of (i) hydropower development; and (ii) agricultural expansion

Driving force	Pressure Indicators		State Indicators	Response indicators
	Extent of pressure	Impact on component state	Ecosystem Services	
Hydropower development	No. of existing and planned projects	Hydrological modifications	Food from fish and OAA	Strategic Environmental Impact Assessment
	Volume of non-active storage	Sedimentation/ Erosion	Soil formation capacity – sediment flux	Operational regulations for fish flows
		Population changes in key biota	Habitat - wetland extent	Operational regulations for sediment discharge
Agricultural expansion	Area of agricultural land	Hydrological modifications	Habitat - wetland extent	Strategic Environmental Impact Assessment
	Area of irrigated agriculture	Contamination & pollution - water quality	Water filtration capacity – nutrient flux	Area of wetlands in protected areas
	Agricultural water use	Population changes in key biota	Genetic resource – biodiversity	Fertiliser and pesticide use regulations
	Fertiliser/pesticide use			

Given the regional and national requirements for any set of indicators it is proposed that a two-tiered approach to the development and implementation of indicators is taken. This would consist of indicators that support both:

(i) a regional assessment at a basin-scale though the evaluation of data collected both at a regional scale and though the integration of local scale data from representative sites; and
(ii) a site assessment of a representative suite of wetlands producing data which can be scaled-up to a regional level but also used for national reporting, some of which would be relevant to all wetland types, and some of which would be relevant only to specific wetland types (e.g. mangroves).

This is illustrated below (***Figure 4-3***) with some examples of potential indicators and data sources where the regional, basin-scale assessment is undertaken by data collected at a regional level (i.e. the aggregation of national datasets, remote sensing and basin-scale monitoring) and then integrated with data collected at a wetland-scale (i.e. wetland inventory data) for each indicator to provide a more complete picture of the state and trends in wetland health and function.

The potential relationships between the regional and local data collection, storage, analysis and reporting are illustrated in ***Figure 4-4***, which may also help with consideration of the delineation of roles and responsibilities between the MRCS and Member Countries under a more decentralised MRC model. All data would originate through the activities of member countries, who would supply relevant national datasets (e.g. forest cover, protected areas) and wetland inventories to the MRCS to enable a basin-scale assessment. Wetland inventory data from a suite of representative wetland types would help to ground-truth national datasets, and when scaled-up to a regional level, support an assessment of ecosystem health, function and services for each of the six wetland types in the basin.

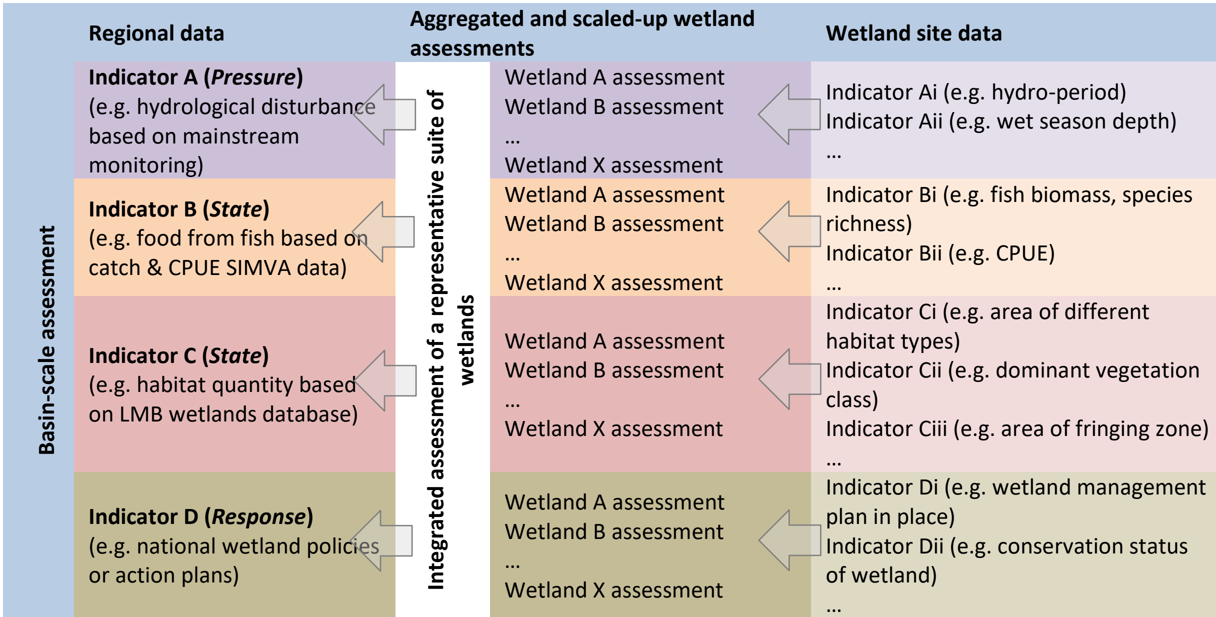


Figure 4-3: Proposed two-tiered assessment of LMB wetland biodiversity, health and function with indicators aligned by theme and representative wetland assessments integrated and scaled-up to help validate broad-scale, basin-wide data.

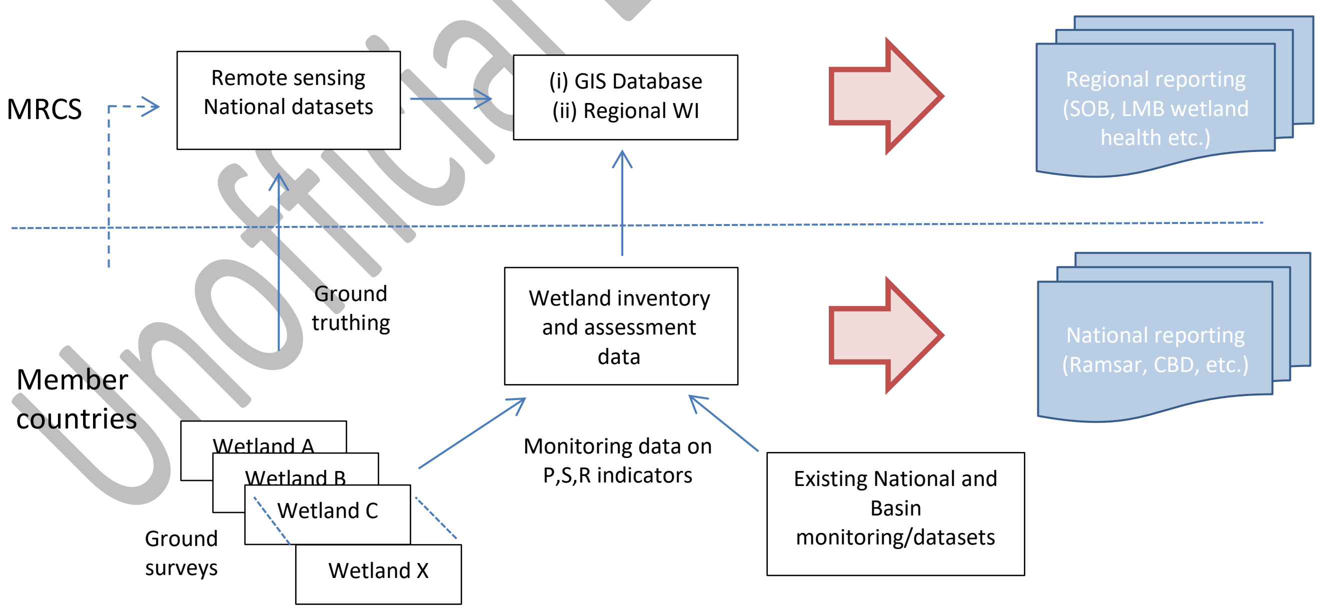


Figure 4-4: Potential relationship between data collection, analysis and reporting at wetland and regional scales.

4.3 Methods for developing indicators of wetland biodiversity, health, function and services

4.3.1 Steps to undertake to develop wetland biodiversity, health, function and services indicators

There are a number of steps that are commonly undertaken when developing ecological indicators. CBD (2003) describes these steps as they relate to biodiversity indicators but they apply equally to indicators of wetland health more broadly. In summary they are:

Step 1: Determine and agree the key policy issues and decisions for which the indicators will be used. This is critical if the indicators are to be a useful source of information in decision-making. The indicators selected need to be those most directly related to wetland health as it is affected or likely to be affected by the major drivers of change within the basin.

Step 2: Determine the audience and clarify how they will use the indicators. It is important to clarify whether or not indicators have a specific or more general purpose, whether they will be used to provide context to decision-making or as an actual input to the decision, and what the audience is most readily able to engage with.

Step 3: Specify the indicator requirements, for example, whether they should encompass all wetland types and what the baseline will be. The scope of the selection problem is an important input to prioritising indicators in order to reduce them to a manageable number.

Step 4: Select suitable indicators, based on an inventory of existing data and application of an agreed set of principles/criteria. The principles and criteria should reflect the indicator requirements as relevant to the audience and the key policy issues and decisions. It is also important to consider not only the individual indicators alone, but also the suite of indicators taken together.

Step 5: Technical design of indicators through the engagement of experts in relevant fields. Once the preferred indicators are broadly known, refinement and design of specific technical aspects including measurement methods, units and analysis can occur. This requires the involvement of experts in fields relevant to the specific indicators.

Step 6: Determine the objectives, terms of reference and technical design of a monitoring programme. In relation to the LMB this may or may not involve the collection of new data through a field monitoring programme. Either way, there should be a clear process and roles agreed for accessing, collating and evaluating data relevant to the indicators.

Step 7: Implement and maintain monitoring programme or undertake periodic assessments, as feasible.

When selecting indicators it is important to distinguish between wetland characteristics and indicators of state or condition; the latter being variable and sensitive to change, while ecosystem characteristics are slow to change, if they change at all. For example, soil type is a characteristic of a wetland but not generally a useful indicator of wetland health.

The Convention on Biological Diversity has also developed a number of principles to apply when developing monitoring indicators of biodiversity. They have been modified here as relevant to wetlands (please see ***Box 4-1***). It is proposed that these principles or similar are applied to the development of indicators of wetland health and function in the LMB.

Box 4-1. Principles for choosing indicators for wetlands (or any other biophysical feature)

1. **Policy relevant and meaningful** – Indicators should send a clear message and provide information at a level appropriate for policy and management decision making by assessing changes in the status of wetlands (or pressures, or responses), related to baselines and agreed policy targets if possible.
2. **Wetland relevant** – Indicators should address key properties of wetland function or related issues as state, pressures, or responses.
3. **Scientifically sound** – Indicators must be based on clearly defined, verifiable and scientifically acceptable data, which are collected using standard methods with known accuracy and precision, or based on traditional knowledge that has been validated in an appropriate way.
4. **Broad acceptance** – The power of an indicator depends on its broad acceptance. Involvement of the policy makers, and major stakeholders and experts in the development of an indicator is crucial.
5. **Affordable monitoring** – Indicators should be measurable in an accurate and affordable way and part of a sustainable monitoring system, using determinable baselines and targets for the assessment of improvements and declines.
6. **Affordable modelling** – Information on cause-effect relationships should be achievable and quantifiable, in order to link pressures, state and response indicators. These relation models enable scenario analyses and are the basis of the ecosystem approach.
7. **Sensitive Indicators** – should be sensitive to show trends and, where possible, permit distinction between human induced and natural changes. Indicators should thus be able to detect changes in systems in time frames and on the scales that are relevant to the decisions, but also be robust so that measuring errors do not affect the interpretation. It is important to detect changes before it is too late to correct the problems being detected.
8. **Representative** – The set of indicators provides a representative picture of the pressures, state, and responses.
9. **Small number** – The smaller the total number of indicators, the more communicable they are to policy makers and the public and the lower the cost.
10. **Aggregation and flexibility** – Indicators should be designed in a manner that facilitates aggregation at a range of scales for different purposes. Aggregation of indicators at the level of ecosystem types (thematic areas) or the national or international levels requires the use of coherent indicators sets

and consistent baselines.

Source: adapted and modified from CBD (2003)

In applying these principles to wetlands of the LMB it may be useful to consider the following regional aspects:

- *Policy relevant and meaningful:* they should be indicators targeted to usefully inform the specific policy issues that national governments are facing in the region, particularly with respect to planned development activities including for water supply, irrigation, hydropower and flood protection (MRC, 2011);

- *Wetland relevant:* they should be relevant to the particular types of wetlands and their ecosystem services that are important to the LMB countries. For instance, there should be indicators that support an understanding of the health and function for each of the six LMB wetland types identified in the MRC database (MRC, 2011) at a regional level in a way which is consistent with wetland types identified at a national level;

- *Scientifically sound:* ensuring that indicators, metrics and monitoring methodologies are supported by appropriate conceptual models and data collection and evaluation techniques which are consistent across all member countries;

- *Broad acceptance:* ultimately to be useful and effective they will need all four countries to agree on the final set of indicators;

- *Affordable monitoring:* they will need to be indicators that can be effectively monitored within national budgets over the long-term. Therefore, whether some existing indicators and monitoring activities can also be applied to wetlands should be a key consideration in their development; member countries will need to have the capacity to implement monitoring against the indicators or draw on existing databases under the more decentralised MRC model that has been agreed;

- *Affordable modelling:* indicators should be usable within existing or foreseeable MRC modelling capacity and support future economic valuation techniques, where appropriate;

- *Sensitive:* they should be indicators that are sensitive to the particular pressures, values, functions or assets of relevance to decisions that member countries need to take. These have largely been identified in 2003 country reports and may require updating as part of the MRC's work programme on wetlands to 2020;

- *Representative:* they will need to be indicators that help member countries and stakeholders understand the pressures, state and responses across the region without actually monitoring every single wetland;

- *Small number:* there should be no more than 8-12 indicators at both regional and national levels;
- *Aggregation and flexibility:* it will be important to be able to aggregate indicators at a regional LMB-scale so as to inform basin-wide development scenarios. There should therefore be indicators at both local (site) and regional scale that are logically consistent.

Developing indicators requires the development of options that align with the overall policy goals, assessment/prioritisation of those options against agreed and accepted criteria and the design of a framework for monitoring, evaluation and reporting.

4.3.2 Examples of indicators of wetland health and function used internationally

The Scientific and Technical Review Panel (STRP) of the Ramsar Convention developed an initial set of indicators for the purposes of measuring the effectiveness of the implementation of the Ramsar Convention (as shown in ***Table 4-2***). These include indicators for Pressures, State and Response but do not define common metrics for countries to apply in monitoring. An additional set of indicators was identified for further assessment by the STRP although it is not clear to what extent these have progressed in recent years (as shown in ***Table 4-3***). All of these indicators are potentially useful in that they were developed specifically for wetland ecosystems and their use would support country reporting requirements under the Ramsar Convention. However, further enunciation of the specific parameters that would be measured and used as evidence for the indicator across the region would be necessary.

Table 4-2: Initial set of indicators developed for the purposes of measuring the effectiveness of the implementation of the Ramsar Convention.

Indicator theme	Indicator title	Sub-Indicator title	Indicator type
Wetland resource – status	The overall conservation status of wetlands	(i) Status and trends in wetland ecosystem extent (ii) Trends in conservation status	S R
Ramsar site – status	The status of the ecological character of Ramsar sites	Trends in the status of Ramsar site ecological character	S
Water quality and quantity	Trends in water quality	(i) Trends in dissolved nitrate (or Nitrogen) concentrations (ii) Trends in Biological Oxygen Demand (BOD)	S
Ramsar sites – threats	The frequency of threats affecting Ramsar sites	The frequency of threats affecting Ramsar sites – qualitative assessment	P
Wetland management	Wetlands sites with successfully implemented conservation or wise use management plans	Wetland sites with successfully implemented conservation or wise use management plans	R
Species/	Overall population trends of wetland	Trends in the status of waterbird	S

Indicator theme	Indicator title	Sub-Indicator title	Indicator type
biogeographic population status	taxa	biogeographic populations	
Threatened species	Trends in threat status of wetland species	(i) Trends in the status of globally threatened wetland dependent birds (ii) Trends in the status of globally threatened wetland dependent amphibians	S
Ramsar site designation process	The proportion of candidate Ramsar sites designated so far for wetland types/features	Coverage of the Ramsar resource by designated Ramsar sites	R

Source: Ramsar Convention, 2005

Table 4-3: Additional indicators developed for the purposes of measuring the effectiveness of the implementation of the Ramsar Convention, identified for further investigation by STRP.

Indicator theme	Indicator title	Indicator type
Ramsar site designation process	Coverage of wetland-dependent bird populations by designated Ramsar sites	R
Wetland ecosystem benefits/services	The economic costs of unwanted floods and droughts	S
Water quality and quantity	Trends in water quantity	P
Legislative and policy responses	Legislative amendments implemented to reflect Ramsar provisions	R
Legislative and policy responses	Wise-use policy	R

Source: Ramsar Convention, 2005

Under the Greater Mekong Sub-region Environmental Performance Assessment programme a number of indicators of environmental performance were developed for each country, including those in the LMB (as shown in ***Table 4-4***). These indicators are potentially useful in that they were developed based on data and information that were available from existing national datasets. However, they are neither focused specifically on wetlands, nor on the LMB region. Only very few are common to more than one country which makes regional evaluation and reporting more difficult. The less focused the indicators are on the LMB, and on wetlands particularly, the less relevant they will be to informing decision-making and policy responses.

A number of other countries have national frameworks to monitor wetland health. For example, the United States Environment Protection Authority is developing a National Wetland Condition Assessment programme. This builds on the US Fish and Wildlife Service's Wetland Status and Trends Programme that considers only wetland extent and habitat type based on remote sensing information. The EPA's programme will involve a more detailed survey of condition using on-ground sampling for vegetation, soils, hydrology, buffer zone, water quality and algae (US EPA, 2015).

Table 4-4: Indicators of environmental condition as used for the GMS National Environmental Performance Assessment.

Resource	Country	Indicator	Indicator type
Forest resources	C,L,T,V	Forest cover as a percentage of total land area	S
	C	Forest concession areas	P
	L	Area under shifting cultivation	P
	T	Available agricultural land per capita	P
	C,T	Reforested areas	R
	C,L,T	Protected forest as a percentage of total land area	R
	V	Ratio of Roundwood production over total forest area	P
Threats to biodiversity	C,L,V	Threatened species as a percentage of globally threatened species	S
	C,V	Loss of critical (or natural forest) habitat	P
	L	Ratio of natural forests to plantation forest	P
	C,L,V	Protected area as a percentage of total land area	R
Fish resources	C	Inland fish consumption	S
	L	Retail price of fish at constant prices	S
	L	Volume of fisheries production	P
	C	Number of community fisheries	R
	L	Expenditure on fish management	R
Water resources	C,L	Percentage of population with access to safe potable water	S
	T	Water consumption by agriculture	P
	T	Area of 'under irrigated' lands	S
	C	Urban and rural population	P
	L	Rural population	P
	C	Urban and rural drinking water provision	R
	L	Expenditure on improved water supply	R
	T	Irrigation water storage capacity	R
	C	Areas under rice cultivation	S
	C	Agricultural population	P
	C	Expenditure on irrigation system construction and maintenance	R
Agricultural land management (and degradation)	C	Average rice yield	S
	C	Agricultural land as a percentage of total land	P
	C	Agricultural land per capita	P
	C	Growth of agricultural irrigated area	R
	C	Demined areas	R
	L	Number of households under Land-Use Planning/Land Allocation programmes	R
	L	Sediment load in selected rivers	S
	L	Number of upland households practicing shifting cultivation	P
	T	Loss of forest area	P
	T	Vulnerable farmland as percent of total farmland	S
	T	Marginal land as percent of total farmland	S
	T	Rehabilitation of degraded land	R
Inland water pollution	T	Discharge of untreated domestic wastewater	P
	T	Water quality in designated water bodies	S
	T	Amount of wastewater treated	R

Resource	Country	Indicator	Indicator type
	V	BOD5 concentration in selected rivers	S
	V	BOD discharges	P
	V	Industrial wastewater discharge fees	R
Solid waste management	L	Percentage of collected waste	S
	L	Urban population	P
	L,T,V	Volume/Generation of municipal solid waste	P
	L,V	Expenditure/Investment on (solid) waste management	R
	T,V	Percentage of collected municipal waste	S
	T	Percentage of waste disposal and utilisation	R
Hazardous waste management	L	Number of UXO related accidents	S
	L	Volume of imported toxic substances	P
	L	Area cleared of UXOs	R
	T	Amount of hazardous substances used	P
	T	Number of health-related incidents relating to hazardous waste	S
	T	Volume of treated hazardous waste	R
Air pollution from mobile source	V	Concentration of SO_2, NO_2, PM and CO in Hanoi and Ho Chi Minh cities	S
	V	Number of vehicles in Hanoi and Ho Chi Minh cities	P
Threats to coastal zones	V	Area of Mangrove forest	S
	V	Growth of aquaculture area	P
Climate change	C, L,T,V	Volume of greenhouse gas emissions	P
	L	Expenditure on reducing the amount of slash-and-burn farming	R
	T	Emission of CO_2 equivalent per unit of GDP	R

Source: MoNRE Thailand, 2008; MoNRE Viet Nam, 2008; Ministry of Environment Cambodia & UNEP, 2008; Science, Technology and Environment Agency Lao PDR and UNEP, 2008

In a bi-national approach with Environment Canada the US EPA also implements State of the Great Lakes reporting which is based on monitoring against indicators for driving forces, pressures, state, impacts and responses. It includes indicators such as sediment contamination, forest disturbance, nutrients in lakes, and fish habitat amongst others (EC and US EPA, 2013).

In Australia, the federal and state governments agreed on a Framework for the Assessment of River and Wetland Health (NWC, 2011). There are several elements of this that are potentially useful for LMB countries. First, it establishes a two-tiered approach. The first tier is a broad regional assessment using remote sensing, modelling, existing databases and GIS tools. It considers indices for wetland extent, catchment disturbance, hydrological disturbance and fringing zone. The second tier is a more detailed condition assessment at a local scale and includes indices for wetland extent, catchment disturbance, hydrological disturbance, fringing zone, water quality and soils, physical form and aquatic biota. Each of these indices has sub-indices and metrics that are determined by the relevant state government jurisdiction as applicable to local conditions (NWC, 2011). This 'federal' model has potential application to the LMB where member countries would undertake monitoring according to their own needs but within an agreed regional framework that allows aggregation and regional reporting on wetland status and trends.

Wetland monitoring in New Zealand is based on indicators of change in hydrological integrity, physicochemical parameters, ecosystem intactness, browsing, predation and harvesting regimes, and dominance of native plants (Clarkson *et al*. 2003). Each of these indicators contributes a numerical score to a composite wetland health index. They were selected based on an understanding that soil and vegetation characteristics are the most important indicators of wetland condition (Cowardin *et al.* 1979; Faulkner et al. 1989; Tiner, 1991; 1999) because they cover all or most wetland types, are permanent features of the landscape and integrate environmental stress factors over time (Clarkson *et al*. 2003).

4.3.3 Existing ecological indicators used by the Mekong River Commission

In order to develop a cost-effective approach to monitoring wetland health and function it is important to consider the utility of existing monitoring activities. At a regional level there are several monitoring programmes that are relevant: water quality monitoring which has been undertaken since 1985; ecological health monitoring which has been undertaken since 2005; biodiversity monitoring, which is still under development, and four fisheries monitoring programmes. Each of these programmes monitors a range of indicators (as shown in ***Table 4-5***) focused on the mainstream of the Mekong River although there are some sampling locations on major tributaries and around the Tonle Sap Lake and other floodplain environments.

Table 4-5: Indicators used by existing monitoring programmes of the Mekong River Commission.

Programme	Indicators	Parameters measured
Water Quality Monitoring	Human Impact on Water Quality Protection of Aquatic Life Agricultural Use	Temperature pH Alkalinity/Acidity Electrical Conductivity (EC) Dissolved Oxygen (DO) Chemical Oxygen Demand (COD) Ammonium (NH_4) Total Nitrite and Nitrate (NO_2, NO_3) Total Nitrogen (T-N) Total Phosphorus (T-P) Faecal Coliform Total Suspended Solids (TSS) Calcium (Ca) Magnesium (Mg) Sodium (Na) Potassium (K) Sulphate (SO_4) Chloride (Cl)
Ecological Health Monitoring	Benthic diatoms Zooplankton Littoral macro-invertebrates Benthic invertebrates	Species abundance Average species richness Average Tolerance Score per Taxa
Biodiversity Monitoring	- Eastern Sarus Crane	To be determined

Programme	Indicators	Parameters measured
	- *Pangasius kremfi* Catfish - Fish biodiversity in deep pools including the Mekong Dolphin in Stung Treng-Kratie - Bird diversity of riparian habitat of the Mekong mainstream - Gibbon population in Central Highland Protected area - Fish diversity in the Mekong Delta	
Fisheries Monitoring		
***Dai* capture fishery**	Fish catch and CPUE	Total annual catch Species abundance & biomass Fish size (mean weight) Population size (age) structure
***Lee* Trap capture fishery**	Fish catch and CPUE	Total annual catch Species abundance and biomass
Fish Abundance and Diversity (Small-scale artisanal) programme	Fish catch and CPUE	Abundance, biomass and diversity Fish size (mean weight)
Larvae Density programme	Fish larvae density	Abundance (per m^3)

While these indicators are clearly relevant to wetlands, noting that rivers are also wetlands under the Ramsar Convention definition, they are focused mostly on mainstream monitoring sites and not at the broader range of ecosystems classified as wetlands in the LMB. Water quality is certainly relevant to all wetland types and the parameters and methodologies used for the MRC water quality monitoring programme should essentially be applicable to wetlands more broadly. However, if the monitoring sites are located only on the mainstream or even on the tributaries in flowing water, then this programme will not pick-up some of the more localised pressures on wetlands of different types throughout the basin. The water quality monitoring programme may also be a more comprehensive indicator of some of the 'Pressures' that wetlands face given the overall quality of the water resources, rather than of wetland health or 'State' specifically. To monitor wetland state using water quality indicators would require sampling at a broader range of wetland types.

The ecological health monitoring programme undertakes monitoring of benthic diatoms, zooplankton, littoral macro-invertebrates and benthic invertebrates. Monitoring of these organisms is a useful way to pick-up early changes in the environment as they are often quite sensitive to change in flow and physicochemical conditions. Whether the same indicators and methods are relevant to other wetland types though requires consideration of the types of biota existing in those environments. Sampling techniques for a different assemblage of macro-invertebrates, for example, are likely to be different in lentic relative to lotic environments.

Biodiversity indicators are expected to be highly relevant to wetlands, although as proposed and agreed with member countries the current indicators are relatively limited in geographic scope and type. For an assessment of the overall state of the wetland resource, biodiversity indicators should be reasonably representative of the flora and fauna found across all the types of environments that are present. Monitoring of 'iconic' species can also give a useful indication of the state of, and trends in, cultural services provided by wetlands and a warning sign that impacts on other species are no doubt occurring as well, but is unlikely to provide a sufficient representation of biodiversity trends more broadly. The fish and bird diversity indicators would appear to be the most readily available, particularly if the geographic scope of bird assessments could also cover some off-river wetland and floodplain areas.

The fisheries monitoring is highly relevant to wetlands given the importance of fish to the overall ecological structure of wetlands and the ecosystem services they provide. However, as the four programmes are focused on catch data and reporting from fishers in a fairly limited range of locations they are generally a better indication of the state of human exploitation of selected components of the fishery and not of the overall status of the resource. This is particularly so given the temporal and spatial biases between fisher behaviour that often occur (Halls *et al*., 2013). Of the four programmes supported by MRC the most widespread is the Fish Abundance and Diversity Monitoring Programme (FADMP), but this is also based on a very small sample size at each location. One of the most important considerations related to fish as an indicator of ecosystem health is taking account of the relatively high inter-annual variability in catch related to hydrological conditions.

Overall, the indicators used in existing monitoring programmes could be applied to wetland areas as well. However, they are unlikely to be sufficient on their own to provide a comprehensive and clear picture of the state of the wetland resource, and there would ideally be a broader range of monitoring stations to ensure that the programme is representative of the range of wetland environments and the different resources and ecosystem services they provide.

4.3.4 Preliminary assessment and short list of options for LMB wetland biodiversity, health and function indicators

Based on a review of existing information and data available to the MRCS there is a range of options for indicators of ecological health that could be further investigated and applied to wetlands in the LMB (***Annex 7***). From this large list and potentially with the addition of others identified by member countries, it will be necessary to reduce the number to a more manageable and focused level. In doing this it is recommended that there are indicators selected covering Pressure, State and Response variables and that there are indicators that are relevant to each of the six major wetland types in the LMB (i.e. seasonally inundated forest, seasonally inundated grassland, swamps, marshes, ponds and lakes, mangroves, aquaculture and rice fields).

Applying a set of criteria to prioritise the selection of indicators to assess wetland health would best be done through one or more workshops with all member countries participating. Proposed criteria, simplified from the broader set of principles in Box 4-1 that could be used to support this are as follows:

1) The indicator relates directly to a key pressure, resource or ecosystem service of wetlands of the LMB (for example, priority might be given to those that relate more closely to hydropower development and land-use change, particularly for agriculture and aquaculture and the subsequent impact of these activities on critical ecosystem services)

2) There is a well understood conceptual link between the indicator and one or more key components (hydrological, physicochemical, biota) of wetland health

3) The indicator is sensitive to human-induced changes so that impacts can be reasonably discerned from natural variability and climate change or climate shifts over which member countries have limited to no control

4) There are existing data available across all four member countries to monitor the indicator, or monitoring can be implemented at a relatively small additional cost that member countries are willing to bear

To commence this process an initial short-list of indicators has been developed (as shown in ***Table 4-6***), based on a review of the options in ***Annex 7*** and consideration of the above criteria as indicated in ***Annex 8***. The application of the criteria in ***Annex 8*** and the choices made to short-list these indicators would require critical review and validation by Member Countries, which would likely result in a revised list as the MRC work programme on wetlands is implemented. This short-list is therefore produced principally for discussion purposes only at this stage.

Indicators have been proposed for the two driving forces of hydropower development and agricultural expansion. While there are a number of other threats to wetland health and function in the Basin (e.g. overexploitation of wetland resources), it is expected that these two will have the greatest basin-scale impacts on wetland health through changes to hydrology, sediment transport, water quality and ecological structure (MRC, 2010b). Some simple direct indicators of the magnitude of the expected pressures are readily available at the basin-scale (e.g. number of new projects and volume of non-active storage) and could be readily assessed for specific high-priority wetlands (e.g. dam sites upstream of wetland areas and wetland area converted to agriculture). Data on water abstraction for irrigation appears to be less readily available although this should be confirmed with Member Countries. At a wetland scale an indicator of catchment disturbance or ecosystem connectivity (e.g. Grill *et al*., 2012) within the catchment in which the wetland is located could also be considered. This would give an indication of the overall level of pressure on wetlands based on their location and is one commonly used in other programmes around the world (e.g. NWC, 2011; EC and US EPA, 2013).

Table 4-6: Proposed short-list of indicators of wetland biodiversity, health and function.

			Basin-scale indicators	Data sources	Wetland-scale indicators	Data sources
Pressure – driving force	Hydropower development		Number of new dams	MRC dams database	Number of new dams upstream of wetland site	MRC dams database
			Volume of non-active storage			
	Agricultural expansion		Number of new irrigation projects and area of irrigated agriculture	National datasets	Area of individual wetlands converted to agriculture	Ground survey/ monitoring
			Water abstraction for irrigation		Catchment disturbance	Land-use data
Pressure/State – impacts on wetland components	Hydrological modification	**Hydrological**	Hydrological disturbance at mainstream monitoring stations	Existing network of hydrological gauges	Hydrological disturbance at sample wetland sites (hydro-period, area of inundation, depth, timing & rate of rise and fall)	Ground survey/ monitoring
	Sediment reduction	**Physicochemical**	Quantity of TSS in the mainstream	Existing water quality monitoring	TSS and sediment flux monitoring at sample wetland sites	Ground survey/ monitoring
	Other Water quality parameters		Nutrients, salinity, pH, DO, BOD, COD.		Nutrients, salinity, pH, DO, BOD, COD, presence of heavy metals.	
	Change in community composition	**Biota**	Dominant vegetation community types across the Basin	Land-use/cover data	Dominant vegetation community types at wetland sites	Ground survey/ monitoring
State – Provisioning Services	Food – fish and OAA		Abundance, biomass and richness of fish populations at Tonle Sap and Khone Falls	*Requires new monitoring effort*	Abundance, biomass and richness of fish populations at sample wetland sites	Ground survey/ monitoring
			Catch data and CPUE	*dai* and *li* fisheries monitoring; SIMVA data		
	Fuel-wood supply		Area of flooded forest	Remote Sensing land cover data	Area of wooded area at wetland site	Ground survey/ monitoring
State – Regulating Services	Flood control		Overall wetland area	Remote Sensing land cover data	Area of sample wetlands	Ground survey/ monitoring

		Basin-scale indicators	Data sources	Wetland-scale indicators	Data sources
	Water purification	Nitrogen and phosphorus levels in the mainstream and tributaries Nutrient retention as modelled based on land cover/characteristics	Existing water quality monitoring Nitrogen/ phosphorus load retained	Nitrogen and phosphorous fluxes at sample wetland sites	Ground survey/ monitoring
State – Supporting Services	Biodiversity	No. of threatened wetland species in the LMB (fish, birds, mammals, amphibians, reptiles, macro-invertebrates)	IUCN Red List assessments Mekong Threatened Species lists	Abundance, biomass, richness of populations of selected (incl. threatened) biota	Ground survey/ monitoring
	Habitat	Area of different wetland types: Seasonally inundated forest; Seasonally inundated grassland; Marsh, swamp, pond, lake; Mangrove; Aquaculture; Rice fields	Remote Sensing land cover data	Area of key habitat types within each sample wetland site [types determined by national classification schemes]	Ground survey/ monitoring
Response	General management	Area of wetland within national protected areas	National datasets	Management plan and conservation activities in place	Public domain
	Agricultural sector management	Regulations on fertiliser and pesticide use	Public domain	Buffer zones in place	Ground survey/ monitoring
	All development management	Environmental impact assessments specifically consider impacts on wetlands	Public domain	Number and type of mitigating measures enacted	Public domain

Considering the impact of these pressures on the hydrological, physicochemical and biotic components of wetlands should lead to the selection of indicators related to change in parameters associated with each of them. Changes in hydrological parameters could be assessed using the existing mainstream gauge network at the basin-scale and through ground survey/monitoring at individual wetland sites. Change in hydrology is an indicator of the impact of a pressure but also a change to the fundamental character of the wetland itself, so important is it to the functions and services produced. The parameters measured will depend on the type of wetland and its individual characteristics but may include hydro-period, area of inundation, depth, and timing and rate of rise and fall.

Because of the impact on sediment transport of both dam construction, and potentially clearing for agriculture, some measure of sediment and/or soils should be included in the set of indicators. At the basin-scale Total Suspended Sediments are already measured through the water quality monitoring programme and this could be expanded to individual off-river wetlands as well. An indicator of sediment flux should also be considered as this relates both to the pressures of development activities but also the ecosystem services associated with nutrient cycling and soil formation. Other water quality indicators that relate to agricultural activity should include nutrients (nitrogen, phosphorous, ammonia), salinity, pH, Dissolved Oxygen, Biological Oxygen Demand and Chemical Oxygen Demand.

Biotic indicators might include measures of biodiversity as a supporting ecosystem service and a key component of wetlands, or vegetation structure as both habitat for other species and a key wetland component in its own right. This could be assessed based on dominant vegetation community types at both a basin-scale using land cover data and a wetland-scale using ground surveys.

To the extent that indicators of the health of ecosystem services are included, provisioning services related to food should be included, with fish and OAA likely to be the most pertinent. At a basin-scale this could include an assessment from monitoring data at a couple of key locations, for example the *dai* fishery at Tonle Sap and the *li* fishery at Khone falls (e.g. Halls *et al*., 2013) supported by SIMVA fish catch data, while at a local scale, field assessments at a range of high-priority wetland sites could be carried out through individual wetland assessments. Another possibility for an indicator of provisioning services would be fuel-wood production capacity as measured through the area of seasonally inundated forest or from ground surveys of wooded area at high-priority wetland sites. Hydropower is also both a provisioning service (benefit) and a potential pressure on wetlands. Data on hydropower (e.g. installed capacity) are generally available for the LMB.

Regulating services such as flood control capacity are probably best indicated at a catchment or basin-scale simply by area of wetland. This can be further refined by looking at area of wetland associated with vulnerable areas (e.g. coastal wetlands protecting infrastructure and urban settlements). This can be done through GIS approaches that link wetlands extent and location to hydrological maps. While cost of damage over time is another way to indicate a change in flood mitigation services. However, there are many confounding factors associated with this, not least of which is the difficulty in distinguishing between natural and human contribution to changes and the impacts of infrastructure development in risk prone areas. Caution must also be urged when using “cost” since this is relative and indicators should capture socio-economic impact and not simply monetary cost incurred (e.g. damaged infrastructure). At a wetland scale, consideration of outlet capacity and vegetation density might also be useful as indicators of the water retention capacity of wetlands. Water purification services would be best indicated by the water quality monitoring described earlier, with a focus on nutrients and the change in concentration at inlet and outlet zones of specific wetlands, where possible. Additional indicators might include nutrient retention derived from land use/cover and other regional hydrological, physiochemical and vegetation data.

Supporting services might include habitat provision, as indicated by area of wetland of different types, as well as different habitat types within a wetland using individual country classification schemes. Biodiversity as a resource for other services could be indicated by the number of threatened wetland species at a basin scale and abundance, biomass and richness of populations of selected biota at a wetland scale.

No indicators are currently easily available for cultural ecosystem services. Some information could be derived from other indicators such as area of natural wetland habitat for aesthetic or landscape appreciation purposes, or could be considered for cultural important 'iconic' species through the selection of indicators of biodiversity.

As documented in ***Annex 8***, all short-listed indicators clearly meet criterion one in that they are directly related to a key pressure, resource or ecosystem service of wetlands in the LMB and all are based on a strong conceptual link between the indicator and wetland health, function or service as required by criterion two. For criterion three there are some ecosystem services (i.e. food from fish and OAA, water purification, and biodiversity) where the indicators may not be as sensitive to human-induced changes relative to natural variability as others and would require some careful design consideration. For example, measurement of fish populations needs to also consider variability in hydrological conditions.

In general, data availability is good at a regional level but unknown at wetland site scale. This is something that requires confirmation with Member Countries and consideration in the finalisation of the Wetland Inventory Methodology and the Wetland Ecosystem Functions, Assets and Services Assessment and Management methodology.

Irrespective of the other indicators selected, it is essential that there is at least an assessment of the overall wetland extent for each type of wetland. This should be a foundation indicator building on the existing MRC LMB 2003 database, which although does not provide information on the health or function of wetlands specifically, clearly provides information on the quantity of wetland resource potentially available to provide the various ecosystem services upon which people depend.

For indicators selected for the assessment of ecosystem services, it is important that both 'stock' and 'flow' indicators are considered, where possible (MEA, 2005). This is because indicators that only measure 'flows' (e.g. fish catch) may not provide an indication of the state of the overall resource (e.g. fish populations) until it is too late (e.g. when fish populations have collapsed). In addition, where it is more straightforward to value ecosystem services (e.g. where the indicator is amenable to applying direct market prices), this would be a valuable aid to decision-making as it is generally a more cost effective way to determine economic value. Table 2 in Annex 7 provides the valuation techniques that are likely to be most applicable to the respective ecosystem services. Note that supporting services are generally not valued directly, as these are services required for the provision of the other services, and doing so might therefore double count the benefits (DEFRA, 2007). Further details of approaches and frameworks for ecosystem services valuation have been provided in section 3 (above).

In developing indicators of 'Response' ultimately the adequacy and effectiveness of the response will be demonstrated if there is a change in 'Pressure' or 'State' indicators linked to the action taken. Response indicators therefore generally only measure inputs or activities rather than the outputs that result from those activities. Nevertheless, they can be useful for sharing information across countries and considering what might be considered 'best practice' mechanisms to mitigate and reverse damage. In this regard, first and foremost it is important to understand what is going on – an adequate information base is essential. This can be achieved with an up-to-date wetland inventory, supported by ongoing monitoring and assessment.

Effective policy and legislative authority is also important to provide direction, guidance and coordination to national and regional efforts. This is particularly important for wetlands given the wide range of sectoral interests across the economy with which they interact (e.g. forests, water resources, energy, agriculture, urban planning, etc.). This is also an important reason for effective governance arrangements that are participatory and accountable, ensuring coordination across government and consultation with stakeholders and the broader community. Management arrangements, including planning, implementing and monitoring are also important both for conservation and restoration actions. Ideally, actions occur at a range of levels both broad-scale and site-specific, and not only at a few important sites.

It is important to consider the broader sustainable development context of wetland indicators. This implies that, as far as possible, a suite of indicators should be able to communicate the relevance of wetlands to development interests. This includes consideration of the links, or potential links, between wetlands indicators and indicators for human development in use in the LMB: for example, linking trends in fisheries with food security including trends in food consumption patterns (where other agencies often have good data). It is often the case that a set of wetland indicators is established, with robust monitoring and evaluation, but in the final analysis it is troublesome to link the information to development interests. Hence the importance of best efforts to capture information relevant to trends in ecosystem services. The best indicators of all, from a communication perspective, are those that are able to bridge the gap between trends in ecosystems and impacts on human well-being. This would include considering wetlands indicators in the context of how they inform, for example, the 2030 Agenda for Sustainable Development and Sustainable Development Goals – including beyond those goals and targets that specifically mention wetlands.

4.4 Issues to address in the development of wetland indicators

4.4.1 Technical design of wetland health indicators

Following the selection of wetland indicators, design elements that need to be considered include the specific parameters to be measured, the metrics that will be used, and the data collection and analysis techniques to be applied. These will vary subject to the indicators selected and need to be developed in consultation with relevant experts.

An important consideration in indicator design is the extent to which it is considered valuable to use the indicators as standalone representations of wetland health and function as a direct measurement (for example, in the way that indicators are used as a measure of achievement against the Sustainable Development Goals) or it is preferable to develop an 'index' of the quality and quantity of wetland resources in the LMB, similar to those used in the MRC Water Quality and Ecological Health monitoring programmes. If the latter approach is taken it will require a methodology to convert sub-indicators and indicators, through a scoring process, into a relative metric of wetland health. While this approach can be a useful representation to a general audience, it is recommended that the MRC focus first on developing and refining a good, broadly accepted set of indicators and only once that is done consider the formulation of an index that could be used for report card style reporting. In any case, it is essential that specific indicators are reported because indices that are based on an integrated set of indicators can mask significant variability between the individual components and therefore limit understanding and awareness of appropriate management responses (NWC, 2011).

If a scoring and weighting approach is used, then how scores will be aggregated needs to be determined. As an example of how this can be done, in New Zealand the Landcare Research organisation designed a protocol to rank palustrine or estuarine wetlands into priority order. This method uses landscape indicators derived from satellite images and other GIS layers. Global indicators are used (representativeness, areal extent, habitat diversity, connectivity) and assigned a value to score wetland sites in the region. The calculation is based on a hierarchy of input parameters (e.g., surface in hectares; number of wetlands in the same buffer zone) that helps define each indicator. The score is then the result of a weighted additive function, which balances the relative importance of each indicator[5]. The protocol ranks wetlands through weighted sum as follows (***Figure 4-5***):

[5] http://www.landcareresearch.co.nz/resources/maps-satellites/ecosat/applications/wetland-mapping

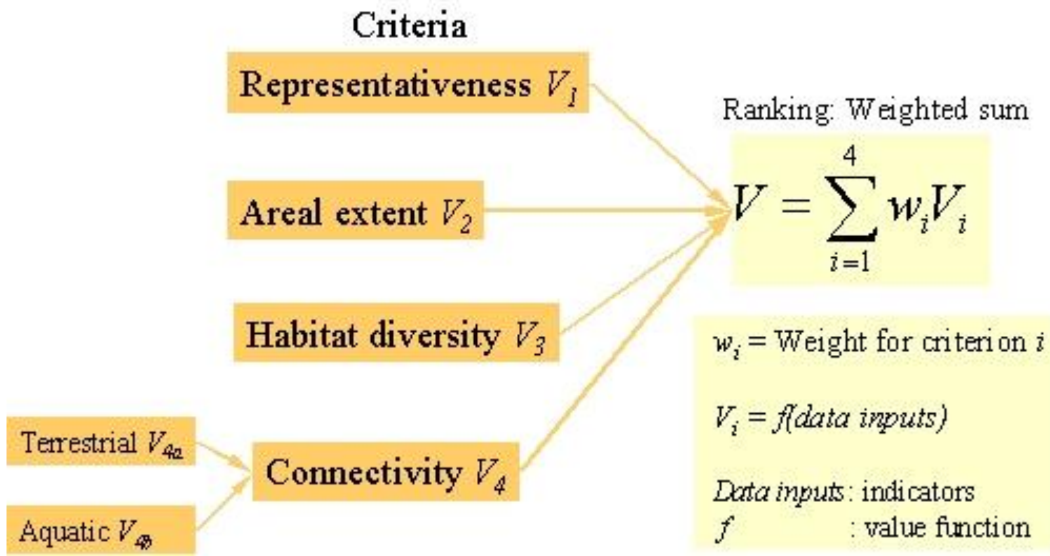


Figure 4-5: Formulation of a score to rank wetlands in New Zealand based on indicators of wetland condition.

It may be necessary to use a combination of direct measurement indicators (e.g. area of wetland) and indices, for example hydrological disturbance, that is based on several sub-indices such as hydro-period, area of inundation, and maximum depth. In this case the latter index would need to be developed with regard to a reference point or baseline.

4.4.2 Identifying a wetland reference point or baseline

Indicators of ecosystem health generally require comparison with a baseline to identify to what extent the system is healthy or not. There are two ways in which this can be done: (i) an assessment of one or more natural, relatively undisturbed wetlands of each type could be undertaken to serve as reference sites; or (ii) an initial assessment could be undertaken to serve as the baseline from which further changes are then evaluated over time.

A reference site is one that is as close as possible to conditions un-impacted by human activity (Downes *et al*. 2002). Reference sites then act as a benchmark against which change at impact sites can be compared (Cottingham *et al*. 2005). However, using reference sites is not straightforward. Firstly, because identifying sites of the same type that are un-impacted by human activity is often problematic; and secondly, because additional sites adds further costs to any monitoring effort. When multiple ecosystem types need to be considered due to the diversity of wetlands, this additional cost can be considerable and consideration needs to be given to the advantages and disadvantages associated with expanding the number of wetlands studied (Carpenter, 1990; Oksanen, 2001; Stewart-Oaten and Bence, 2001; Johnson, 2002).

The second approach is concerned only with the change in wetland health from a point in time, rather than seeking some ideal standard of wetland health as a comparison, and is essentially the approach taken by the Ramsar Convention in considering changes in ecological character, whereby the change when notification is required is identified from the time of listing of the site rather than from some presumed natural state. This approach is also consistent with an ecosystem services framework where it is the marginal change in service provision under different policy interventions that is important for decision making (DEFRA, 2007) rather than any particular quantity or quality of service provision, notwithstanding the difficulties associated with identifying thresholds and irreversibility of ecosystem functions which make economic valuation problematic in many circumstances.

The point in time that is generally used is the time that the first assessment is undertaken. Comparison is then made not to an idealised version of a natural wetland but to changes that occur only after a particular date. This may be a more cost effective approach for the LMB countries than using reference sites that may also be affected by pressures over time. Where there are existing metrics for ecosystem health (e.g. for water quality) these should be used to evaluate the extent to which deviation from the norm occurs, bearing in mind that different wetland types with different biotic assemblages may have different ranges considered to be healthy. For example, dissolved oxygen levels are often higher in flowing water than in static water, and also vary due to temperature differences.

4.4.3 Prioritising wetlands for assessment

Undertaking a wetland-scale assessment requires the selection of wetlands where monitoring and assessment can occur over a period of time. Issues to consider when prioritising wetlands include the following:

1. Be clear about the goals and objectives; what is being prioritised and why, and what action will be taken as a result. For instance, if the purpose is to select sites for management investment and conservation activities, then it is important to be clear about what kinds of activities will be in-scope. Some may be more or less relevant, or more or less costly, at different sites. If, however, the purpose is to select sites for monitoring, then it is important to consider which sites are likely to reveal the most about state and trends of similar types of wetlands. They should have characteristics representative of those of the same type and include those both likely to be impacted to a greater and lesser extent by the key threats to wetland health in the region.

2. In any prioritisation exercise it is important to always consider cost. The highest value sites may also be the most expensive to monitor and for conservation investment activities. There are two general approaches to considering cost:

    a. Select the highest value individual sites. In which case the purpose is to rank sites from highest to lowest value and select as many in the list that the budget will allow.

b. Select the highest value suite of sites. In which case the purpose is to rank the sites from highest to lowest based on benefit/cost ratio and select as many in the list as possible.

3. Consider whether or not any criteria are essential and therefore offer a binary choice rather than a ranking. For example, it may be considered essential that the site has some status under international agreements such as the Ramsar Convention in order to support Member Countries in their national reporting obligations.

4. Develop the scoring and weighting approach for each criterion, recognising that no weighting given to the criteria in effect weights all criteria equally.

5. Determine how scores will be aggregated to give an overall priority. For instance is it a simple matter of adding all scores for each criterion or should some criteria be multiplied because they have a compounding impact on each other (e.g. if having a management plan was a criterion then having a plan for a site with higher biodiversity value might be considerably more valuable than one for a site with lower biodiversity).

There are ten Ramsar sites within the LMB (as shown in ***Table 4-7***). For the purposes of undertaking a wetland assessment which might then be used to inform future conservation and management activities the recommended approach is simply to start with these ten sites, or otherwise add to this list by applying the criteria and process of wetland site selection (please refer to ***Technical Note No. 01/2017***) to the remaining wetlands on the list of 97 important wetlands in the LMB identified by member countries (Vathana, 2003; Phittayaphone, 2003; Choowaew, 2003; Thinh, 2003; MRC, 2015b).

Table 4-7: Ramsar sites by country within the Lower Mekong Basin

Ramsar sites within the Lower Mekong Basin	Country
Boeng Chhmar and Associated River System and Floodplain	Cambodia
Middle stretches of the Mekong River north of Stoeng Treng	Cambodia
Xe Champhone	Lao PDR
Beung Kiat Ngong Wetlands	Lao PDR
Nong Bong Kai non-hunting area	Thailand
Kut Ting Marshland	Thailand
Bung Khong Long non-hunting area	Thailand
Lang Sen Wetland Reserve	Viet Nam
Tram Chim National Park	Viet Nam
Mui Ca Mau National Park	Viet Nam

If this is insufficient to distinguish high-value sites for investment then additional criteria may be required. These could include ecological, economic and social aspects. For example:

- The site has recognised status under international agreement or national policy. For example, the Ramsar Convention, the National Protected Area network, as an Important Bird Area, a Biosphere Reserve or a Greater Mekong Sub-region environmental hotspot.
- The site is recognised as an important location for the provision of food and other resources upon which local livelihoods depend
- The site contains a diverse assemblage of habitats that support high biodiversity
- The site is under significant threat due to development activities
- The site supports significant cultural heritage values
- etc.

For the purposes of selecting sites for monitoring of wetland health, ideally a stratified sampling approach would be implemented to ensure a broad coverage of the overall wetland resource roughly in proportion to the different types of wetlands that exist. This would involve sub-dividing the LMB into zones and selecting wetlands of different types within those zones roughly in proportion to their overall number. This sub-division could be done using different eco-regions or different ecological zones, for example, as described in MRC (2015). For that study the eco-regions used were the 11 defined as part of a strategic conservation planning process undertaken by WWF (Baltzer *et al*., 2001), namely:

i) Cardamom Mountain rain forests
ii) Central Indochina dry forests
iii) Indochina mangroves
iv) Luang Prabang mountain rain forests
v) Northern Annamites rain forests
vi) Northern Indochina subtropical forests
vii) Northern Khorat Plateau moist deciduous forests
viii) Northern Thailand-Laos moist deciduous forests
ix) Southeastern Indochina dry evergreen forests

x) Tonle Sap freshwater swamp forests
xi) Tonle Sap-Mekong peat swamp forests

The ecological zones used were a composite of a WWF classification based on elevation, rainfall, soils and natural vegetation (Goichot, 2006) and an adaptation by ICEM in order to build on the vegetation-based characteristics of the ecoregions by explicitly including geophysical and hydrological characteristics (MRC, 2015b). The ten zones are:

i) Mid-elevation dry broadleaf forest
ii) Low-elevation dry broadleaf forest
iii) Low-mid elevation moist broadleaf forest
iv) High-elevation moist broadleaf forest
v) Swampy forest Tonle Sap
vi) Upper floodplain wetland, lake (CS to VTE)
vii) Mid floodplain, wetland, lake (VTE to Pakse)
viii) Lower floodplain, wetland, lake (Pakse to Kratie)
ix) Lower floodplain, wetland, lake (Kratie to Delta)
x) Mangrove/delta

Given the inclusion in the latter list of physical and hydrological characteristics in addition to a biotic component, this regionalisation would be preferable to the former. This use of eco-regions would also align with the MRC Climate Change Adaptation Initiative work on the Basin-wide impacts of climate change on ecosystems. However, the main purpose is simply to ensure a broad coverage of the overall wetland resource across the Basin and so either approach would be reasonable.

It is also important to consider not only ecological zoning but also the zoning of wetlands with regards to socio-economic setting including threats to their health. For example, one drawback with selecting high biodiversity sites or some Ramsar Sites can be that they are often located in relatively more remote locations and subject to less immediate threat that wetlands located, for example, near to major urban settlements or areas vulnerable to agricultural expansion. Information is required on the overall status and trends in wetlands in the LMB – and not just charismatic or high biodiversity value sites – otherwise monitoring and indicators can give a false impression of overall trends. A related consideration is that the location of a wetland is a critical factor with regards to the extent of ecosystem services that it delivers. For example, a wetland might have high levels of flood regulation services if influencing the hydrology of areas near flood vulnerable infrastructure and communities; but the same wetland, with the same hydrology, located in an area that does not influence vulnerable areas will have much lower (or no) flood regulation services.

4.4.4 Evaluating wetland biodiversity, health, function and services using indicators

Indicators are just that, indicators. They provide an indication of wetland health and function and are not of themselves a comprehensive assessment. To be used as a basis for a comprehensive assessment requires extrapolation or inferences to be made about broader ecosystem changes.

For this reason it is important to be clear about any regionalisation or classification of wetlands within the LMB so that indicators of change across the Basin can be inferred or extrapolated from change at locations which are considered ecologically similar. It is therefore necessary for the regionalisation and classification approach to be agreed up front and not to change significantly over time. As a result, a broader classification approach such as the identification of six broad wetland classes for MRC (2011) would be preferable to one with a large number of highly detailed delineations. To the extent that there are more detailed classification systems within Member Countries, these should still be mapped and aligned in a hierarchical way as sub-classes to the broader regional classification.

When it comes to making inferences, sampling design is especially important to ensure a statistically significant sample relative to the population (Steele, 2001). In determining wetland health and function a stratified random sampling approach would be beneficial. This would involve the sampling of random wetland areas of different classes within defined ecological units (e.g. eco-regions). However, the cost of the monitoring effort required to do this is likely to be prohibitive in the foreseeable future, and as noted earlier it may therefore only be feasible to commence an assessment of high priority wetlands, relying on regional basin-wide data to provide an assessment of the overall state of the resource until sufficient numbers of priority wetland areas have been added to the sample set over time.

Indicators that are useful for decision-making would ideally be amenable to modelling to predict changes associated with different development actions. Those that can be linked to hydrological changes (e.g. fish productivity, sediment supply) or land-use changes (e.g. landscape nutrient retention) through existing models are therefore ideal.

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6. ANNEXES

Annex 1: Main wetland types, important resources, functions and threats as identified in 2003 inventory and assessment for each country

	Number and area of important sites in Mekong Basin	Main wetland types	Important Resources and Attributes identified	Key functions identified	Key threats identified	Information on wetland health / biological resources
Cambodia	24 1,255,150 ha	Flooded evergreen forest Flooded forest, fallow land Swampy vegetation Grassland susceptible to flooding Paddy fields (rainfed) Receding rice fields Mangrove Open water areas, lakes, etc.	Fisheries Water supply Energy supply Genetic resources Biological diversity	Groundwater recharge Flood control/protection Nutrient transport and retention Habitat provision	Deforestation/clearing Drainage/reclamation/modification Modified hydrological regime Pollution Sedimentation/siltation Over-exploitation of resources	Includes names of important species (fish, birds, other vertebrates) at important wetland sites
Laos PDR	13 141,300 ha	Permanent and seasonal flooded forest (Swamp) Large pools in rivers Perennial rivers Permanent dam/reservoir Rice fields	Fisheries Agricultural resources Water supply Genetic resources Biological diversity Cultural significance Landscape and aesthetic Wilderness	Groundwater recharge Protection from natural forces Flood control Nutrient/toxicant retention Nutrient transport Research/education Habitat provision	Drainage/reclamation/modification Modified hydrological regime Pollution Sedimentation/erosion Overharvesting incl. destructive harvesting practices Invasion and spread of alien species Inappropriate management	Includes some numbers and names of different species (fish, reptile, other animal) and dominant vegetation types at important wetland sites
Thailand	39 1,601,082 ha	Riverine: Permanent rivers & streams with perennial rapids Riverine: Banks, beaches and bars Riverine floodplain: Floodplains wet rice, including rainfed & irrigated rice Riverine floodplain: Seasonal backswamps & marshes Lacustrine: Permanent freshwater lakes Lacustrine: Permanent dams & reservoirs Lacustrine: Seasonal freshwater lakes, including floodplain lakes	Forest resources Wildlife resources Fisheries Forage resources Flora resources Agricultural resources Water supply Energy supply Clay/Sand/Salt resources Medicinal resources Biological diversity Unique cultural heritage Trans-boundary significance	Groundwater recharge Groundwater discharge Flood control/protection Shoreline stabilisation/erosion control Sediment/toxicant retention Nutrient retention Biomass export Storm protection/windbreak Micro-climate stabilisation Water transport Recreation/tourism Education/outreach	Encroachment/modification Modified hydrological regime Development projects Sedimentation/erosion Pollution Illegal hunting/harvesting Over-exploitation of resources Invasion of alien species Excessive growth of aquatic plants Water allocation Salinity Tourism Deforestation/illegal logging Inappropriate management	Includes numbers of different species (fish, birds, plants, mammals, reptiles, insects), important and threatened species at important wetland sites
Viet Nam	10 95,259 ha	Seasonally swamp forest Mangrove forest swamp Permanent rivers and canals Grass swamps Rice fields	Forest resources Water supply Fisheries Agricultural resources Biological diversity	Flood control/protection Improved water quality Sediment retention (and accumulation) Pollutant dilution/dispersal Nutrient transport and retention Carbon sink/biomass production Water transport (navigation) Recreation/tourism Habitat provision	Encroachment/Modification Modified hydrological regime Development projects (reduced) Sedimentation/erosion Pollution Invasion of alien species	Includes numbers of different species (fish, birds, plant), important and threatened species, and dominant vegetation types known at important wetland sites

Annex 2: List of Threatened Mekong Fauna

No.	Scientific name	Common name	Global threat status: Critically Endangered	Global threat status: Endangered	Global threat status: Vulnerable	Cambodia	Lao P.D.R.	Thailand	Viet Nam
	MAMMALS		1	4	2	7	7	6	6
1	*Lutrogale perspicillata*	Smooth-coated otter			VU	x	x	x	x
2	*Lutra sumatrana*	Hairy-nosed otter		EN		x	x	x	x
3	*Aonyx cinerea*	Small-clawed otter			VU	x	x	x	x
4	*Prionailurus viverrinus*	Fishing cat		EN		x	x	x	x
5	*Orcaella brevirostris*	Irrawaddy dolphin (Mekong population)	CR			x	x		
6	*Axis porcinus*	Hog deer		EN		x	x	x	x
7	*Rucervus eldii*	Eld's deer		EN		x	x	x	x
	BIRDS		3	6	10	13	9	16	16
8	*Acrocephalus tangorum*	Manchurian reed-warbler			VU	x	x	x	x
9	*Anas formosa*	Baikal teal			VU			x	
10	*Aythya baeri*	Baer's pochard		EN				x	x
11	*Cairina scutulata*	White-winged duck		EN		x	x	x	x
12	*Egretta eulophotes*	Chinese egret			VU			x	x
13	*Grus antigone*	Sarus crane			VU	x	x		x
14	*Grus nigricollis*	Black-necked crane			VU				
15	*Haliaeetus leucoryphus*	Pallas's fish-eagle			VU	x		x	
16	*Heliopais personata*	Masked finfoot			VU	x	x	x	x
17	*Houbaropsis bengalensis*	Bengal florican	CR			x			x
18	*Leptoptilos dubius*	Greater adjutant		EN		x	x	x	x
19	*Leptoptilos javanicus*	Lesser adjutant			VU	x	x	x	x
20	*Mergus squamatus*	Scaly-sided merganser		EN				x	x
21	*Mycteria cinerea*	Milky stork			VU	x		x	x
22	*Platalea minor*	Black-faced spoonbill		EN				x	x
23	*Pseudibis davisoni*	White-shouldered ibis	CR			x	x	x	x
24	*Rynchops albicollis*	Indian skimmer			VU	x	x	x	x
25	*Pseudibis gigantea*	Giant ibis	CR			x	x	x	x
26	*Tringa guttifer*	Spotted greenshank		EN		x		x	x
	REPTILES		5	4	5	10	10	11	13
27	*Amyda cartilaginea*	Asiatic softshell turtle			VU	x	x	x	x
28	*Batagur baska*	Mangrove terrapin	CR			x		x	x
29	*Chitra chitra*	Southeast Asian striped softshell turtle	CR					x	
30	*Crocodylus siamensis*	Siamese crocodile	CR			x	x	x	x
31	*Cuora amboinensis*	Asian box turtle			VU	x		x	x
32	*Cuora trifasciata*	Chinese three-striped box turtle	CR				x		x
33	*Cuora galbinifrons*	Indochinese box turtle	CR			x	x		x
34	*Heosemys grandis*	Giant Asian pond turtle			VU	x	x	x	x
35	*Hieremys annandalii*	Yellow-headed temple turtle		EN		x	x	x	x
36	*Malayemys subtrijuga*	Malayan snail-eating turtle			VU	x	x	x	x
37	*Pelochelys cantorii*	Giant softshell turtle		EN		x	x	x	x
38	*Platysternon megacephalum*	Big-headed turtle		EN			x	x	x
39	*Sacalia quadriocellata*	Four-eyed turtle		EN			x		x
40	*Siebenrockiella crassicollis*	Black marsh turtle			VU	x		x	x
	AMPHIBIANS		0	1	10	3	6	0	9
41	*Bombina microdeladigitora*	Small-webbed bell toad			VU				x
42	*Leptobrachium banae*	Red-legged leaflitter toad			VU	x	x		x
43	*Limnonectes toumanoffi*	Toumanoff's wart frog			VU	x			x
44	*Nanorana liui*				VU				
45	*IngeranaLiui*				VU				
46	*Quasipaa spinosa*	Giant spiny frog			VU		x		x
47	*Nanorana yunnanensis*	Yunnan spiny frog		EN			x		x
48	*Odorrana jingdongensis*				VU		x		x
49	*Rhacophorus annamensis*	Annam flying frog			VU	x			x
50	*Kurixalus baliogaster*				VU		x		x
51	*Rhacophorus exechopygus*				VU		x		x
	FISH		5	6	2	9	8	13	6
52	*Yasuhikotakia sidthimunki*	Dwarf botia	CR				x	x	
53	*Chela caeruleostigmata*	Leaping barb	CR			x		x	
54	*Dasyatis laosensis*	Mekong freshwater stingray		EN		x	x	x	x
55	*Himantura chaophraya*	Giant freshwater stingray			VU			x	
56	*Himantura oxyrhynchus*	Marbled freshwater stingray		EN		x	x	x	
57	*Himantura signifer*	White-edged freshwater whipray		EN			x	x	
58	*Pangasianodon gigas*	Mekong giant catfish	CR			x	x	x	x
59	*Pristis microdon*	Freshwater sawfish	CR			x		x	
60	*Pristis zijsron*	Narrowsnout sawfish	CR			x		x	x
61	*Probarbus jullieni*	Jullien's golden carp		EN		x	x	x	x
62	*Puntius speleops*				VU			x	
63	*Scleropages formosus*	Asian arowana		EN		x	x	x	x
64	*Tenualosa thibaudeaui*	Laotian shad		EN		x	x	x	x
	Total		14	21	29	42	40	46	50

Source: MRC (2010a) modified from WWF and IUCN Red List.

Annex 3: Population trend and recent change of status for Threatened Mekong Fauna

Species [wetland/terrestrial][key threats]	Population trend	Status change
Mammals		
Smooth coated Otter [ws][hl]	decreasing ➘	Nil
Hairy-nosed Otter [ws][hl/ht]	decreasing ➘	Vulnerable to Endangered ➘
Small-clawed Otter [ws][hl]	decreasing ➘	Near Threatened to Vulnerable ➘
Fishing Cat [ws][hl]	decreasing ➘	Vulnerable to Endangered ➘
Irrawaddy Dolphin (Mekong population) [ws][ht]	decreasing ➘	Nil
Hog deer [ws][hl/ht]	decreasing ➘	Nil
Eld's deer [ts][hl/ht]	decreasing ➘	Vulnerable to Endangered ➘
Birds		
Manchurian reed warbler [ws][hl]	decreasing ➘	Nil
Baikal teal [ws][ht]	increasing ➚	Nil
Baer's pochard [ws][hl/ht]	decreasing ➘	Nil
White-winged duck [ws][hl]	decreasing ➘	Nil
Chinese egret [ws][hl/ht]	decreasing ➘	Nil
Sarus crane [ws][hl/ht]	decreasing ➘	Nil
Black-necked crane [ws][hl]	decreasing ➘	Nil
Pallas's fish-eagle [ws][hl]	decreasing ➘	Nil
Masked finfoot [ws][hl]	decreasing ➘	nil
Bengal florican [ts][hl]	decreasing ➘	nil
Greater adjutant [ws][hl/ht]	decreasing ➘	Nil
Lesser adjutant [ws][hl]	decreasing ➘	Nil
Scaly-sided merganser [ws][hl]	decreasing ➘	Nil
Milky stork [ws][hl/ht]	decreasing ➘	Vulnerable to endangered ➘
Black-faced spoonbill [ws][hl/ht]	stable ➔	Nil

Species [wetland/terrestrial][key threats]	Population trend	Status change
White-shouldered ibis [ws][hl/ht]	decreasing ➘	Nil
Indian skimmer [ws][hl]	decreasing ➘	Nil
Giant ibis [ws][hl/ht]	decreasing ➘	Nil
Spotted greenshank [ws][hl/ht]	decreasing ➘	Nil
Reptiles		
Asiatic softshell turtle [ws][ht]	-	Nil
Mangrove terrapin [ws][ht]	-	Endangered to Critically Endangered ➘
Southeast Asian striped softshell turtle [ws][ht]	-	Nil
Siamese crocodile [ws][hl/ht]	decreasing ➘	Endangered to Critically Endangered ➘
Asian box turtle [ws][ni]	-	Nil
Chinese three-striped box turtle [ws][ni]	-	Endangered to Critically Endangered ➘
Indochinese box turtle [ts][ni]	-	Nil
Giant Asian pond turtle [ws][ni]	-	Nil
Yellow-headed temple turtle [ws][hl/ht]	-	Vulnerable to Endangered ➘
Malayan snail-eating turtle [ws][hl]	-	Nil
Giant softshell turtle [ws][hl/ht]	-	Vulnerable to Endangered ➘
Big-headed turtle [ws][ht]	-	Nil
Four-eyed turtle [ws][ni]	-	Vulnerable to Endangered ➘
Black marsh turtle [ws][hl/ht]	-	Nil
Amphibians		
Small-webbed bell toad [ni]	-	Nil
Red-legged leaflitter toad [ws][hl]	decreasing ➘	Nil
Toumanoff's wart frog [ws][hl]	decreasing ➘	Nil
Nanorana liui [ws][hl/ht]	decreasing ➘	Nil
Ingerana Liui [ws][hl]	decreasing ➘	Nil
Giant spiny frog	decreasing ➘	Nil

Species [wetland/terrestrial][key threats]	Population trend	Status change
[ws][hl/ht]		
Yunnan spiny frog [ws][hl/ht]	decreasing ↘	Nil
Odorrana jingdongensis [ws][hl/ht]	decreasing ↘	Nil
Annam flying frog [ws][hl]	decreasing ↘	Nil
Kurixalus baliogaster [ws][hl]	decreasing ↘	Nil
Rhacophorus exechopygus [ws][hl]	decreasing ↘	Nil
Fish		
Dwarf botia [ws][hl/ht]	decreasing ↘	Critically Endangered to Endangered ↘
Leaping barb [ws][hl]	decreasing ↘	Critically endangered to Endangered ↘
Mekong freshwater stingray [ws][hl/ht]	decreasing ↘	Nil
Giant freshwater stingray [ws][hl/ht]	decreasing ↘	Nil
Marbled freshwater stingray [ws][hl/ht]	-	Nil
White-edged freshwater whipray [ws][hl/ht]	-	Nil
Mekong giant catfish [ws][hl/ht]	decreasing ↘	Vulnerable to Critically Endangered ↘↘
Freshwater sawfish [ws][hl/ht]	decreasing ↘	Nil
Narrowsnout sawfish [ws][hl/ht]	decreasing ↘	Endangered to Critically Endangered ↘
Jullien's golden carp [ws][ht]	decreasing ↘	Nil
Puntius speleops [ws][ht]	stable →	Nil
Asian arowana [ws][hl/ht]	decreasing ↘	Nil
Laotian shad [ws][hl/ht]	decreasing ↘	Endangered to vulnerable ↗

Remark: ***Wetland or terrestrial species***

[ws] = wetland species for some or all of its life-cycle; 60 of 63

[ts] = terrestrial species only; 3 of 63

Threats – reasons for declining populations

[hl] = habitat loss (including degradation due to pollution or reduction in prey); 49 of 63

[ht] = harvest and trade (whether directly or as bycatch); 37 of 63

[ni] = no information; 6 of 63

Annex 4: Change in land-use between 2003 and 2010 for wetland-related land cover.

Land Cover Types	in 2003		in 2010		Area Variation of land cover	
	Ha	%	Ha	%	Ha	%
Total Area	**67,740,486**	**100**	**67,740,486**	**100**		
Flooded Forest	472370	0.70%	511680	0.76%	39309	8.32%
Grassland	2209475	3.26%	892976	1.32%	-1316499	-59.58%
Mangrove	198383	0.29%	132629	0.20%	-65755	-33.15%
Marshes/ Swamp area	104538	0.15%	281611	0.42%	177073	169.39%
Aquaculture	431298	0.64%	709006	1.05%	277709	64.39%
Water body	1309804	1.93%	1698823	2.51%	389019	29.70%

Source: IKMP (2015)

Annex 5: Monitoring scores determined by Birdlife International for Important Bird Areas that are likely to contain wetlands with the Lower Mekong Basin. Condition scores were based on an assessment of habitat suitability.

Cambodia

Site	Monitoring	Threats status score	Condition status score	Action status score
Beuung Chhmar / Moat Khla	2009	very high	unfavourable	high
Dei Roneat	-	-	-	-
Prek Toal	2008	medium	near favourable	medium
Preah Net Preah / Kra :anh / Pourk	2007	high	very unfavourable	low
Stung / Chi Kreng / Kampong Svay	2013	high	-	low
Lower Stung Sen	2008	medium	unfavourable	low
Chhnuk Tru	-	-	-	-
Veal Srongae	2009	high	very unfavourable	low
Stung Sen / Santuk / Baray	2009	high	unfavourable	low
Northern Santuk	2009	high	very unfavourable	negligible
Ang Tropeang Thmor	2010	medium	very unfavourable	high
Basset Marsh	2009	high	unfavourable	negligible
Boeung Veal Samnap	2009	high	near favourable	negligible
Bassac Marsh	2009	very high	favourable	negligible
Mekong River from Kratie to Lao PDR	2009	high	very unfavourable	low
Upper Stung Sen Catchment	2008	high	unfavourable	medium
O Skach	2009	high	-	negligible
Chhep	2009	high	very unfavourable	medium
Western Siem Pang	2013	high	-	low
Sekong River	-	-	-	-
Sesan River	2013	very high	-	negligible
Lomphat	2013	very high	-	low
Upper Srepok catchment	2009	medium	favourable	medium
Mondulkiri – Kratie lowlands	2009	very high	-	low
Snoul / Keo Sema / O Reang	2009	very high	-	low
Boeung Prek Lapouv	2010	medium	favourable	high
Kampong Trach	2013	very high	-	low

Laos PDR

Site	Monitoring	Threats status score	Condition status score	Action status score
Dong Khantung	2008	medium	-	low
Siphandon	2008	medium	-	negligible
Mekong River from Phou Xiang Thong to Siphandon	2008	low	-	negligible
Xe Khampho / Xe Pian	-	-	-	-
Attapu Plain	2008	high	-	negligible
Phou Xiang Thong	2008	high	-	low
Upper Xe Bangfai	2008	high	-	negligible
Nakai Plateau	-	-	-	-
Phou KhaoKhoay	2008	medium	-	low
Mekong River from Luang Prabang to Vientiane	2008	high	-	negligible
Upper Lao Mekong	2008	medium	-	negligible

Thailand

Site	Monitoring	Threats status score	Condition status score	Action status score
Mekong Channel near Pakchom	-	-	-	-
Nong Bong Kai	2007	high	very unfavourable	low
Nam Nao	-	-	-	-
Phu Khieo	2007	medium	unfavourable	High

Viet Nam

Site	Monitoring	Threats status score	Condition status score	Action status score
Tram Chim	-	-	-	-
Lang Sen	-	-	-	-
Kien Luong	2008	high	near favourable	negligible
Ha Tien	2008	high	very unfavourable	negligible
U Minh Thuong	2008	medium	very unfavourable	medium
Ca Mau	-	-	-	-
Bac Lieu	2008	medium	unfavourable	medium
Dat Mui	-	-	-	-
Tra Cu	-	-	-	-
Chua Hang	-	-	-	-
Bai Boi	-	-	-	-
Ba Tri	-	-	-	-
Binh Dai	-	-	-	-

Annex 6: Lists of high priority wetlands in each LMB country as published in MRC (2015a) and identified in 2003 country reports (Vathana, 2003; Phittayaphone, 2003; Choowaew, 2003; Thinh, 2003), with additional sites identified in Lao PDR by P. Phiapalath for MRC (2015a) and in Viet Nam by Viet Nam EPA (2005).

List of important wetland sites in Cambodia

No.	Wetland Site	Location	Coordinates		Area (ha)	Marsh	River/ Creek	Lake	Flooded Forest	Rice Field	Lotus Field	Stream
1	Stung Treng Mekong River Flooded Forest	Stung Treng Provincial Town	13° 11' 50" - 13° 56' 00" N	105° 52' 00" - 106° 03' 50" E	48,000		X		X	X		
2	Tonle Sekong River System	Stung Treng	13° 31' 00" - 14° 28' 00" N	105° 57' 30" - 106° 26' 00" E	34,750		X		X			
3	Tonle Sesan River System	35 km from Ratanakiri Provincial Town	13° 32' 00" - 14° 06' 00" N	105° 58' 00" - 107° 27' 50" E	146,250		X					
4	Tonle Sre Pork River System	30 km from Ratanakiri Provincial Town in the South	13° 01' 15" - 13° 33' 20" N	106° 17' 30" - 107° 30' 00" E	157,500	X	X		X			X
5	Kratie River System	Kratie	12° 08' 35" - 13° 12' 00" N	105° 28' 50" - 106° 09' 00" E	142,250		X		X	X		
6	Peam Chileang Mekong River System	10 km from Kampong Cham Provincial Town in the N-E	12° 00' 00" - 12° 18' 30" N	105° 28' 50" - 105° 52' 00" E	63,750	X	X	X				
7	Siem Bok Mekong River System	Kampong Cham	11° 50' 10" - 12° 00' 00" N	105° 02' 00" - 105° 29' 00" E								
8	Boeung Veal Sam Nap	10 km in the North-East of Phnom Penh	11° 33' 17" - 11° 38' 25" N	105° 00' 15" - 105° 06' 00" E	10,850	X		X	X			
9	Boeung Prang	11 km in the North-East of Phnom Penh	11° 32' 00" - 11° 45' 25" N	105° 07' 00" - 105° 15' 00" E	12,600	X		X	X	X		
10	Boeung Pring	Prey Veng Province about 30 km from Neak Loeung	11o 22' 15" - 11o 29' 27" N	105o 23' 00" - 105o 26' 15" E	16,000	X		X	X			
11	Boeung Khsach Sor	Prey Veng	11o 23' 00" - 11o 22' 15" N	105o 19' 17" - 105o 23' 28" E		X		X	X			
12	Upper Stung Sen Creek System	55 km in the South-West of Preah Vihea Province	13o 48' 00" - 14o 13' 00" N	104o 32' 20" - 104o 58' 30" E	80,000	X	X			X		
13	Prek Toal	Battambang	12o 59' 00" - 13o 20' 30" N	103o 26' 30" - 103o 43' 25" E		X	X	X	X			
14	Moat Peam	15 km in the South of Siem Reap Provincial Town	13o 03' 00" - 13o 19' 00" N	103o 43' 00" - 104o 12' 00" E	45,000	X		X	X	X		
15	Stung Daun Try	60 km from Pursat Provincial Town in the North-East	12o 44' 00" - 13o 00' 00" N	103o 37' 00" - 103o 53' 00" E	103,000	X	X	X	X	X		
16	Pursat Great Lake System	25 km in the North of Pursat Provincial Town	12o 28' 00" - 12o 51' 00" N	103o 52' 30" - 104o 23' 35" E	55,000	X		X	X	X		
17	Moat Khla	Siem Reap	12o 44' 15" - 13o 04' 00" N	103o 08' 00" - 104o 15' 00" E	45,000	X		X	X	X		
18	Boeung Chhmar	Kampong Thom	12o 44' 25" - 12o 55' 20" N	104o 15' 10" - 104o 22' 00" E	33,000	X	X	X	X	X		
19	Lower Stung Sen	15 km in the West of Kampong Thom Town	12o 31' 50" - 12o 49' 00" N	104o 27' 40" - 104o 47' 00" E	61,200	X	X	X	X	X		
20	Boeung Veal Pork	10 km from Kampong Chhnang Provincial Town	12° 17' 00" - 12° 32' 00" N	104° 02' 00" - 104° 45' 00" E	56,500	X	X	X	X	X		
21	Boeung Thom	About 5 km in the last of Kampong Chhnang Provincial Town	12° 09' 00" - 12° 31' 10" N	104° 42' 00" - 104° 59' 00" E	72,500	X	X	X	X	X		
22	Boeung Sam Rong	Kandal	11° 39' 10" - 11° 42' 00" N	104° 46' 20" - 104° 48' 10" E		X		X	X	X	X	
23	Boeung Ta Mouk	Kandal	11° 37' 00" - 11° 40' 00" N	104° 46' 25" - 104° 48' 20" E		X		X	X	X	X	
24	Prasat Tuyav Lake	South-East of Phnom Penh about 57 km (Kandal Province)	11° 07' 00" - 11° 12' 20" N	105° 05' 27" - 105° 10' 00" E	72,000	X		X	X	X	X	

List of important wetland sites in Lao PDR

No	Wetland	Location/ Province	Geographic coordinate	Areas ha	Perrennial river	Seasonal river	Large pools in river	Riverine floodplain	Flooded forest	Permanent lakes	Dam/reservoir	Permanet ponds	Pasture/grass	Marsh/Swamp	Rice fields
1	Nam Ngum Reservoir	Vientiane & Vientiane Prefecture	18°12'N -102°48'E	25,000	x	x				x	x	x	x		
2	That Luang Swamp	Vientiane Prefecture	17º56'N- 102º39' E	2,000	x			x				x		x	
3	Nong Chanh	Vientiane Prefecture	17º56'N-02º37'30" E	2,300	x					x		x			
4	Nam Theun	Khammuane	17º45'N -105º10' E	5,000	x	x	x	x							
5	Nongluang Wetland Group	Savannakhet	16º15'N -105º22' E		x	x				x			x		x
6	Xe Champhon	Savannakhet	16º 35'N - 16º18'N/ 105º12'E -105º18'E	24,000	x	x	x	x	x	x	x	x	x	x	x
7	Dong Hua Sao	Champasack	14º58'N -106º06' E	30,000	x	x		x				x	x		
8	Bung Nong Ngom Wetland Group	Champasack	14º46'N-06º3'30"E	800					x	x		x		x	x
9	Seephandon Wetland	Champasack	14º 56'N- 14º40'N/ 105º59'E-106º 06'E	6,000	x	x	x	x	x						
10	Xe Kong Plain	Champasack, Attapeu	14º 27'N - 14º 39'E/ 106º17'N-106º29'E	35,000	x					x		x			
11	Xe pian-Xe hampho	Attapeu	14º 44'N-106º 24'E	2,000						x		x		x	
12	Nong FA	Attapeu	15º6'30" N-107º25'20"E	100						x					
13	Vang Tat Wetland	Sekong-Attapeu	15º2'30" N-107º28'E	100						x		x	x		
14	Nong Kham Sean	Sithanua, Vientiane		15									x	x	
15	Nong Veng	Sithanua, Vientiane		30									x	x	
16	Limestone lake	Hinboun, Khammouane		1								x			

List of important wetland sites in Thailand

	Names of Sites	Province(s)	Geographic coordinates	Areas / Length	Floodplains	Rivers and streams	River pools	Rapids	Lakes	Ponds	Marshes	Grassland	Ricefields	Flooded forests	Reservoir
1	Chiang Saen Basin including Nong Bong Khai Wildlife Non-Hunting Area	Chiang Rai	20.24549 N / 100.05019 E	6,240 ha	x	x			x		x		x		
2	Nong Luang	Chiang Rai	19.84459 N / 99.94636 E	1,471 ha					x		x	x	x		
3	Nong Hang	Chiang Rai	19.49296 N / 99.79610 E	279 ha							x				
4	Nong Leng Sai	Phayao	19.35629 N / 99.82786 E	960 ha							x				
5	Kwan Phayao	Phayao	19.16333 N / 99.90584 E	2,053 ha					x		x				
6	Kok River	Chiang Rai, Chiang Mai	19' 30" – 20' 12" N, 99' 10" – 100' 08" E	290 km		x	x								
7	Bung Khong Long Wildlife Non-Hunting Area	Nong Khai	17.96158 N / 104.03189 E	1,290 ha					x		x				
8	Lower Nam Mong Basin	Nong Khai	17' 48-57" N, 102' 31-38" E	240 ha		x			x	x	x		x		
9	Nong Hua Khu Wildlife Non-Hunting Area	Udorn Thani	17' 35" N, 102' 37" E (17.58821 N / 102.59868 E)	11 ha							x				
10	Nong Han Kumphawapi	Udorn Thani	17.11328 N / 103.02025 E	4,500 ha					x		x		x		
11	Nong Han	Sakhon Nakhon	17.26017 N / 104.15562 E	12,520 ha					x		x				
12	Nong Waeng Wildlife Non-Hunting Area	Chaiyaphum	15' 55-56" N, 102' 16-17" E	20 ha							x				
13	Bung Lahan	Chaiyaphum	15.599063 N / 101.894060 E	2,909 ha					x		x				
14	Mun River and flooded forests	Maha Sarakham, Buriram, Surin, Sisaket	15' 28" N, 103' 00" E – 15' 08" N, 104' 25" E	60,400 ha	x	x	x	x			x			x	
15	Mun River alongside Kaeng Tana National Park	Ubon Ratchathani	15' 18" N, 105' 29" E	8,000 ha		x	x	x							
16	Lam Nam Chi	Chaiyaphum	15'54" N, 102' 20" E – 15'59" N, 102' 24" E	1,000 ha	x	x			x		x				
17	Confluence of the Mun and Chi Rivers	Sisaket, Ubon Ratchathani	15' 10-15" N, 104' 35-50" E	9,750 ha	x	x					x	x	x	x	
18	Lam Plai Mat	Buriram	14' 47-50" N, 102' 52-58" E	1,900 ha	x	x					x	x	x	x	
19	Huai Chorakhe Mak Reservoir Wildlife Non-Hunting Area	Buriram	14.90878 N / 103.05183 E	620 ha											x
20	Huai Talat Reservoir Wildlife Non-Hunting Area	Buriram	14' 51-53" N, 103' 03-06" E	709 ha											x
21	Sanambin Reservoir Wildlife Non-Hunting Area	Buriram	14' 38-39" N, 103' 04-06" E	571 ha							x	x	x		x
22	Lam Dome Yai and wetlands of Pa Yot Dome Wildlife Sanctuary	Ubon Ratchathani	14' 13-30" N, 104' 59" - 105' 07" E	30 km; 22,540 ha	x	x	x	x							
23	Goot Ting Reservoir	Nong Khai	18.29675 N / 103.66212 E	2,200 ha											x
24	Nong Kom Ko	Nong Khai	17.82969 N / 102.72790 E	944 ha	x						x				
25	Nong Din Dam	Chaiyaphum	16' 24" N, 102' 07" E	22 ha					x		x				
26	Nong Bua Ban Khwao	Chaiyaphum	15' 46" N, 101' 55" E	12 ha						x					
27	Nong Tahan	Ubon Ratchathani	14' 58" N, 104' 56" E	11 ha						x					
28	Nong Khai Lake	Nong Khai	17' 52" N, 102' 48" E	400 ha					x						
29	Nong Gah Sark/Nong Lahan Key Nok	Chaiyaphum	15' 36" N, 102' 03" E	235 ha											x
30	Nong Bung Rawee	Chaiyaphum	15' 46" N, 101' 47" E	250 ha					x		x				
31	Wetlands of Phu Khieo Wildlife Sanctuary	Chaiyaphum	16' 05-35" N, 101' 21-55" E	156,000 ha	x	x					x				
32	Mekong River	Chiang Rai, Loei,	20' 00-10" N, 100' 15-30" E	> 2,400 km		x	x	x							
32	Mekong River	Nong Khai, Nakhon Phanom, Mukdahan, Amnaj Charoen, Ubon Ratchathani	20' 00-10" N, 100' 15-30" E	> 2,400 km		x	x	x							
33	Songkhram River and its floodplains	Udorn Thani, Sakhon Nakhon, Nong Khai, Nakhon Phanom	17.63888 N / 104.24416 E	1,300,100 ha	x	x								x	
34	Doon Lam Pan Wildlife Non-Hunting Area	Maha Sarakham	15' 46-47" N, 103' 01-02" E	50 ha		x					x				
35	Nong Pla Koon	Roi Et	16' 02" N, 104' 02" E	80 ha	x						x				
36	Bung Klua / Bo Kae	Roi Et	16.018181 N / 104.020068 E	75 ha											x
37	Nong Sam Muen	Chaiyaphum	16' 23-25" N, 102' 00-07" E	560 ha	x						x				
38	Kaeng La Wa	Khon Kaen	16' 05-11" N, 102' 40-43" E	1,120 ha	x				x						
39	Huai Sua Ten	Khon Kaen	16' 45-48" N, 102' 45-48" E	1,040 ha	x	x									x

List of important wetland sites in Viet Nam

No	Wetland site	Location/ Province	Coordinates	Area (ha)	Melaleuca forest	Peat land	Swamp	Lotus swamp	Grassland	Rice field	Open water	Natural lake	Reservoir	Waterways	Inland wetlands	Estuary wetlands	Sub-tidal and coastal wetlands	Mangrove	Mudflat	Sandy beach	Shrimp ponds
1	U Minh Thuong	Kien Giang	9° 31’- 9° 39’N 105° 03’ - 105° 07’E	8154	x	x	x		x		x			x							
2	Tram Chim	Dong Thap	10°40’-10°47’N 105°26’-105°36’	7588	x			x	x						x						
3	Lang Sen	Long An	10°44’-10°48’N 105°4 – 105°48’E	3280	x		x		x					x	x						
4	Thanh Phu	Ben Tre	Estuaries of Mekong River	4800										x		x		x	x	x	x
5	Tra Su	An Giang	10°33’-10°36’N 105°02’-105°04’E	860			x		x						x						
6	Lam truong Tinh Doi	An Giang	10°18’-10°23’N 105°02’-105°05’E	2053			x		x						x						
7	Ha Tien grass plain	Kien Giang	10°20’-10°29’N 104°32’-104°39’E). Kien Luong district (10°09’-10°17’N 104°34’-	16,000	x		x		x												
8	Lung Ngoc Hoang	Can Tho	9° 41’ - 9° 45’ N 105° 39’- 105° 43’ E	2800	x				x	x											
9	Vo Doi	Ca Mau	9° 11’ – 9° 18’ N 104° 52’ - 104° 59’ E	3724	x	x	x		x						x						
10	Mui Ca Mau	Ca Mau	8° 38’ – 8° 47’ N 104° 45’ - 104° 54’ E	` 24,000													x	x	x		x
11	Yaly Lake	Kon Tum	14°12’ – 15° 15’ N 107° 28’ - 108° 23’ E	6,450							x		x								
12	Bien Ho Lake	Gia Lai	14°05’ N 108° E	300							x	x									
13	Ayun Ha Lake	Gia Lai	13°25’ N 108°22' E	700							x		x								
14	Nam Ka Lake	Dak Lak	12°25’ N 108°06' E	1,240							x	x	x								
15	Lak Lake	Dak Lak	12°21’ – 12° 25’ N, 108° 08’ - 108° 18’ E	500							x	x									
16	Ea Ral Lake	Dak Lak	13°21’ N 108°14' E	102			x				x	x									
17	Trap K Sor Lake	Dak Lak	13°06’52" N 108°17'21" E	96			x				x	x									
18	Lo Go Xa Mat	Dong Nam Bo	11°24’30”N 106°00’30”E						x			x									

Annex 7: Potential indicators of Pressure, State and Response to support and evaluation of wetland biodiversity, health, function and services

Table 1: Options for 'Pressure' indicators on wetland health and function in the LMB based on a review of available data and information.

Category	Activity/impact	Indicator	Possible metrics
Reclamation/ modification of wetlands for other uses	Conversion to agricultural uses	Extent of irrigated agriculture	Area of irrigated land (ha)
			Number of irrigation projects (#)
		Extent of agricultural activity	Area of land used for agriculture (ha)
	Conversion to urban/industrial uses	Urban/industrial development	Number of new residential/industrial development projects in reporting period (#)
Contamination and pollution	Use of fertilisers and pesticides	Consumption of nitrogen and phosphates	Volume of Nitrogen and Phosphorus imported (tonnes/yr)
	Production and disposal of urban/industrial waste	Wastewater discharge	Proportion of wastewater treated versus not treated (%)
		Presence of POPs, heavy metals and other trace elements	Concentration of POPs, heavy metals and other trace elements in the water column or sediments of wetlands (conc.)
Over-exploitation of wetland resources	Use of wetland resources for livelihoods	Population growth	Number of inhabitants in the LMB (#)
		Fishing and OAA catch	Fishing catches (kg/yr)
			OAA harvest (kg/yr)
			CPUE (kg/household)
			Number of households dependent on fishing and OAA (#)
		Harvest of wildlife and other NTFP	No. of threatened wetland species identifying exploitation as reason for decline (#)
Sedimentation and erosion	Removal of sediment	Existing and planned dam construction	No. of dams both existing and planned (#)
			Total volume of non-active dam storage (m^3)
	Addition of sediment	Deforestation activity	Area of forest cover (ha)
			Rate of deforestation (ha/yr)
			Area of forest designated for primary production (ha)
			Production of timber (tonnes)
	Coastal erosion	Removal of coastal mangroves	Area of coastal mangrove forests (ha)
	Water quality deterioration	Total Suspended Solids	Concentration of TSS in the water column (conc.)
		Sediment flux	Sediment flux (tonnes/day)
Introduction of invasive	Alteration of ecosystem	Presence and extent of invasive	Number of invasive alien species present in wetland areas (#)

Category	Activity/impact	Indicator	Possible metrics
alien species	structure	alien species	Geographic extent of presence (presence by country and/or wetland type)
Modification of the hydrological regime	Hydropower and agriculture development	Hydrological disturbance at a basin-scale	Discharge volume and timing, flood frequency, duration and magnitude of peak
			Area of inundation by wetland type (ha)
			Rates of water level rise and fall and fluctuation frequency (m/day)
		Potential hydrological disturbance at a basin-scale	Modelled area of inundation by wetland type based on development proposals (ha)
		Water abstractions for urban or agricultural use	Volume of water used by agriculture (m^3/yr)
			Volume of water used by major urban areas (m^3/yr)
		Construction of dams and other barriers	No. of dams and other barriers constructed and planned (#)
		Hydrological disturbance at a wetland-scale	Seasonal area of inundation (ha)
			Seasonal water depth (m)
			Rates of water level rise and fall (m/day)
			Average hydroperiod (days inundated/year)
Meteorological	Climate change	Precipitation	Annual, wet season and dry season means (mm)
		Temperature	Annual average maximum (°C)
		Modified hydrological regime	Flood peak magnitude (m^3/d) and timing (days)
			Flood duration (days)
			Length of transition season and onset of flooding (days, month)
			Dry season water levels (m)
		Sea level rise	Annual and seasonal sea-level means (m)

Table 2: Options for 'State' indicators on wetland health and function in the LMB as identified for relevant ecosystem services based on a review of available data and information. Wetland types are identified by SIF (Seasonally Inundated Forest); SIG (Seasonally Inundated Grassland); MSPL (Marsh, Swamp, Pond, Lake); M (Mangrove); A (Aquaculture); and R (Rice field).

Category	Ecosystem Service	Indicator & measure of 'Stock' (S) or 'Flow' (F)	Possible metrics	Most relevant wetland types (SIF, SIG,MSPL,M,A,R)	Potential economic valuation methods
Provisioning	Food from fish and other biota	Fish populations (S)	Species abundance, biomass and richness	All	Market value
		Fish catch (F)	CPUE (kg/household)	All	
		OAA populations (S)	Species abundance, biomass and richness	All	
		OAA catch (F)	CPUE (kg/household)	All	
		Rice growing capacity (S)	Area of rice cultivation (ha)	R	
		Rice production (F)	Crop yield (tonnes/ha)	R	
		Aquaculture capacity (S)	Area of aquaculture ponds (ha)	A	
		Aquaculture production (F)	Production quantities by type (tonnes)	A	
	Fuel-wood and timber supply	Timber and fuel-wood production capacity (S)	Area of seasonally inundated forest (ha)	SIF, MSPL, M	
			Area of remaining natural forest (ha)	SIF, MSPL, M	
		Rate of timber extraction and fuel-wood consumption (F)	Volume or value of extracted timber or fuel-wood (kg or $)	SIF, MSPL, M	
	Non-timber forest products (NTFPs)	Harvest of NTFPs (F)	Volume or value of harvest (kg or $)	SIF, MSPL, M	Market value, Contingent valuation, Choice Modelling, Benefit transfer
	Medicines	Availability of biota from which medicines are derived (S)	Population numbers of key species from which medicines are derived (e.g. turtles/otters/plants) (#)	SIF, SIG, MSPL, M	
Regulating	Flood control	Scale of flooding (F)	Flood magnitude (m^3), frequency (ARI) and extent (ha)	All	Avoided costs, Benefit transfer
			Annual cost of flooding ($)	All	
	Groundwater recharge	Groundwater level (S)	Depth below ground surface (m)	R	Production function, Avoided costs, Benefit transfer
	Removal of pollutants	Wetland water quality (S)	Concentration of nitrates, phosphates, ammonium, DO, COD (conc.)	All	
	Natural hazard avoidance	Extent of coastal erosion (F)	Length of affected coastline (km)	M	Avoided costs, Benefit transfer
Cultural	Spiritual, religious, cultural and historical	Populations of iconic species (S)	Numbers of Sarus Crane, Siamese Crocodile, Mekong Dolphin and Giant Mekong Catfish (#)	SIF, SIG, River	Contingent valuation, Choice

Category	Ecosystem Service	Indicator & measure of 'Stock' (S) or 'Flow' (F)	Possible metrics	Most relevant wetland types (SIF, SIG,MSPL,M,A,R)	Potential economic valuation methods
	values	Remnant natural wetlands (S)	Proportion of natural vs artificial wetland area (%)	All	modelling, Travel cost, Benefit Transfer
	Aesthetic appreciation of natural features	Habitat loss for iconic species (S)	Wetland area where iconic species known to occur (ha)	SIF, SIG, River	
	Educational, training and recreational opportunities	Availability of national park (S)	Area of wetlands within national parks (ha)	All	
Supporting	Habitat	Total wetland area (S)	Area by wetland type (ha)	All	Valued through the provision of other ecosystem services
	Spawning and nursery grounds	Availability of spawning and nursery grounds (S)	Presence or absence of spawning or nursery grounds for key biological groups (presence/absence)	SIF, SIG, MSPL, M	
	Soil formation Sediment retention	Net change in sediment (F)	Sediment flux (tonnes/yr)	SIF, SIG, M	
	Store of genetic material (Biodiversity)	Birds (S)	Overall species abundance and richness No. of threatened species	All	
		Fish (S)			
		Mammals (S)			
		Amphibians (S)			
		Reptiles (S)			
		Invertebrates (S)			
		Plants (S)			

Table 3: Options for 'State' indicators on wetland health and function in the LMB as identified for relevant ecosystem components.

Ecosystem component	Indicator	Metrics
Hydrology	Hydro-period	Time inundated
	Seasonal depth	Wet season and dry season maximum depth
	Seasonal area of inundation	Wet season and dry season maximum area
	Timing and rate of water rise and fall	Month, rate
Physicochemical	Sediment flux (accumulation/dissipation)	Rate of accumulation or dissipation
	Soil chemistry	Nutrients, Organic Carbon, pH, contaminants
	Water quality	Nutrients, DO, pH, Salinity, COD, BOD, etc.
	Habitat types	Area of open water, emergent vegetation, literal zone etc.

Biota	Dominant vegetation types	Area of cover
	Species populations	Abundance, biomass, richness

Table 4: Options for 'Response' indicators on wetland health and function in the LMB based on a review of available data and information.

Category	Reference	Indicator	Possible metrics
Information base	Availability and relevance of information on wetlands	Existence of wetland inventory and database	Inventory includes all wetland types and all wetland areas
		Inventory and database accessible to the public	Available on the internet
National and regional authority for action to be taken on wetlands	Policy and legislation which provides direction and coordination on wetland issues	Existence of national wetlands policy	Wetlands policy provides guidance on all sustainable management of all wetlands, just Ramsar sites, or specific geographical areas or types of wetlands
		Recognition of wetland issues in related policies and legislation (e.g. land, water, forest, planning laws)	References to conservation, sustainable development or 'wise-use', protection or rehabilitation of wetlands
		Existence of EIA requirements that address wetland impacts	References to conservation, sustainable development or 'wise-use', protection or rehabilitation of wetlands either in legislation or in guidance documentation for proponents
Governance arrangements	Administrative arrangements which provide for accountability and inclusiveness	Existence of national multi-agency wetland committee	All relevant ministry portfolios represented Number of meetings that take place Committee addresses issues for all wetlands, just Ramsar sites, or specific geographical areas
		Existence of wetland stakeholder and community consultative mechanisms	Committees/reference panels/consultative groups address issues for all wetlands, just Ramsar sites, or specific geographical/wetland areas
		Reporting mechanisms in place	Reports available on the internet
Management arrangements	Plans in place to address wetland issues	Existence of strategies and action plans for wetlands	Plans/Strategies for all wetlands, just Ramsar sites, or specific geographical/wetland areas
	Plans to address wetland issues implemented	Projects funded and implemented at important wetland sites	Implementation activities for all wetlands, just Ramsar sites, or specific geographical/wetland areas
	Monitoring of implementation undertaken	Existence of monitoring programme for wetland health and trends	Monitoring activities for all wetlands, just Ramsar sites, or specific geographical/wetland areas
	Conservation status of wetlands	Wetland area within the national protected area estate	Proportion of wetland area by type included in the protected area estate for each country
		Extent of the national Ramsar estate	Number of current and planned Ramsar sites

Annex 8: Application of four key criteria to selection of indicators of wetland biodiversity, health and function

			Basin-scale indicators	Data sources	Wetland-scale indicators	Data sources	Relates to key policy issue	Strong conceptual basis	Sensitivity to human impacts	Data availability[6]
Pressure – driving force	Hydropower development		Number of new dams Volume of non-active storage	MRC dams database	Number of new dams upstream of sample wetland site	MRC dams database	☑	☑	☑	☑ R ☑ w
	Agricultural expansion		Number of new irrigation projects and area of irrigated agriculture	National datasets	Area of sample wetlands converted to agriculture	Ground survey/ monitoring	☑	☑	☑	☑ R ☒ w
			Water abstraction for irrigation		Catchment disturbance	Land-use data	☑	☑	☑	? R ☑ w
Pressure – impacts on component state	Hydrological modification	**Hydrological**	Hydrological changes at mainstream monitoring stations	Existing network of hydrological gauges	Hydrology at sample wetland sites (hydro-period, area of inundation, depth, timing & rate of rise and fall)	Ground survey/ monitoring	☑	☑	☑	☑ R ☒ w
	Sediment reduction	**Physicochemical**	Quantity of TSS in the mainstream	Existing water quality monitoring	TSS and sediment flux monitoring at sample wetland sites	Ground survey/ monitoring	☑	☑	☑	☑ R ☒ w
	Other Water quality parameters		Nutrients, salinity, pH, DO, BOD, COD.		Nutrients, salinity, pH, DO, BOD, COD, presence of heavy metals.		☑	☑	☑	☑ R ☒ w

[6] R = Regional scale; w = wetland scale

			Basin-scale indicators	Data sources	Wetland-scale indicators	Data sources	Relates to key policy issue	Strong conceptual basis	Sensitivity to human impacts	Data availability[6]
	Change in community composition	Biota	Dominant vegetation community types across the Basin	Land-use maps	Dominant vegetation community types at sample wetland sites	Ground survey/ monitoring	☑	☑	☑	☑ R ☒ w
State – Provisioning Services	Food – fish and OAA		Abundance, biomass and richness of fish populations at Tonle Sap and Khone Falls Catch and CPUE	Requires new monitoring effort *dai* and *li* fisheries monitoring data; SIMVA data	Abundance, biomass and richness of fish populations at sample wetland sites	Ground survey/ monitoring	☑	☑	☒	☒ R ☒ w
State – Provisioning Services	Fuel-wood supply		Area of flooded forest	Remote Sensing land cover data	Area of wooded area at sample wetland site	Ground survey/ monitoring	☑	☑	☑	☑ R ☒ w
State – Regulating Services	Flood control		Overall wetland area	Remote Sensing land cover data	Area of sample wetlands	Ground survey/ monitoring	☑	☑	☑	☑ R ☑ w
State – Regulating Services	Water purification		Ammonium, nitrogen and phosphorus levels in the mainstream and tributaries	Existing water quality monitoring	Ammonium, nitrogen, phosphorous fluxes at sample wetland sites	Ground survey/ monitoring	☑	☑	☒	☑ R ☒ w
State – Supporting ...	Biodiversity		No. of threatened wetland species in the LMB (fish, birds, mammals, amphibians,	IUCN Red List assessments	Abundance, biomass, richness of populations of selected biota at sample wetland sites	Ground survey/ monitoring	☑	☑	☒	☑ R ☒ w

		Basin-scale indicators	Data sources	Wetland-scale indicators	Data sources	Relates to key policy issue	Strong conceptual basis	Sensitivity to human impacts	Data availability[6]
		reptiles, macro-invertebrates)							
	Habitat	Area of different wetland types: Seasonally inundated forest; Seasonally inundated grassland; Marsh, swamp, pond, lake; Mangrove; Aquaculture; Rice fields	Remote Sensing land cover data	Area of key habitat types within each sample wetland site [types determined by national classification schemes]	Ground survey/ monitoring	☑	☑	☑	☑ R ☒ w
Response		Area of wetland within national protected areas	National datasets	Management plan and conservation activities in place	Public domain	☑	☑	☑	☑ R ☑ w
		Regulations on fertiliser and pesticide use	Public domain	Buffer zones in place	Ground survey/ monitoring	☑	☑	?	☑ R ☒ w
		Environmental impact assessments specifically consider impacts on wetlands	Public domain	Number and type of mitigating measures enacted	Public domain	☑	☑	?	☑ R ☒ w

Annex 9. Further guidance and sources of information on wetland services, valuation and stakeholder & policy analysis

Organisation/source	**URL**	**Policy**	**Stakeholders**	**Function/services Analysis**	**Function/services Valuation**
Association of Environmental and Resource Economists	http://www.aere.org				✓
Commonwealth Scientific & Industrial Research Organisation	https://www.csiro.au	✓			✓
Conservation Finance Guide	https://portals.iucn.org/library/node/9191	✓			✓
Convention on Biological Diversity	https://www.cbd.int			✓	✓
Ecological Society of America	http://esa.org/ecoservices		✓	✓	
Economic and Social Commission for Asia and the Pacific	http://www.unescap.org	✓	✓		
Ecosystem Services Project	http://www.ecosystemservicesproject.org			✓	✓
Environment Canada Environmental Valuation Reference Inventory	http://www.evri.ca				✓
Environmental Protection Agency New South Wales	http://www.epa.nsw.gov.au/envalue/			✓	✓
Environmental Economics, World Bank	http://www.worldbank.org/environmentaleconomics	✓	✓	✓	✓
Forest Trends	http://www.forest-trends.org	✓			✓
Foundation for Sustainable Development	http://www.fsd.nl			✓	✓
Guiana Shield Initiative	http://www.guianashield.org	✓	✓		✓
International Institute of Ecological Economics	http://www.ecoeco.org				✓
IUCN Biodiversity Economics	http://www.biodiversityeconomics.org				✓
IUCN Economics and Environment	https://www.iucn.org/theme/economics	✓	✓		
IUCN Water and Nature Initiative	http://www.waterandnature.org	✓	✓		✓
IUCNs Integrated Wetlands Assessment Toolkit	https://portals.iucn.org/library/sites/library/files/documents/2009-015.pdf	✓	✓	✓	✓
International Water Management Institute	http://www.iwmi.cgiar.org/	✓	✓		
Livelihoods	http://www.livelihoods.org	✓	✓		

Organisation/source	URL	Policy	Stakeholders	Function/services Analysis	Function/services Valuation
Millennium Ecosystem Assessment	http://www.millenniumassessment.org/en/index.html	✓	✓	✓	✓
Natural Capital Coalition	http://naturalcapitalcoalition.org				
Network Nature Network	http://valuing-nature.net			✓	✓
Overseas Development Institute	http://www.odi.org.uk	✓	✓		
Ramsar Convention	http://www.ramsar.org	✓	✓	✓	✓
UK Department of Environment, Food and Rural Affairs	http://www.defra.gov.uk		✓	✓	
University of Maryland Ecosystem Valuation	http://ecosystemvaluation.org				✓
University of Vermont, Ecological Economics	http://www.uvm.edu/giee/			✓	✓
Wetlands International	http://www.wetlands.org	✓		✓	✓
World Wildlife Fund (World Wide fund for Nature)	http://www.wwf.org	✓	✓		✓