The Mekong River Commission

THE COUNCIL STUDY

STUDY ON THE SUSTAINABLE MANAGEMENT AND DEVELOPMENT OF THE MEKONG RIVER, INCLUDING IMPACTS OF MAINSTREAM HYDROPOWER PROJECTS

BioRA PROGRESS REPORT 1:

Appendix D

April 2015

Appendix D. FIELD TRIP PART I – SPECIALISTS' NOTES

This appendix presents summary trip notes, insights and comments on Field Trip Part I: Mekong Delta and Tonle Sap Great Lake from the specialists as follows:

Dr Lois Koehnken:	Sediment, water quality and geomorphology
Dr Dirk Lamberts	Tonle Sap Great Lake processes
Dr Andrew MacDonald	Vegetation
Prof. Nguyen Thi Ngoc Anh	Delta macrophytes
Ms Duong Thi Hoang Oanh	Delta algae
Dr Ian Campbell	Macroinvertebrates
Prof. Ian Cowx	Fish
Dr Kenzo Utsugi	Delta fish
Dr Duc Hoang Minh	Herpetofauna
Mr Anthony Stones	Birds and mammals.

These contributions have been left fairly unstructured, as the intention here was to capture individual impressions of (and responses to the opportunities to see parts of) the ecosystem and its users.

D.1. DR LOIS KOEHNKEN (SEDIMENTS, WATER QUALITY AND GEOMORPHOLOGY LEAD SPECIALIST)

The Council Study field trip provided an extended opportunity to discuss the various disciplines with the NMC representatives and international specialists. Especially useful was being able to discuss the 'linkages' between the disciplines within the DRIFT context.

During the trip, observations and linkages that were highlighted and discussed in the fields of geomorphology, sediment transport and water quality included:

- The turbidity levels in the canals in the delta were much higher than those present in the mainstream Mekong or Bassac on the same days. This demonstrated that the canals generate additional suspended sediment in the system, which needs to be considered within the context of DRIFT. In general, seeing how extensive the canal system is and how important the canals are for shipping and living highlighted the importance of including canals in the DRIFT assessment.
- Visiting the biological hot spots such as such as Tram Chim and Prek Toal, provided examples of the existing linkages between hydrology, sediment and nutrient input and how changes to hydrology or sediment and nutrient input may alter these already sensitive environments.
- The relationships between riparian vegetation and river side gardens and bank stability were observed and discussed in detail as we travelled by boat between Chau Doc and Phnom Penh, which helped with refining geomorphic indicators.
- A better understanding of sedimentation patterns (spatial and temporal) within the flooded forest of the Tonle Sap system was gained, as was an understanding of how this process under pins primary productivity in the ecosystem.
- Travelling through Prek Toal enabled the group to observe the characteristics of the sediments on bank and on the bed of the shallow channels and adjacent lake. The reddish

colour of the suspended material was markedly different from the bed material, which highlighted the different dissolved oxygen (redox) conditions of the bed and overlying water. This is important for understanding how water quality parameters such as oxygen and iron will cycle within the lake and floodplain.

- Observing some of the endangered species in the river, such as the Asian openbilled storks in Tram Chim and eagles in Prek Toal, provided an insight into the natural characteristics of the lower Mekong ecosystem. Comparing these sites with the cleared and developed areas of the delta and Tonle Sap demonstrated how modified the environment is, even though the hydrology has only recently been altered.
- Water quality issues associated with the dry season were observed in the canals in the delta and near the Tonle Sap by the presence of algal blooms.
- Overall it was an excellent opportunity to gain local knowledge from the riparian participants, and to put the local examples in a global perspective.

D.2. DR ANDREW MACDONALD (VEGETATION LEAD SPECIALIST)

D.2.1. Mekong Delta

Apart from the vast and therefore highly significant marshlands that were observed from the boat as we approached Phnom Penh (Bassac marsh in particular, node 56, but generally from nodes 53-57, 64), natural vegetation in the formalized 'Delta' regions (nodes 54-82, 100-102) play relatively limited roles in the constitution and integrity of the river's biological diversity and productivity of the lower Mekong River on account of modern, intensive agriculture in the region and the fine-tuned control of water flow by an intricate system of irrigation canals. Notable exceptions to this general trend include the occasional flooded forests and natural wetlands that are protected, such as the Tram Chim National Park ('Plain of Reeds,' node 66), Lang Sen Wetland Reserve (node 67, not seen) and a collection of disjunct mangrove communities that line the brackish shorelines of navigable water courses and to a limited extent, the (unobserved) coastline at the mouth of the delta. The relatively small size of these natural vestiges of native vegetation makes them predictably more sensitive and less resilient to environmental changes than larger refugia, and therefore more vulnerable to impacts of changes in water flow. For example, it was brought to our attention that slight decreases in water levels had a significant impact on the community structure of native grasslands at Tram Chim. Subtle changes in water levels and/or timing of flooding can affect the abundance (frequency and density) of a specific sedge, which can affect the abundance of a charismatic and threatened crane species, the keynote animal attraction of this popular parkland. This plant-bird relationship serves as an example for considering the complexities of interrelationships between living members of the LMB. Unfortunately, the natural history of most Mekong River creatures and their natural associates are poorly understood.

In observing the treatment of rice fields during the dry season across Viet Nam's delta region -- i.e., the removal all rice stems and leaves after harvests to serve as bovine fodder, and then following through with a thorough burning of vegetative residues -- it becomes apparent just how little agricultural lands contribute to the river system in terms of biomass and fertility during monsoonal floods. It is noteworthy that these practices probably apply to more than 95% of the modern delta region, which was historically a mosaic of flooded forests and marshlands.

Based on past observations, it seems as though there is an increase in *Melaleuca* plantations on the delta floodplain, presumably on account of the growing need for local wood sources. Given that natural *Melaleuca* forests tend to be monocultures, these plantations represent a native habitat that might be interpreted as flooded forest reserves and may also contribute to the productivity of fish populations during floods.

D.2.2. Tonle Sap Lake

Two sites on Tonle Sap Lake provide contrastive perspectives on the roles and fate of Cambodia's critical floodplain. The Prek Toal site is confined within a protected zone and exemplifies one of few significant successes in modern Cambodian conservation initiatives. Large populations of large aquatic fowl flourish in a vegetation that retains its original structure and species composition. The site is a popular attraction for tourists. Very slight changes in the height of the soggy terrain determines whether trees will grow large enough to support bird rookeries or otherwise, as short and highly ramified trees that are optimal for the reproduction and development of fish fry. The mixture of large and small-statured plants provides the required elements for large waterfowl reproduction and survival, and just as well for a healthy fishery.

In contrast, the floodplain vegetation that surrounds the thriving fishing village of Kampong Kleang is exploited in many and various ways, the impacts of which are predictably threatening to the future of local fishing communities. This fishing village has grown substantially since I first visited the site in 1996, at which time the most damaging human activities involved the degradation of floodplain forest by wood collectors to smoke fish. Today the impacts relate primarily to land conversion for the sake of agriculture. Large swaths of forests have been removed to accommodate rice and mung bean farms, the former of which occupies the outer floodplain and the latter the inner boundaries of the floodplain. A satellite perspective using GOOGLE EARTH reveals almost half the flooded forest has been removed on the north shore of the lake between Kampong Kleang and Siem Reap River. These changes have taken place over the course of only 20 years and do not augur well for sustainable fish production. Since potentially similar reductions of the inner and outer floodplain vegetation are possible for the entirety of the Tonle Sap floodplain if high and low water levels are diminished on account of profligate dam development, Kampong Kleang provides a window into what the Tonle Sap as a whole could become in the short term. One's imagination is required to extrapolate the shape of things to come in the long term.

D.3. PROF. NGUYEN THI NGOC ANH (DELTA MACROPHYTES LEAD SPECIALIST)

Field visit by boat (visual observation and taking photos) combined with interviewing local people/authorities in the Mekong river delta (Viet Nam) and Tonle Sap Lake (Cambodia) from March 22nd to 26th, 2015 with regard to aquatic macrophytes are summarized, and reference is made to previous studies for identification of aquatic macrophytes in the survey areas.

D.3.1. 22/3/2015: Tram Chim National Park

The Tram Chim National Park located in Tam Nong district of the Mekong Delta province of Dong Thap and its total area is more than 7500 ha. Its main functions are to conserve a flooded Melaleuca forest ecosystem of the Mekong River, which is a typical wetland ecosystem of the Plain

of Reeds and a habitat for many rare water birds, especially the Eastern Sarus Crane (*Grus antigone*).

The vegetation of Tram Chim National Park comprises a mixture of seasonally inundated grassland, regenerating Melaleuca forest and open swamp. Melaleuca is distributed throughout the national park, both in plantations and in scattered patches in areas of grassland or open swamp. There are six widespread grassland communities at Tram Chim including *Mimosa pigra*, of which the community dominated by *Eleocharis dulcis* (food source for sarus crane)*, Panicum repens*, *Ischaemum* sp. and wild rice *Oryza rufipogon* is of the highest conservation significance. The other grassland communities are dominated by *Eleocharis ochrostachys*, *Panicum repens*, *Ischaemum rugosum* and *Vossia cuspidata*.

In open swamp and along small older channels are dominated by water lilies such as *Nelumbo nucifera*, *Nymphoides indica* along with *Nymphaea nouchali*, *Nymphaea pubescens*, and *Nymphaea tetragona*. *Nymphoides indica*, lotus *Nelumbo nucifera*, water lettuce *Pistia stratiotes.*

According to the manager, the changes of vegetation communities in Tram Chim are affected by hydrological regime regulation (water source, flow velocities, flood frequency, and duration) and water levels generated by the Mekong River, but controlled by a series of sluices in the park.

Appendix Figure 1 Six typical vegetation communities in Tram Chim national Park

D.3.2. 23/3/2015 (morning): Catfish farms at An Nhon island

Catfish farms at An Nhon island located in Chau thanh district, Dong Thap province belong to Mekong (Tien) River.

Vegetation communities along and upper dikes of fish ponds consist of *Eclipta alba, Alternanthera sessilis, Eleusine indica, Phyllanthus urinaria, Ludwidgia adscendens, Ludwidgia hyssopifolie,*

Phyllanthus urinaria, Nymphoides indicum, Comelina diffusa. Water hyacinth (*Eichornia crassipes*) and water spinach (*Ipomaea aquatica*) are dominant in the reservoir near by the fish ponds.

Vegetation communities along the bank of the river comprise *Persicaria attenuate*, *Polygonum tomentosum*, *Centrostachys aquatica* and *Anthurium* spp. They often form large patches with long floating stems that root at the lowest nodes, grow on the margins of the river bank.


Water hyacinth in reservoir


Vegetation community along river bank


Vegetation community in catfish pond

Appendix Figure 2 Typical vegetation communities in catfish farm, An Nhon island, Dong Thap province

D.3.3. 23/3/2015 (afternoon): Catfish farms at Nam Viet Company- Long Xuyen city - An Giang province

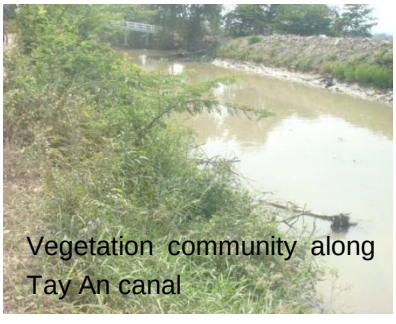
Catfish farm in Nam Viet Company located at Tay An commune, My Thoi ward, Long Xuyen City, An Giang province. Water for the catfish ponds is taken from Tay An canal, which is 5 km away from Bassac (Hau) River.

Vegetation communities along and upper dike of catfish ponds are similar to those observed in catfish farm from An Nhon Island.

In Tay An canal, water hyacinth (*Eichhornia crassipes*) present along either sides of the canal and dominate over other macrophytes (*Phragmites karka*).


Vegetation community along fish pond dike

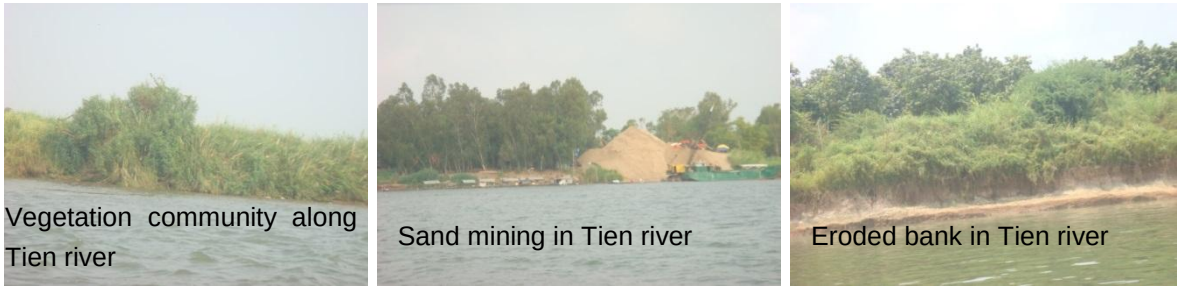

Vegetation community upper dike of fish pond


Vegetation community along Tay An canal

Appendix Figure 3 Vegetation communities in catfish farm, Nam Viet Company and Tay An canal, An Giang province

D.3.4. 24/3/2015: Travel by boat from Chau Doc to Phnom Penh

The river from Chau Doc to Phnom Penh is the Mekong (Tien) River. Vegetation communities are similar to those observed in Bassac (Hau) River. Recently, sand mining has also become intensively for construction works resulting in erosion both sides of the river.



Vegetation community along Tien river

Sand mining in Tien river

Eroded bank in Tien river

Appendix Figure 4 Typical vegetation communities along the Mekong River between Chau Doc and Phnom Pehn

D.3.5. 25/3/2015: Tonle Sap Lake

The Tonle Sap Great Lake in Cambodia, the largest natural freshwater lake in Southeast Asia, is situated in the floodplain of the Mekong River, and is thus is directly linked to water levels of the Mekong River, and to any alterations in to water resource development and/or climate change. It is a critical freshwater ecosystem in the Mekong River Basin. The Tonle Sap floodplain comprises a mosaic of habitats that provide shelter and food to both aquatic and terrestrial biota. These habitats are diverse in appearance and structure, including gallery forests, grasslands, shrub lands, and rice fields.

Vegetation community in open area of Tonle Sap Lake

Sedge community in open area of Tonle Sap Lake

Water hyacinth community in open area Tonle Sap Lake

Vegetation communities in tributary of Tonle Sap Lake

Mimosa with other vegetation in tributary of Tonle Sap Lake

Dried water hyacinth attached on the trees in tributary of Tonle Sap Lake

Appendix Figure 5 Typical vegetation communities in the Prek toal

The Tonle Sap Lake is particularly characterized by high turbidity and a large annual fluctuation in lake water levels between the dry (low water depth: ≤1 m) and wet season (high water level: 6–8 m as seen the mats of dried water hyacinth attached on the top of the high trees). Therefore, submerged aquatic macrophytes are virtually absent. In the open area of the Tonle Sap Lake, sedge communities (*Cyperus malaccensis*, *Cyperus halpan*, *Rhynchospora corymbosa*, *Scirpus grossus*) are dominant, follow by a free-floating water hyacinth (*Eichchornia crassipes*).

In the tributary river which connected to Tonle Sap Lake show more diversity of vegetation communities. A wide variety of aquatic plants/grass are present both sides of tributary rivers such as *Brachiaria mutica*, *Echinochloa stagnina*, Leersia hexandra, *Leptochloa chinensis*, *Oryza rufpogon*, *Paspalum scrobicularum*, *Sacciolepis interrupta*, *Vossia cuspidate*, *Colocasia sp*., Reeds *Phragmites karka*, water hyacinth, *Eichchornia crassipes.* Moreover, the giant mimosa (*Mimosa diplotricha*) forms the dense, impenetrable thickets in the upper banks of the river.

D.3.6. Kampong Kleang Lake (26/3/2015)

Kampong Kleang is located on the flood plains of the Tonle Sap lake, belong to Siem Reap province and about 55 km outside of the city. This commune is one of the largest permanent settlements on the lake “stilts village”. As all communities around the lake, the fishing community of Kompong Khleang undergoes dramatic and continual changes due to the seasonal flood levels caused by the reverse flow of the Tonle Sap River.

For this reason, the ecosystem and natural resource of this area seem to be identical to the Tonle Sap Lake as seen by turbid water and low water depth. In the open area of the lake, aquatic plants is almost lacking while in the channel, vegetation communities are similar to those observed in the tributary river from the Tonle Sap Lake *i.e.* water spinach (*Ipomoea aquatica*), water hyacinth (*Eichchornia crassipes*), *Sacciolepis interrupta*, *Vossia cuspidate*, *Colocasia sp*., Reeds *Phragmites karka*, invasive *Mimosa diplotricha*.

Appendix Figure 6 Typical vegetation communities in the Kampong Kleang

In summary, the trip by boat in these areas provided important context for the biological research assessment in the Mekong River. However, more detailed studies on aquatic macrophytes (field sampling and laboratory analysis to quantify biomass, productivity and identification of macrophytes) are needed to link among hydrological, soils, and vegetation characteristics throughout the Mekong River. These works can predict changes in vegetation cover as a result of future scenarios (hydropower, water abstractions, climate change) in the Mekong River Basin.

D.4. MS DUONG THI HOANG OANH (DELTA MACROALGAE SPECIALIST)

D.4.1. Tram Chim National Park

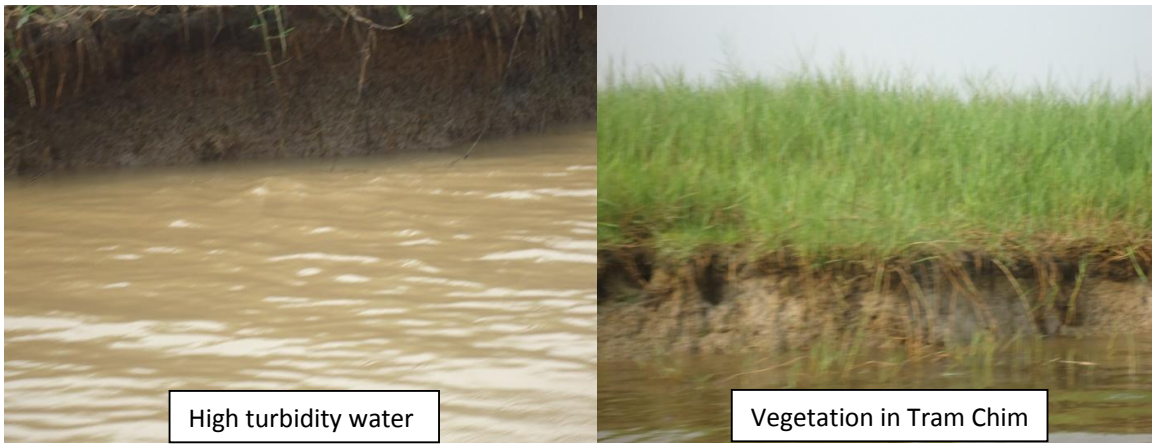
Tram Chim National Park is one of the wetland areas belonging to Dong Thap, Tien Giang and Long An provinces.

The vegetation of Tram Chim National Park comprises a mixture of seasonally inundated grassland more than 130 species, regenerating *Melaleuca* forest and open swamp. *Melaleuca* is distributed throughout the national park, both in plantations and in scattered patches in areas of grassland or open swamp. There are five widespread grassland communities at Tram Chim, of which the community, dominated by *Eleocharis dulcis* and wild rice. *Oryza rufipogon.* is of the highest conservation significance. Tram Chim is one of the few places in the Plain of Reeds where this community is likely to survive to any extent, and, therefore, one of the most important sites for the conservation of wild rice in Viet Nam. The other grassland communities are dominated by *Eleocharis ochrostachys, Panicum repens, Ischaemum rugosum* and *Vossia cuspidata*. Another vegetation type found at Tram Chim is lotus swamp, which is dominated by lotus *Nelumbo nucifera*, along with *Nymphaea nouchali, N. pubescens* and *N. tetragona*.

Tram Chim was recognised as an important bird sanctuary in Vietnam which supports significant numbers of water birds, especially the Sarus Crane. Tram Chim National Park is one of the best developed and most well known sites for ecotourism in the Mekong Delta and it stores water during flood times. In particular, a well-operating water drainage system helps direct a great amount of aquatic species on the Mekong River. The increasing shade of Melaleuca in forest in Tram Chim prevents light for algal photosynthesis but in flood many forest trees die and this reduction will provide more light for algae growth. In flood, alluvial provide nutrients to algae growth. Alluvial water lacks light; therefore, Cyanobacteria grows more easily than any other algae.

Melaleuca forest

Lotus swamp



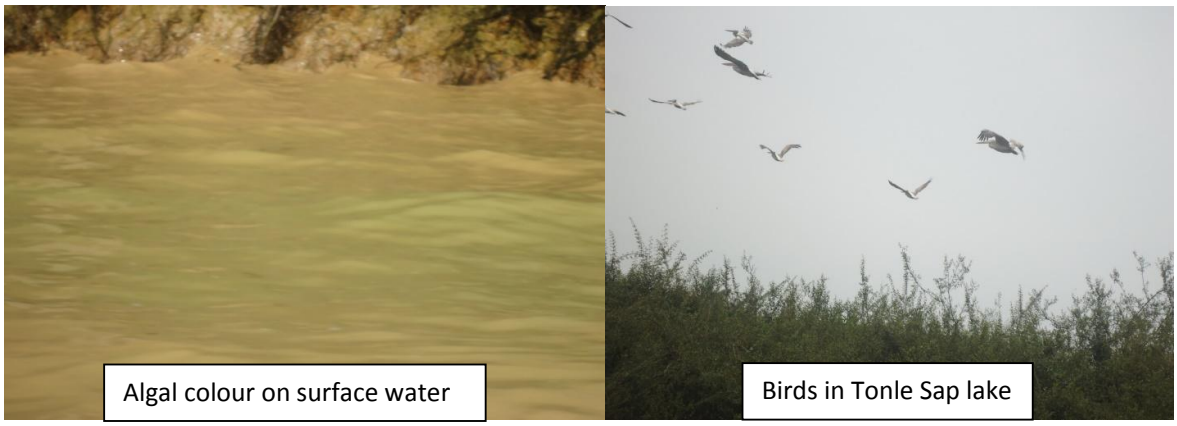
Appendix Figure 7 Typical habitats in the Tram Chim National Park

D.4.2. Tonle Sap Lake

The Tonle Sap Great Lake is one of the largest freshwater lakes in Southeast Asia. The unique hydrological regime of Tonle Sap Lake is characterized by an annual inflow of Mekong waters into the lake basin during the wet season, when the water levels in the Mekong rise. At the end of the wet season, the flow reverses and the lake empties again. This hydrological cycle supports and maintains high biodiversity and productivity, particularly fish, plant communities, and wildlife.

When we were at the lake, it was very shallow from about 0.5 to 1 m. Most of the water in the Tonle Sap Lake comes from the Mekong River. The flooding time in the Tonle Sap Lake is usually in May and June and it lasts about 5 months. At this time the water level of the lake increases up from 6 to 9 metres. The surface of the lake is very extensive and is not hidden by any trees, so a lot of sunlight is available for algal photosynthesis. However, high turbidity of water by alluvium will prevent light for algal development. The observations in our fieldtrip indicate that the water in the lake has no colour of algae visibility. In contrast, *Cyanobacteria* can develop in water with low clarity and stability, so we saw the green colour of algae in the canal leading to the lake. Sedimentation occurs almost exclusively in the flood and alluvial provides nutrients to algae growth. Tonle Sap seasonally inundated vegetation ecosystem comprises: forests, shrubs, grasslands, receding and floating rice fields… The floodplain vegetation plays an important role in ecosystem by providing nutrient for algal growth from the decayed plants.

Appendix Figure 8 Bank and floating vegetation (*Eichornia*) at Tonle Sap Lake



Appendix Figure 9 Water colouration and birds at Tonle Sap

D.5. DR IAN CAMPBELL (MACROINVERTEBRATE LEAD SPECIALIST)

D.5.1. 22 March Tram Chim National Park, Viet Nam

The park was established primarily because of unusual vegetation (plain of reeds) and dense bird populations. Channels constructed for the purposes of water management in the delta generally and in the park contain extensive areas of clay which contain numerous holes 3-5 mm diameter (Appendix Figure 10). They may be geological in origin but seem more likely to be the burrows of insects or annelids. Appendix Figure 10 is not clear but the holes are evident especially in the

bank towards the right hand side of the picture. Odonata were numerous along the channels. Golden apple snail is a management problem within the park. Snails were not observed but their distinctive egg masses were clearly evident.

Appendix Figure 10 Clay banks along a canal in Tram Chim National Park with holes thought to be burrows of invertebrates.

D.5.2. 23 March Canals and Fish Farms near My Thoi

A local woman was observed harvesting molluscs (snails and bivalves) from a canal in the vicinity of My Thoi (Appendix Figure 11), so these are clearly a significant human food item in the delta.

Appendix Figure 11 Woman harvesting snails and bivalves from a canal near My Thoi Village, Viet Nam.

D.5.3. 24 March – Mainstream, Chau Doc to Phnom Penh.

There was no evidence of significant invertebrate use obvious along this section of the river. A number of plants processing "trash fish" for fish food to supply Viet Namese fish farms were evident (Appendix Figure 12), as was sand extraction (Fig. 4). We know from the MRC bioassessment program that invertebrates are abundant along this section of the river.

D.5.4. 25 & 26 March Tonle Sap Great Lake, Cambodia.

Dragonflies and some snail shells were evident around the Prek Toal core area at Tonle Sap biosphere reserve. One banded krait snake was also observed. Of some concern was the large area near Kompomg Kleang cleared and now planted with mung beans (Appendix Figure 14) with apparent extensive use of insecticides (Appendix Figure 15).

Appendix Figure 12 **Floating plant processing "trash fish" into fish food, Mekong River, Viet Nam.**

Appendix Figure 13 **Dredges extracting sand from the bed of the Mekong River, Viet Nam.**

Appendix Figure 14 Mung Bean crop near Kompong Kleang

Appendix Figure 15 Discarded insecticide bag near Kompong Kleang

D.5.5. 28 March Chong Kneas Port, Tonle Sap Great Lake.

(Dr Campbell visited Chong Kneas Port on his own, after the Preparation Meetings and Field Visits)

In the Chong Kneas area the ADB have funded the development of a port (Appendix Figure 16) presumably to service boat traffic between Siem Reap and Phnom Penh. Of interest is the cultivation of water lillies as a crop on the flood plain (Appendix Figure 17) and extensive harvesting of aquatic insects (presumably dytiscid beetles and giant water bugs) as a cash crop for human food (Appendix Figure 18).

Appendix Figure 16 ***The constructed port at Chong Kneas***

Appendix Figure 17 ***Water lily crop near Chong Kneas***

Appendix Figure 18 **Light traps for harvesting aquatic insects on the floodplain of the Tonle Sap Great Lake between Siem Reap and Chong Kneas.**

D.6. PROF. IAN COWX (FISH SPECIALIST)

Prof. Cowx was not part of trip to the Mekong Delta. He joined the team in Siem Reap for the Tonle Sap portion of the field visits.

D.6.1. Tonle Sap

The itinerary for the field visit was a boat trip on the Tonle Sap and a visit to Prek Toal, Biosphere Reserve on Thursday, March 26 2015 and a visit to Kampong Khlang in Tonle Sap on Friday, March 27, 2015. Both visits provided a general overview of the Tonle Sap and a basic understanding of the functioning of the lake. Of particular value was to see the intensity of fishing on the lake and the scale of operation and diversity of gears as well as the nature reserve and diversity of bird and plant life. In addition it was interesting to see the expansion of the millet production and destruction of the flooded forest in recent years.

Unfortunately the visit was during the dry season and thus the lake level was low and fishing operations restricted or fishers were just preparing for the next flood season. Consequently we did not get to see what was being caught by fishers or indeed talk to any fishers to gain their perspectives. It would be good to have seen the situation in the wet season to compare the conditions and also spend time talking to local people.

The field trips were a little fragmented in that we were split between minibuses and boats and there was not always the opportunity to talk to the national experts in other fields of expertise. The national experts in fisheries were well informed and provided good insights into the problems but I am not sure this was transferred fully to the other experts.

D.7. DR KENZO UTSUGI (DELTA FISH SPECIALIST)

D.7.1. 22 March (Tram Chim National Park)

We visited Tram Chim National Park. It is a protected wetland area. A lot of bird species were observed. To maintain the underground water level, water channels are built accordingly.

In the water channels, we found a lot of fish. Although the observation was just superficial, I could identify some species. Most of the fish species I could find were air-breathing species (included in the so-called black fishes) such as *Channa striata* and *Trichopodus trichopterus*.

The flow in the park is not directly related to the Mekong's hydrology, but might be a replica of some habitats in the Mekong Basin.

D.7.2. 23 March (Fish farms)

We visited two fish farms in the Mekong Delta.

The first farm is located on the river bank. The farm cultures a single species, *Pangasianodon hypophthalmus* only. They feed fish with conventional pellet food for catfishes. They use some chemicals for reducing ammonia in the pond water.

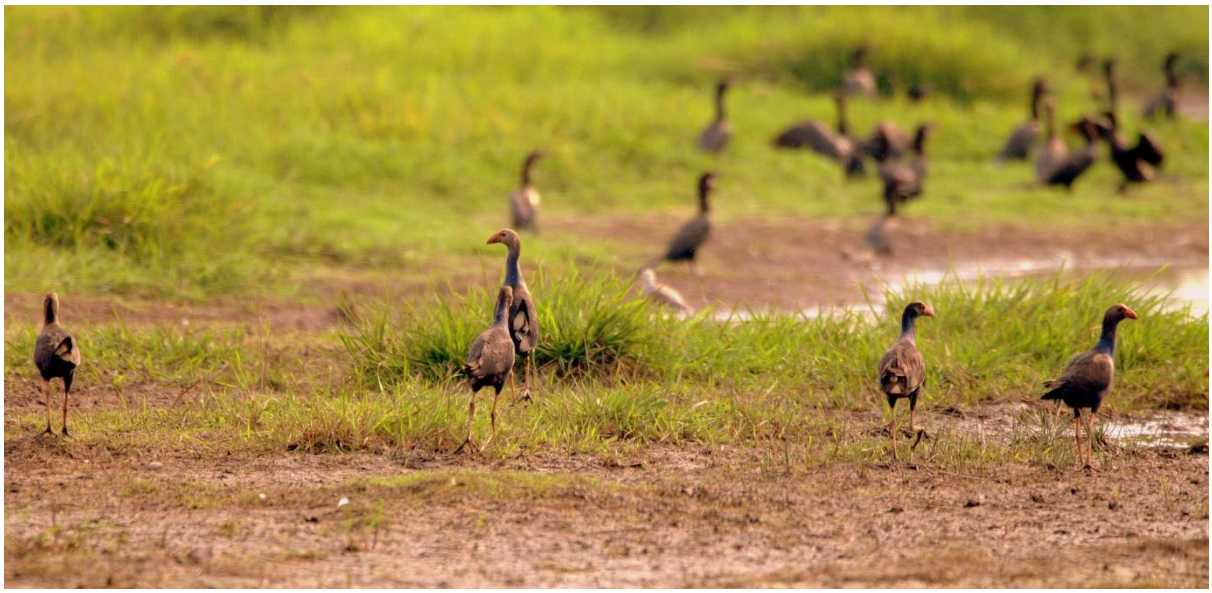
The second farm is located a bit far from the river that is a water source of the fish ponds.

They culture a single species, *Pangasianodon hypophthalmus* only. They use fish farming technique following 'good practise' promoted by Viet Namese government. Used water is kept in a large sedimentation pond before returning to the river.

D.8. DR DUC HOANG MINH (HERPETOFAUNA LEAD SPECIALIST)

D.8.1. Visit to Tram Chim National Park:

The 7 740 ha national park is fully protected by dykes and water-gate systems. It is reported that the park supports about 49 species of reptiles and 15 species of amphibians. At the time of the visit, there was no direct sighting of reptiles or amphibians in the field except two species of house gecko recorded at the headquarters of the park. Open water bodies and Lotus swamps in the park are preferable habitats for water snakes (Holomatidae, Natricidae) and water turtle (*Malayemis subtrijuga*). Most herptiles are nocturnal so day-time visit often resulted in low or no encounters.



Appendix Figure 19 A group of swamp hen on grassland habitat in Tram Chim National Park

D.8.2. Dong Thap Province – An Giang Province

Visit fish farm near Mekong River then a fish farm near Long Xuyen City. On the river bank along Mekong River in Vinh Long Province (near My Thuan Bridge), a dyke system made of soil, has been built to protect fish ponds. To prevent the bank from erosion, local people fixed a patch of floating macrophytes (mostly water hyacinth). According to the owner of the fish farm, some water snakes were occasionally found in the patch and sometime a cobra was also found in a hole along the dyke. The area is quite develop and may support a few water-dependent reptiles and riparian reptiles.

D.8.3. Mar. 24, 2015: Chau Doc City – Phnom Penh (by boat) then traveled to Siam Riep City

Main vegetation types along Mekong River from Tan Chau to Phnom Penh are agricultural land including corn, chili and paddy field. Some islands/islets covered by grasses or one crop vegetation occur in the mainstem. Sand mining was observed in many places that can cause to change or flow direction, lead to bank erosion.

Appendix Figure 20 Corn harvest near Tan Chau Town

Appendix Figure 21 Sand mining in the mainstem of Mekong River, Viet Nam

Bank erosion was also observed in many places. There is no report on herpetofauna in this area; however, habitat along this river section would not support diversity of herptiles.

Some remnants of riverine forest occur on the left bank between Neak Luong and Phnom Penh. This kind of habitat may play an important role in reserving semi aquatic reptiles and amphibians.

Appendix Figure 22 Remnant forest along Mekong River, Cambodia

D.8.4. Mar. 25, 2015: Visit Prek Toal Bird Conservation Area

At least five species of turtles and 14 species of snakes, of which eight are specialist water snakes, have been recorded in the Great Lake. Three other lizards, including two species of monitor and one gecko, were also recorded. During the field visit, only two individuals of the garden-fence lizard (*Calotes versicolor*) were observed along the road to the temporary tourist wharf. Water snake exploitation, mostly happened in the peak of wet season, is important income of local fishermen of the region.

Appendix Figure 23 Snakes and frogs are main food of the Greater Adjustant

D.8.5. Visit Kampong Khlang in Tonle Sap

Habitats of the area are quite similar to those in Prek Toal but more disturbed due to high density of human population and land conversion. Seasonally inundated forest Kampong Khlang provides habitat for floodplain reptiles and amphibians.

Appendix Figure 24 Seasonally inundated forest and fishing traps in Kampong Khlang

D.9. ANTHONY STONES (BIRDS AND MAMMALS LEAD SPECIALIST)

D.9.1. Mekong Delta - Tram Chim Nature Reserve

It was evident from the study visit that the delta is heavily utilised. The river and river channels were heavily populated, often with 'ribbon' development including light industry, sawmills, brick kilns and fish farms along long stretches of the main channel, which is typically > 500m in width here. Where built infrastructure was lacking, the land along the channel banks was heavily cultivated.

There appeared to be little, if any, natural banktop vegetation (there were some mature semi-mature trees associated with settlements). There was some lower bank and within channel vegetation which appeared to be semi-natural.

The landscape was dominated by rice paddies, and homesteads with 'extended gardens' supporting bananas and other crops adjacent to homesteads.

No mammals were seen and bird species observed were commoner species of open countryside, e.g. black-shouldered kite, pond herons, little egrets, wintering brown shrikes and barn swallows.
As we travelled north towards the Cambodian border, there was evidence of family land holdings but also evidence of other industrial activity notably sand-dredging from the river. On both sides of the river, the banks were of low earth cliffs which were several metres in height.

Tram Chim Nature Reserve, a Ramsar site since 2010, is 7 300 ha about 25 km from the Mekong River and represents one of the last remaining fragments of the Plain of Reeds ecosystem. There are various initiatives underway to ensure the development of more sustainable management for the site, including water level management using a sluice gate system to ensure maintenance of suitable grassland habitat for the cranes. The site is internationally recognised for its wintering population of Eastern Sarus crane (23 present on our visit), but historically with numbers in the hundreds. The seasonally inundated grasslands, open swamp, wetland systems and regenerating Melaleuca forest also support a number of other waterbird species (ducks, waders and egrets / storks). The park is an important visitor attraction with visitor numbers have increased substantially since is declaration as a Ramsar site. The site seemed very well-managed with an informative visitor centre and shop, and with an excellent system for managing visitors through the use of a boat system along the channel network, thus minimising widespread disturbance to birds and other wildlife. The village rendezvous with the watchtower overlooking the swamp and forest is also a strong focal point.

D.9.2. Fish farms

We visited two fish farms. The first of these was c. 120 km from the estuary mouth. Saline influence is experienced up to c. 100 km upstream from the river mouth, so the river is freshwater here. This farm (in Dong Thap province) had six 'ponds', with water being pumped between ponds as required. The fish produced is catfish, with 2 000 tonnes of fish produced per annum. The farm lies 5 km from the Bassac River and the water levels in the ponds can be 'tied' to the tidal rhythms of the river (twice per day). The hatchery for this farm was in Hung Mo (?) district (c. 60 km away). Wastewater is pumped through a bed of aquatic plants (phytoremediation using Amaranthis) and then into the river.

The fish are fed pellets made locally of rice, beans etc. 1.5 kg of feed is needed to produce 1 kg of fish, with fish being fed twice per day.

There was little wildlife associated with either of the fish farms which were in heavily agriculturalised landscapes. The few bird species seen: house sparrow; pond heron; barn swallow and black-shouldered kite, were typical species of open countryside. The fish farms were busy places, with a number of domesticated dogs present, and at the second farm, bird wires were observed strung out across a pond, presumably to catch migrant barn swallows.

D.9.3. Tonle Sap Lake

The drive from Siem Reap to the village from where we caught the longtail boat was through heavily utilised agricultural areas, with paddies, bananas, and palms which were particularly evident around farmsteads. There was evidence of commoner bird species of the wider countryside, including egrets and small parties of Asian Openbill stork.

We took a longtail boat along a narrow, shallow channel towards the Great Lake itself. More bird species became apparent very quickly, and included small flocks of egrets and pond herons, little cormorants, large-billed crow (at least two nests and 18 birds were observed in one of the floating villages), barn swallows (hawking over the open water and perched on any available posts), black drongos, dollarbird and numbers of white-vented and common mynas.

As we approached the lake itself, more specialised wetland bird species were observed, including small flocks of painted storks, Asian openbills, darter and wintering whiskered terns (a species marsh tern that winters on Tonle Sap Lake).

The main channel into Tonle Sap Lake was fringed with sedge beds and the vast expanse of open water in the landscape could be truly appreciated. As we left the lake and approached Prek Toal, the channel narrowed to c. 30 m wide. As we travelled along the channel there was an increase in the numbers and diversity of wetland bird species. The banks were fringed with a 'scrub forest' (thick low thorn forest), which appeared impenetrable, with stands of Melaleuca forest, some of which had clearly been used as waterbird roosts for considerable lengths of time. In areas this vegetation gave way to tracts of pen swampy grassland (in one of these a 'lek' of c. 100 purple swamp hen was observed). The number of herons, egrets, cormorants and pelicans increased, with grey and purple heron feeding along the channel edge, which in places was confined, and flocks of tens of spot-billed pelicans feeding in the river itself. Tens of birds were perched atop the Meleleuca trees and these included spot-billed pelicans, night herons, lesser and greater adjutant storks, common darters, and several grey-headed fish-eagles which were perched on an overhanging tree branch above the main channel.

Appendix Figure 25 A grey-headed fish-eagle perched on an overhanging tree branch above the main channel at Prek Toal

On leaving the Prek Toal bird area we visited the visitor centre on one of the floating villages – this was informative and well-located, and the presence of a watchtower meant that it was possible to

climb up and have far-reaching views over the complex of wetlands and low forest that lie adjacent to the lake itself.

It is clearly of significant importance to waterbirds in terms of the variety of habitats present (from open water to climax forest vegetation), the feeding and nesting opportunities it affords these species, and its relative inaccessibility.

Appendix E. LIST OF PRELIMINARY BIORA INDICATORS FOR COMMENT

The table below has place for comment on each of the suggested indicators, as well as space to suggest additional indicators for each discipline/sub-discipline. Please send suggestions to: cate@southernwaters.co.za and alison@southernwaters.co.za.

Discipline/sub-discipline	Code	Indicator	Comments		
			Agree	Disagree	Suggested alterations
MAR	MAR	Mean annual runoff			
Dry-season hydrology	Do	Onset			
	Dd	Duration			
	Dq	Minimum 5-day discharge			
	Ddv	Average daily volume			
	mxiDry	Maximum instantaneous discharge			
	raiDry	Maximum rate of change in discharge			
	diDry	Within-day range in discharge			
Transitional season hydrology	T1v	Average daily volume			
	mxiT1	Maximum instantaneous discharge			
	raiT1	Maximum rate of change in discharge			
	diT1	Within-day range in discharge			
Wet season hydrology	Fo	Onset			
	Fd	Duration			
	Fq	Maximum 5-day discharge			
	Fdv	Average daily volume			
	Fv	Flood volume			
	mxiWet	Maximum instantaneous discharge			
	raiWet	Maximum rate of change in discharge			
	diWet	Within-day range in discharge			
Channel hydraulics	avCV	Average velocity			
	maxCD	Maximum depth			
	minCD	Minimum depth			
	avCD	Average depth			
	CSS	Shear stress			
	Slope	Bed slope			
	Elevation	Bed elevation			
	Inun2C	Inundation of secondary channels			

Discipline/sub-discipline	Code	Indicator	Comments		
			Agree	Disagree	Suggested alterations
Floodplain hydraulics	FpO	Onset of inundation			
	FpDd	Duration of inundation			
	InunArea	Inundated area			
	avFpV	Average velocity			
	maxFpV	Maximum velocity			
	avgFpD	Average depth			
	maxFpD	Maximum depth			
Sediments	SedLoad	Sediment loads			
	SedConc	Sediment concentrations			
	SedGrain	Sediment grain-size distribution			
	FpD	Floodplain deposition.			
Water quality	Salinity	Salinity/conductivity (extent of salinity intrusion)			
	Temp	Temperature			
	pH	pH			
	DO	Dissolved oxygen			
	TSS	Total Suspended sediment (from sediment model)			
	ALK	Alkalinity			
	SO4	Sulphate			
	TOTN/ NO32	Nitrogen species (Total Nitrogen, Nitrate + Nitrite, Ammonia)			
	TOTP/ PO4	Phosphorus species (Total Phosphorus, Dissolved reactive phosphorus)			
	Si	Silica			
	COD	Chemical oxygen demand.			
Geomorphology	Erosion	Erosion (bank / bed incision)			
	Fine/Coarse	Sediment fining / coarsening			
	Sandbar	Exposure of sandy bars, islands and insets			
	Rockreef	Exposure of rocky reefs			
	PDepth	Pool depth			
	Clarity	Water clarity			

Discipline/sub-discipline	Code	Indicator	Comments		
			Agree	Disagree	Suggested alterations
Channel vegetation	CUCover	Extent of upper bank vegetation cover			
	CLCover	Extent of lower bank vegetation cover			
	CHerb	Extent of herbaceous marsh vegetation (submerged, floating and emergent)			
	CBioRip	Biomass of riparian vegetation			
	CBioAlg	Biomass of algae (planktonic and benthic)			
	CComm	Community structure and species composition			
Floodplain vegetation	FForest	Extent of flooded forest cover			
	FHerb	Extent of herbaceous marsh vegetation			
	FBio	Biomass of riparian/aquatic cover			
	FBioBG	Biomass of cyanobacteria			
	FBioAlg	Biomass of algae (planktonic and benthic)			
	FComm	Community structure and species diversity			
	RipInv	Extent of Invasive riparian plant cover			
	FloatInv	Extent of floating and submerged invasive plant cover			
Macroinvertebrates	Hept	Heptageniid mayflies			
	Beat	Baetid mayflies			
	Emerge	Dry season emergence			
	Palin	Palingeniid mayflies			
	SnailA	Snail abundance			
	SnailD	Diversity of snails			
	N. aperta	Neotricula aperta			
	Bivalve	Bivalves abundance			
	Poly	Polychaet worms			
	Crust	Shrimps and crabs			
	LitDiv	Littoral diversity			
	LitASPT	Littoral ATSP			
	BenDiv	Benthic Diversity			
	BenASPT	Benthic ATSP			
	Zoo	Zooplankton abundance			

Discipline/sub-discipline	Code	Indicator	Comments		
			Agree	Disagree	Suggested alterations
Fish	Rithron	Rithron resident species			
	CRes	Main channel resident (long distant white) species			
	CSpawn	Main channel spawner (short distance white) species			
	FSpawn	Floodplain spawner (grey) species			
	Gen	Eurytopic (generalist) species			
	FRes	Floodplain resident (black fish)			
	ERes	Estuarine resident species			
	Anad	Anadromous species			
	Catad	Catadromous species			
	Marine	Marine visitor species			
	NonN	Non-native species			
Herpetofauna	AquSerp	Aquatic serpents			
	SAquSerp	Semi-aquatic serpents			
	AquTur	Aquatic turtles			
	SAquTur	Semi-aquatic turtles			
	Amphib	Amphibians			
	SAquRep	Aquatic/semi-aquatic reptiles			
	SpAmphib	Species richness of riparian amphibians			
	SpRep	Species richness of riparian reptiles			
	DivAmphib	Diversity riparian amphibians			
	DivRep	Diversity riparian reptiles			
Birds	CGround	Medium / large ground-nesting channel species			
	SeaFV	Small non-flocking land bird of seasonally flooded vegetation			
	TreeWB	Tree-nesting large waterbird			
	CHole	Bank-/hole-nesting species			
	Grambeds	Flocking non-aerial passerine of tall graminoid beds			
	FGround	Large ground-nesting species of floodplain wetlands			
	CForest	Channel-using large species which require bank side forest			
	CRock	Natural rocky crevice nester in channels			
	WoodWater	Dense woody vegetation / water interface			
Mammals	Dolphin	Irrawaddy dolphin			
	Otter	Otters			
	Ung	Wetland ungulates			

Appendix F. PRELIMINARY BIORA LINKS

Appendix Table 1 Links to modelled time series (hydrology, hydraulics, sediments and water quality). Codes given in Appendix E

	Indicators	#	Hydrology																					Hydraulics												Sediments					Water quality														
			MAR	Do	Dd	Dq	Ddv	mxiDry	raiDry	diDry	mxiT1	raiT1	diT1	Fo	Fd	Fq	Fv	Fdv	mxiWet	raiWet	diWet	T2s	raiT2	aveCV	maxCD	minCD	CSS	Slope	Elevatio	Inun2C	FpD	InunAre	aveFPV	maxFpV	minFpD	SedLoa	SedCon	SedTGr	SedOn	SedDur	Salinity	Temp	pH	TSS	ALK	SO4	NO32	NH4N	TOTN	PO4P	TOTP	Si	DO	COD	Barrier
Geomorphology	Erosion (bank / bed incision)	14					y		y			y						y		y	y		y				y	y								y			y	y															
	Sediment fining / coarsening	5																									y	y								y		y																	
	Exposure of sandy bars, islands, insets	14			y		y		y			y						y		y			y				y									y			y	y															
	Exposure of rocky reefs	12					y		y			y						y		y			y				y									y			y	y															
	Width of active back channels	8					y		y			y						y		y			y		y																														y
	Pool depth	5																									y									y			y	y															
	Water clarity	3																						y													y							y											
	~~Extent of gravel substrate~~	0																																																					
Vegetation	BC: extent of upper bank vegetation cover	7																							y	y								y				y																	
	BC: extent of lower bank vegetation cover	6																							y	y												y																	
	BC: extent herbaceous marsh vegetation (submerged, floating & emergent cover)	12																							y	y			y	y				y				y																	
	BC: Biomass riparian vegetation	14																							y	y				y				y				y																	
	BC: Biomass algae (planktonic and benthic)	41			y					y	y				y		y					y		y	y	y	y		y	y			y	y		y	y	y	y	y		y	y	y	y	y	y	y	y	y	y	y	y	y	
	BC: Wetland community structure; spp diversity	17																							y	y			y	y				y				y									y	y	y	y	y				
	FP: extent flooded forest cover	19																							y	y			y	y	y	y		y	y	y	y	y			y		y		y	y							y		
	FP: extent herbaceous marsh vegetation (submerged, floating &emergent)	28																							y	y			y	y	y	y		y	y	y	y	y			y		y	y	y	y	y	y	y	y	y		y		
	FP: Biomass of riparian/aquatic cover	28																							y	y			y	y	y	y		y	y	y	y	y			y		y	y	y	y	y	y	y	y	y		y		
	FP: extent of cyanobacteria	24																																							y	y	y	y	y	y	y	y	y	y	y	y	y	y	
	FP: biomass of algae (planktonic &benthic)	47			y					y	y				y		y					y		y	y	y	y		y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	
	FP: wetland community structure; spp diversity	28																							y	y			y	y	y	y		y	y	y	y	y			y		y	y	y	y	y	y	y	y	y		y		
	Banks: Invasive riparian plant cover	15																							y	y						y		y	y			y					y		y	y							y		
	Aquatic: Inv floating & sub plant cover	25																							y	y					y	y		y		y	y	y			y		y	y	y	y	y	y	y	y	y		y		
Macroinvertebrates	Heptageniid mayflies (stony habitat)	10				y																		y														y									y	y	y	y	y		y		
	Baetid mayflies (sandy habitat)	9				y																																y									y	y	y	y	y		y		
	Dry season emergence	11				y	y	y																														y									y	y	y	y	y		y		
	Palingeniid mayflies (silty habitat)	9				y																																y									y	y	y	y	y		y		
	Snail abundance	9																																				y									y	y	y	y	y		y		
	Diversity of snails	8																																				y									y	y	y	y	y		y		
	Neotricula aperta (schistosomaisis host)	8																																				y									y	y	y	y	y		y		
	Bivalves abundance	9																																				y									y	y	y	y	y		y		
	Polychaete worms (salinity indicator)	9																																				y			y						y	y	y	y	y		y		
	Shrimps and crabs	10																																				y			y						y	y	y	y	y		y		
	Littoral Inverts diversity	13				y																		y														y			y						y	y	y	y	y		y		
	Littoral Inverts ATSP	13				y																		y														y			y						y	y	y	y	y		y		
	Benthic Inverts diversity	10				y																																y			y						y	y	y	y	y		y		
	Benthic Inverts ATSP	10				y																																y			y						y	y	y	y	y		y		

	Indicators	#	Hydrology																				Hydraulics												Sediments							Water quality														Barrier
			MAR	Do	Dd	Dq	Ddv	mxiDry	raiDry	diDry	mxiT1	raiT1	diT1	Fo	Fd	Fq	Fv	Fdv	mxiWet	raiWet	diWet	T2s	raiT2	aveCV	maxCD	minCD	CSS	Slope	Elevatio	lnun2C	FpD	lnunAre	aveFPv	maxFpV	minFpD	SedLoa	SedCon	SedTGr	SedOn	SedDur	Salinity	Temp	pH	TSS	ALK	SO4	NO32	NH4N	TOTN	PO4P	TOTP	Si	DO	COD	
	Zooplankton Abundance	10	y																				y																		y													
Fish	Rithron resident	23	y	y	y	y				y			y	y	y		y						y			y										y	y			y												y	
	Main channel resident (long distant white)	26	y		y	y				y			y	y	y								y			y			y		y					y	y			y												y	y
	Main channel spawner (short distance white)	30	y		y	y				y			y	y	y								y			y			y		y					y	y			y												y	y
	Floodplain spawner (grey)	32	y		y	y								y	y	y	y					y							y	y	y					y	y																y	
	Eurytopic (generalist)	4																																			y																	
	Floodplain resident (black fish)	28	y		y	y								y	y	y	y					y								y	y					y	y			y												y	
	Estuarine resident	8																																	y		y			y													
	Anadromous	15	y		y	y							y	y	y								y			y											y	y														y	y
	Catadromous	7																																			y	y														y	y
	Marine visitor	4																																	y					y													
	Non-native	6								y			y																							y																y	
Herpetofauna	Ranid & microhylid amphibians	17			y									y																	y					y				y													
	Aquatic serpents	14												y											y						y									y												y	
	Semi-aquatic serpents	7												y																											y													
	Aquatic Turtles	15								y					y											y						y									y													
	Semi-aquatic Turtles	4								y					y																																								
	Amphibians -human consumption	3												y	y																																								
	Aqu/semi-aqu reptiles: human consumptn &farmed crocs	5			y									y	y																	y																							
	Species richness of riparian/FP amphibians	13			y									y					y		y	y								y		y					y																	
	Species richness of riparian/FP reptiles	11												y					y		y	y								y		y																						
	Diversity index of riparian/FP amphibians	13			y									y					y		y	y								y		y					y																	
	Diversity index of riparian/floodplain reptiles	11												y					y		y	y								y		y																						
Birds	Medium – large ground-nesting channel spp	7																																																					
	Tree-nesting large waterbirds.	8																																																				
	Bank / hole nesting species	5																																																				
	Flocking non-aerial pass of graminoid beds	3																																																			
	Large ground-nesting spp: wetland FP	3																																																			
	Channel-using large spp: bankside forest	8																																																			
	Natural rocky crevice nester in channels	4																																																			
	Dense woody vegetation / water interface	4																																																			
	Small non-flocking landbird of seasonally flooded vegetation	11																																																		
Mammals	Irrawaddy dolphin	5																																																			
	Otters	10																																																			
	~~Small carnivores~~	0																																																		
	Wetland ungulates	2																																																		

Appendix Table 2 Links to geomorphology, vegetation and macroinvertebrates. Codes given in Appendix E

	Indicators	#	Geomorphology							Vegetation													Macroinvertebrates															
			Erosion	FineCoarse	Sandbars	Rockreefs	PDepth	Clarity	~~Gravel~~	CUCover	CLCover	CHerb	CBioRip	CBioAlg	CComm	FForest	FHerb	FBio	FBioBG	FBioAlg	FComm	RipInv	FloatInv	Hept	Baet	Emerge	Palin	SnailA	SnailD	*N. aperta*	Bivalve	Poly	Crust	LitDiv	LitASPT	BenDiv	BenASPT	Zoo
Geomorphology	Erosion (bank / bed incision)	14											y																								
	Sediment fining / coarsening	5	y																																		
	Exposure of sandy bars, islands, insets	14	y										y																								
	Exposure of rocky reefs	12	y																																		
	Width of active back channels	8																																			
	Pool depth	5																																			
	Water clarity	3																																			
	~~Extent of gravel substrate~~	0																																			
Vegetation	C: extent of upper bank vegetation cover	7	y		y	y																															
	C: extent of lower bank vegetation cover	6	y		y	y																															
	C: extent herbaceous marsh vegetation (submerged, floating & emergent cover)	12	y		y	y																y	y														
	C: Biomass riparian vegetation	14	y		y	y				y	y	y										y	y														
	C: Biomass algae (planktonic and benthic)	41			y	y	y	y				y	y									y	y														
	C: wetland community structure; spp diversity	17	y		y	y																y	y														
	FP: extent flooded forest cover	19	y		y	y																															
	FP: extent herbaceous marsh vegetation (submerged, floating &emergent)	28	y		y	y																y	y														
	FP: Biomass of riparian/aquatic cover	28	y		y	y																y	y														
	FP: extent of cyanobacteria	24			y	y	y	y								y	y	y		y		y	y														
	FP: biomass of algae (planktonic &benthic)	47			y	y	y	y								y	y	y	y			y	y														
	FP: wetland community structure; spp diversity	28	y		y	y																y	y														
	Invasive riparian plant cover	15	y		y							y				y	y																				
	Aquatic: Invasive floating & sub plant cover	25	y					y				y				y	y					y															
MacroInvertebrates	Heptageniid mayflies (stony habitat)	10		y																																	
	Baetid mayflies (sandy habitat)	9		y																																	
	Dry season emergence	11		y																																	
	Palingeniid mayflies (silty habitat)	9		y																																	
	Snail abundance	9		y																																	
	Diversity of snails	8		y																																	
	Neotricula aperta (schistosomaisis host)	8		y																																	
	Bivalves abundance	9		y																																	
	Polychaete worms (salinity indicator)	9		y																																	
	Shrimps and crabs	10		y																																	
	Littoral Inverts diversity	13		y								y					y																				
	Littoral Inverts ATSP	13		y								y					y																				
	Benthic Inverts diversity	10		y																																	
	Benthic Inverts ATSP	10		y																																	
	Zooplankton Abundance	10		y																																	
Fish	Rithron resident	23	y	y				y																y													
	Main channel resident (long distant white)	26	y	y			y																					y		y		y					
	Main channel spawner (short distance white)	30	y	y			y									y												y		y		y					

	Indicators	#	Geomorphology							Vegetation													Macroinvertebrates														
			Erosion	FineCoarse	Sandbars	Rockreefs	PDepth	Clarity	~~Gravel~~	CUCover	CLCover	CHerb	CBioRip	CBioAlg	CComm	FForest	FHerb	FBio	FBioBG	FBioAlg	FComm	RipInv	FloatInv	Hept	Baet	Emerge	Palin	SnailA	SnailD	*N. aperta*	Bivalve	Poly	Crust	LitDiv	LitASPT	BenDiv	BenASPT	Zoo
	Floodplain spawner (grey)	32					y					y				y	y		y			y							y		y		y					
	Eurytopic (generalist)	4										y							y																		
	Floodplain resident (black fish)	28										y				y	y		y	y		y							y									
	Estuarine resident	8										y				y	y																				
	Anadromous	15																																			
	Catadromous	7																																			
	Marine visitor	4																																			
	Non-native	6																																			
Herpetofauna	Aquatic serpents	14										y				y																					
	Semi-aquatic serpents	7			y						y		y																								
	Aquatic Turtles	15	y		y							y	y			y												y					y				
	Semi-aquatic Turtles	4	y								y																										
	Amphibians -human consumption	3																																			
	Aqu/semi-aqu reptiles: human consumption &farmed crocs	5																																			
	Species richness of riparian/FP amphibians	13	y								y		y		y																						
	Species richness of riparian/FP reptiles	11	y								y		y		y																						
	Diversity index of riparian/FP amphibians	13	y								y		y		y																						
	Diversity index of riparian/floodplain reptiles	11	y								y		y		y																						
Birds	Medium – large ground-nesting channel spp	7			y			y	y																							y					
	Tree-nesting large waterbirds.	8														y														y		y					
	Bank / hole nesting species	5	y																						y	y											
	Flocking non-aerial pass of graminoid beds	3															y	y			y																
	Large ground-nesting spp: wetland FP	3															y	y			y																
	Channel-using large spp: bankside forest	8								y						y		y																y		y		
	Natural rocky crevice nester in channels	4				y																		y	y	y											
	Dense woody vegetation / water interface	4														y	y	y			y																
	Small non-flocking landbird of seasonally flooded vegetation	11			y						y		y				y	y			y			y	y	y	y						y				
Mammals	Irrawaddy dolphin	5					y																									y					
	Otters	10						y			y	y										y								y		y					
	~~Small carnivores~~	0																																			
	Wetland ungulates	2														y	y																				

Appendix Table 3 Links to fish, herpetofauna, birds and mammals. Codes given in Appendix E

	Indicators	#	Fish											Herpetofauna									Birds									Mammals			
			Rithron	CRes	CSpawn	FSpawn	Gen	FRes	ERes	Anad	Catad	Marine	NonN	AquSerp	SAquSerp	AquTurt	SAquTurt	Amphib	SAqRep	SpAmphib	SpRep	DivAmph	DivRep	CGround	SeaFV	TreeWB	CHole	Grambeds	FGround	CForest	CRock	WoodWater	Dolphin	Otter	~~Cam~~	Ung
Geomorphology	Erosion (bank / bed incision)	14																																	
	Sediment fining / coarsening	5																																	
	Exposure of sandy bars, islands, insets	14																																	
	Exposure of rocky reefs	12																																	
	Width of active back channels	8																																	
	Pool depth	5																																	
	Water clarity	3																																	
	~~Extent of gravel substrate~~	0																																	
Vegetation	BC: extent of upper bank vegetation cover	7																																	
	BC: extent of lower bank vegetation cover	6																																	
	BC: extent herbaceous marsh vegetation (submerged, floating & emergent cover)	12																																	
	BC: Biomass riparian vegetation	14																																	
	BC: Biomass algae (planktonic and benthic)	41																																	
	BC: wetland community structure; spp diversity	17																																	
	FP: extent flooded forest cover	19																																	
	FP: extent herbaceous marsh vegetation (submerged, floating &emergent)	28																																	
	FP: Biomass of riparian/aquatic cover	28																																	
	FP: extent of cyanobacteria	24																																	
	FP: biomass of algae (planktonic &benthic)	47																																	
	FP: wetland community structure; spp diversity	28																																	
	Invasive riparian plant cover	15																																	
	Aquatic: Invasive floating & sub plant cover	25																																	
MacroInvertebrates	Heptageniid mayflies (stony habitat)	10																																	
	Baetid mayflies (sandy habitat)	9																																	
	Dry season emergence	11																																	
	Palingeniid mayflies (silty habitat)	9																																	
	Snail abundance	9																																	
	Diversity of snails	8																																	
	Neotricula aperta (schistosomaisis host)	8																																	
	Bivalves abundance	9																																	
	Polychaete worms (salinity indicator)	9																																	

	Indicators	#	Fish											Herpetofauna									Birds									Mammals			
			Rithron	CRes	CSpawn	FSpawn	Gen	FRes	ERes	Anad	Catad	Marine	NonN	AquSerp	SAquSerp	AquTurt	SAquTurt	Amphib	SAqRep	SpAmphib	SpRep	DivAmph	DivRep	CGround	SeaFV	TreeWB	CHole	Grambeds	FGround	CForest	CRock	WoodWater	Dolphin	Otter	Carn	Ung
	Shrimps and crabs	10																																	
	Littoral Inverts diversity	13																																	
	Littoral Inverts ATSP	13																																	
	Benthic Inverts diversity	10																																	
	Benthic Inverts ATSP	10																																	
	Zooplankton Abundance	10																																	
Fish	Rithron resident	23																														y			
Fish	Main channel resident (long distant white)	26																														y			
Fish	Main channel spawner (short distance white)	30																														y			
Fish	Floodplain spawner (grey)	32																								y	y								
Fish	Eurytopic (generalist)	4																																	
Fish	Floodplain resident (black fish)	28																								y	y								
Fish	Estuarine resident	8																																	
Fish	Anadromous	15																																	
Fish	Catadromous	7																																	
Fish	Marine visitor	4																																	
Fish	Non-native	6																																	
Herpetofauna	Ranid & microhylid amphibians	17			y																					y			y	y				y	
Herpetofauna	Aquatic serpents	14			y		y																			y			y					y	
Herpetofauna	Semi-aquatic serpents	7																											y					y	
Herpetofauna	Aquatic Turtles	15			y		y																												
Herpetofauna	Semi-aquatic Turtles	4																																	
Herpetofauna	Amphibians -human consumption	3																																	
Herpetofauna	Aqu/semi-aqu reptiles: human consumptn &farmed crocs	5																																	
Herpetofauna	Species richness of riparian/FP amphibians	13																																	
Herpetofauna	Species richness of riparian/FP reptiles	11																																	
Herpetofauna	Diversity index of riparian/FP amphibians	13																																	
Herpetofauna	Diversity index of riparian/floodplain reptiles	11																																	
Birds	Medium – large ground-nesting channel spp	7	y	y	y																														
Birds	Tree-nesting large waterbirds.	8				y		y						y	y																				
Birds	Bank / hole nesting species	5				y		y																											
Birds	Flocking non-aerial pass of graminoid beds	3																																	
Birds	Large ground-nesting spp: wetland FP	3																																	

	Indicators	#	Fish											Herpetofauna									Birds									Mammals			
			Rithron	CRes	CSpawn	FSpawn	Gen	FRes	ERes	Anad	Catad	Marine	NonN	AquSerp	SAquSerp	AquTurt	SAquTurt	Amphib	SAqRep	SpAmphib	SpRep	DivAmph	DivRep	CGround	SeaFV	TreeWB	CHole	Grambeds	FGround	CForest	CRock	WoodWater	Dolphin	Otter	~~Carn~~	Ung
	Channel-using large spp: bankside forest	8												y	y																					
	Natural rocky crevice nester in channels	4																																		
	Dense woody vegetation / water interface	4																																		
	Small non-flocking landbird of seasonally flooded vegetation	11																																		
Mammals	Irrawaddy dolphin	5	y	y	y																															
Mammals	Otters	10	y	y	y																															
Mammals	~~Small carnivores~~	0																																		
Mammals	Wetland ungulates	2																																		

Appendix G. LIST OF COUNCIL STUDY BIORA DISCPLINE SPECIALISTS

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