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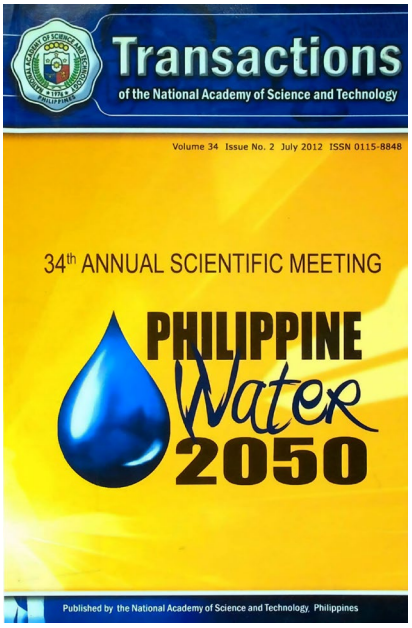

Ecology and Biodiversity of Major Inland Bodies of Water: Challenges and Opportunities

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ECOLOGY AND BIODIVERSITY OF MAJOR INLAND BODIES OF WATER: CHALLENGES AND OPPORTUNITIES

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Abstract

Water is essential to life linking different ecosystems. Wetland or inland water bodies support the widest range of ecosystem services to humanity from being sources of potable drinking water, water for agricultural activities, and hydroelectric power to sites of aquaculture/fishery services. This paper focuses on the Philippines' three major wetlands: Laguna Lake, Lake Lanao and Agusan Marsh. Biodiversity and environmental integrity of these bodies of water are critically confronted by the different problems generated through the services they provide such as introduction of invasive species and rise of domestic, industrial and agricultural pollutants including potential impacts from climate change. Management still remains a challenge in these areas. Localized rehabilitation programs that have been put forward should be implemented urgently to stop and if possible reverse environmental degradation in these major inland bodies of water.

Keywords: Agusan Marsh, biodiversity, conservation, ecology, freshwater, Laguna Lake, Lanao Lake

Introduction

Water, which is fundamental to life, links ecosystems from the mountains/ridges to the coasts/reefs, the open ocean and the atmosphere. Freshwater available mostly in lakes, both natural and artificial, provide the widest range of ecosystem services to humanity (Austin Declaration, 2011).

The Philippine Archipelago bounded in the west by the West Philippine Sea and the Pacific Ocean in the East, has 216 major lakes, 18 major rivers, and a number of minor rivers, marshes and swamps. These inland waters/wetlands, including the groundwater, are replenished with abundant fresh water during many months of the year, mostly during the Southwest

Monsoon. Management, which is critical during and before the periods of abundance in order to gain fully on one hand and prevent or mitigate negative effects as flooding and landslides, on the other hand, remains a challenge. Further, biodiversity and environmental integrity of these wetland/inland bodies of water need to be conserved and protected for their ecosystem services.

This paper presents the highlights of the Round Table Discussions (RTDs) hosted by the Biological Sciences Division of the National Academy of Science and Technology (NAST) on three major wetlands in the Philippines namely, Laguna Lake, Lake Lanao and Agusan Marsh which focused on their biodiversity and ecology. Contributions from our invited speakers and discussants have been synthesized and additional materials incorporated to be able to link this chapter on maintenance of biodiversity and ecosystem integrity with the rest of papers delivered during the "34th Annual Scientific Meeting: Philippine Water 2020, held at Manila Hotel on 11 to 12 July 2012.

The Laguna Bay and its Watershed

"Laguna de Bai", more popularly known now as Laguna Bay, has an area of about 3,813.2 km^2 with a maximum depth of 18-20 m and an average depth of 2.5 m. It has 24 sub-basins and coastline of 286 km. The Pasig River is the only outlet of the bay which connects it to Manila Bay that drains eventually to the South China Sea. About 100 streams withdraw water to the lake.

The "watershed" is partly forested (about 2,929 km^2) but the urbanized and agro-industrialized Laguna area constitutes a greater part. Metropolitan Manila is quite near its vicinity (Figure1). Mount Makiling has a number of endemic, vascular (flowering plants) and non-vascular plants (ferns) (Department of Tourism, DOT http://www.visitmyphilippines.com/index.php?title=Mt.Makiling&Page=1&pid=6726). Biodiversity pool in the lake has apparently been affected by the aquaculture activities that have been ongoing in this multifunction fresh water body.

The number of finfish species in the lake varied (i.e. from 16 to 31) based on several studies from 1959 to 2009 (Tamayo-Zafaralla, 2012). These

finfish species are either "indigenous", "introduced" or "exotic", and "migratory". The intermittent rise in the number of species during this period could be accounted for by the introduction of "exotic" and "migratory" species naturally/accidentally through the waterways/ interconnections with other bodies including floodwaters and the aquaculture. No in-depth study has been done on these finfish "introductions". There are also unpublished reports that indigenous fish like *ayungin* and *kanduli* are becoming extinct in the area since they are generally not part of the recent harvests of local fishermen. Tamayo-Zafaralla (2012) reported that the number of total finfish species has decreased from 31 to 16 between 1991 to the present. This could have been partly a result of the impact on the finfish biodiversity by invasive/exotic species.

Figure 1. Map of Laguna de Bay from Google map. (http://maps.google.com.ph/maps?q=laguna+de+bay&hl=en&ll=14.453299,121.499176&spn=0.754005,1.3592&sll=7.893309,124.264297&sspn=0.385638,0.676346&t=h&hnear=Laguna+de+Bay&z=10)

Water Services

The water in Laguna de Bay has been used to generate power of about 300 MW (with future a target of 600 MW). A hydroelectric power station is located in Kalayaan, Laguna. Also, the Manila Water Works and Sewage System (MWSS) has designated Maynilad as a concessionaire (from 2007 to 2037) to tap further the lake as source of potable water. At present the lake is source of potable water to Muntinlupa including Ayala Alabang Village. Although Umiray, Angat and Ipo Dams can apparently supply the water needs for Metro Manila and adjacent areas, Laguna de Bay has been considered as a future buffer supply with about 100-200ML/day capacity (Martinez, 2012).

Aquaculture/Fishery Services

Fish culture in Laguna de Bay started in 1965 and production increased through the years. In 2012, about 11,248.29 hectares are used as fish pens and 1,949.24 hectares for fish cages. Milkfish and tilapia are the major fish types cultured in the lake. Annual combined aquaculture of open fisheries production could reach up to more than 90,000 MT/year as in 2009 (Palma, 2012).

Socio-Economic and Environmental Challenges

The lake is bounded by six provinces (Cavite, Laguna, Batangas, Rizal, Quezon and National Capital Region), 12 cities and 49 municipalities with about 13 million residents. There are about 4247 wet industries and 4679 dry industries operating within these areas (Santos-Borja, 2012). Aside from its economic role (primarily as aquaculture site), the waters of the lake are used as transport route for people traversing their culture sites or moving from one barangay/municipality to the other.

As in any other busy bays, the waters can be challenged by organic and inorganic nutrient loading from land and the water activities. Tamayo-Zafaralla (2012) reports that about 68.5% of the "pollutants" in Laguna Lake is from domestic source, while 19.0% from industry, 11.5% from agriculture and about 1% from forestry.

Beginning 2007, algal biomass has increased up to more than 40,000 mg/m^3 in five stations in the bay indicating eutrophication. Associated with this, there were 29 fish kill incidences from 2005-2012 (Santos-Borja, pers. comm.). Fish kills are generally associated with low oxygen and high algal biomass. The better side of the "picture" is that the LLDA through its "Environmental User Fee System (EUFS) has apparently partially addressed this eutrophication problem. Biological Oxygen Demand loading per firm (BOD/firm) in the Laguna Lake was reduced by 58% from 1997 to 2008, with 3754 firms covered at 8% rate of increase/year due to EUFS (Santos-Borja 2012).

Several invasive species have been reported in Laguna de Bay. Janitor fish (*Pterogoplichthys disjunctivus*) and clown knifefish (*Chitala ornata*) seem to be the most destructive. This clown knifefish (Figure 2) can grow up to more than 10 kg and harvest of the species could be up to several tons weekly. This carnivore/predator cost much lower at Php15.00/kg compared to the milkfish and tilapia (at about Php100/kg), which they consumed as food (Dir. Perez of Bureau of Fisheries and Natural Resources, pers. comm.).

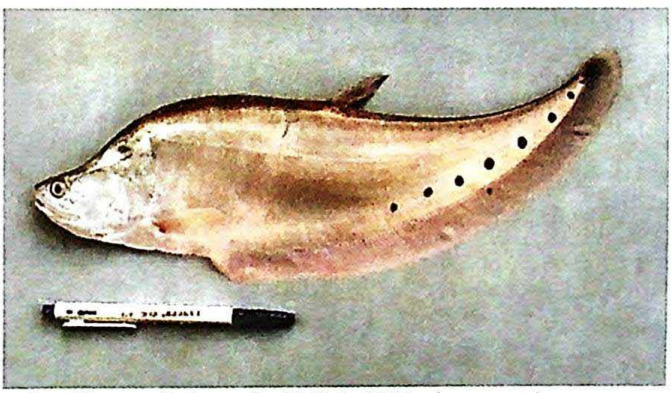

Figure 2 . Photo of clown knifefish (*Chitala ornata*). (http://nas.er.usgs.gov/XIMAGESERVERX/2005/20051104161858.jpg)

Another major environmental problem in the lake is "shallowing". Bathymetry studies conducted by the National Institute of Geological Sciences in 1963, 1973, 1983 and 1997 have shown that in 1997, the lake became shallower by 0.30 m (Santos-Borja, 2012).

Environmental problems in the Laguna de Bay region identified in the "New Master Plan" for the area include: denuded watershed, increasing

development pressures, uncontrolled reclamation influx of informal settlers and illegal structures on shore lands. Flooding and habitat destruction have remained to be major socio-economic and environmental challenges for this Region and specifically the Bay which is the initial/primary outlet of flood water and flood debris from its watershed and Metro Manila specifically during the Southwest Monsoon. In September 2009, typhoon "Ondoy" severely flooded these areas for weeks.

Laguna de Bay Management

Laguna de Bay can be considered the best managed freshwater system in the country primarily because of the early establishment of the 'Laguna Lake Development Authority'. There are several flagship programs being implemented by LLDA, namely: (1) Environmental Management Program, (2) Fisheries Development Program, (3) Watershed Management Program, (4) Shoreline Management Program, and (5) Institutional Reform and Development Program. The LLDA also has a 2020 Spatial Development Master Plan Framework for Laguna de Bay basin. Its principally centers on land and lake water physical development which in turn aims to (1) rehabilitate and protect the watershed considering the sustainability of economic asset sources; (2) in terms of shore land, the focus is protecting buffer zones and securing productive, environmentally-conscious lakeshore community stakeholders; and (3) to maintain a healthy ecosystem in the lake and its rivers and offer host complementary uses; thus, the formation of an Integrated Lake Basin Authority, which is co-managed by financially independent stakeholders (Santos-Borja 2012).

Lake Lanao and its Watershed

Lake Lanao is the second largest lake in the Philippines and the biggest in Mindanao. The watershed area is 180,460 hectares while, the lake are is about 35,600 hectares It is bounded by three provinces, i.e. Lanao del Norte, Lanao del Sur and North Cotabato. There are 28 towns and cities within the watershed area (Figure 3).

The Lake Lanao watershed is socio-culturally important to the Meranaos/Maranaos. In 1992, it was declared as a protected area under Proclamation No. 871. The land use in the watershed consists of: open/cultivated/agricultural areas (47,705 hectares), brushland (9817

hectares), residual forest (23,981 hectares), virgin forest (48,298 hectares), mossy forest (15,659 hectares) and the rest are residential, built up and open areas (Metillo and Hansel, 2012).

Biodiversity

The Lake Lanao watershed has been considered as 'Key Biodiversity Area (KBA)' an 'Important Bird Area (IBA)' and 'Important Plant Area (IPA)' (United Nations Environment Programme, UNEP Global Biodiversity Outlook 2, 2006).

Figure 3. Map of Lake Lanao from Google map. (http://maps.google.com.ph/maps?hl=en&ll=7.893309,124.264297&spn=0.385638,0.676346&t=h&z=11)

The flora consists of montane forests and dipterocarps with orchid and palm species dominating. *Rafflesia* that produces "giant" flowers is also present. The common bird species are Philippine eagle, bitterns, egrets, herons, ducks, geese, coots, crakes, rails, waterhens, crow, kingfisher, hawk-eagle, and Mindanao bleeding heart. Eighteen (18) cyprinid species are endemic to Lake Lanao with the belief that 16 may be extinct. The lake is also home to several endemic freshwater crabs. Biodiversity studies in the areas however are lacking to verify these claims and to check on the current status of the flora and fauna of both the lake and its watershed (Metillo and Hansel, 2012).

Water Services

The Lake Lanao-Agus River system constitutes the main hydropower (66%) source and irrigation for Mindanao. Agus River, the only outlet of the lake extends 36 km. In 1950, with the authorization of President Elpidio Quirino, the Agus River (Figure 4) and the 'great' Maria Cristina Falls were *harnessed* for hydropower development and potable water supply. In 1975, the Agus Hydroelectric Plant was constructed and Agus 1, 4 and 7 were then constructed in 1979 and Agus 5 in 1980. The Lake Lanao situated in a type III climate is a natural reservoir of water with 180 to 237 rainy days and 2873 mm average rainfall. The volume of water is 21.254 km^3 and the critical depth is set at 699.0 m for management purposes (Hansel and Metillo 2012).

Fishery and Aquaculture

Earlier, for example in 1984, the harvest of fish in the lake was about 3.12 T/fishermen/yr. or 8.5T/km^{-2} (de Silva *et al.*, 1991 as cited by Metillo and Hansel, 2012). There has been no updated report on the fish catch from Lake Lanao. There is a report however, that 66.6% the catch was dominated by the invasive goby species, Hypseleotris *agilis* unlike the endemic *Puntius lindog* that accounts for only 0.01% of the catch. Culture of carp and other fish species including *Puntius binotatus* has been done in Lake Lanao (Metillo and Hansel, 2012).

Socio-Economic and Environmental Challenges

Lake Lanao and its shore land is paramount to the history, culture, religion and livelihood of Meranaos/Maranaos whose population now is

Figure 4. Maria Cristina Falls, site of Agus 6 which is a part of the Agus River set of Hydroelectric Plants (HEPs). (http://upload.wikimedia.org/wikipedia/tl/f/f6/Hidroelektriko_Agus6.jpg)

about 700,000. Catchment agriculture in the area involves the following crops: rice, corn, coconut, coffee, cassava, sweet potato, certain vegetables, cacao, abaca, lanzones and durian. The Maranaos have been dependent on the lake for fishery and to certain extent aquaculture harvest while the watershed around the lake has been partly converted to farms over the years. Rampant timber poaching has also been reported in the watershed (Adiong, 2012). The Lake and watershed environment have also been challenged by socio-economic pressures as quarrying, inappropriate farming, untreated wastewater, thereby resulting to water pollution/eutrophication and sedimentation/siltation (Metillo and Hansel, 2012).

Development Initiatives and Management

An Integrated Lake Basin Management (ILBM) has been functional for Lake Lanao and its watershed. In 2006, a River Basin Control Office was created through Executive Order 510. Various trainings, seminars, workshops have been undertaken to help the ILBM including the USAID program "Ecosystem Governance (Eco-governance)". A Lake Lanao Integrated Development Plan (IDP) which includes lake water clarification has been part of the government and non-governmental organizations (NGOs) initiatives.

Based on the assessments of the local government and the other stakeholders, a "Lake Lanao Watershed Reservation (LLWR) and Mountain Ranges Natural Park" should be declared as a Protected Area under the Natural Park Category. A legislative bill authorized by Senator Loren Legarda is now pending to create a "Lake Lanao Development Authority" (patterned after Laguna Lake Development Authority) which hopefully would enhance the lake's management (Hansel and Metillo, 2012; Adiong, 2012).

Agusan Marsh

Agusan Marsh is bounded by Regions 9 (Zamboanga Peninsula - Isabela City, Zamboanga City, Zamboanga del Norte, Zamboanga del Sur and Zamboanga Sibugay), 11 (Davao - Compostela Valley, Davao City, Davao del Norte, Davao del Sur, Davao Oriental) and 13 (Caraga - Agusan del Norte, Agusan del Sur, Butuan City, Dinagat Islands, Surigao del Norte, Surigao del Sur), and with a retarding basin of 59 lakes and ponds. It has a type IV climate (i.e. with average humidity of 86%, average temperature of 25.6°C and average rainfall of 4.3mm/yr. distributed year-round). The Agusan Marsh watershed is about 111,540 hectares, the river basin area is about 1.2 M hectares and the marsh area about 19,196 hectares It has been estimated that this ecosystem stores 15% of the entire fresh water reservoir of the country (Department of Environment and Natural Resources, http://www.denr.gov.ph/) (Figure 5).

Biodiversity

Declared as protected area under RA 7586 of 'Natural Integrated Protected Area System (NIPAS) Act', and considered a 'Ramsar Site' (wetland protected area under the Ramsar Convention) of international significance, the marsh is indeed one of the most important diversity sites in the country. In 2006, Agusan Marsh has been nominated as a "UNESCO World Heritage Site".

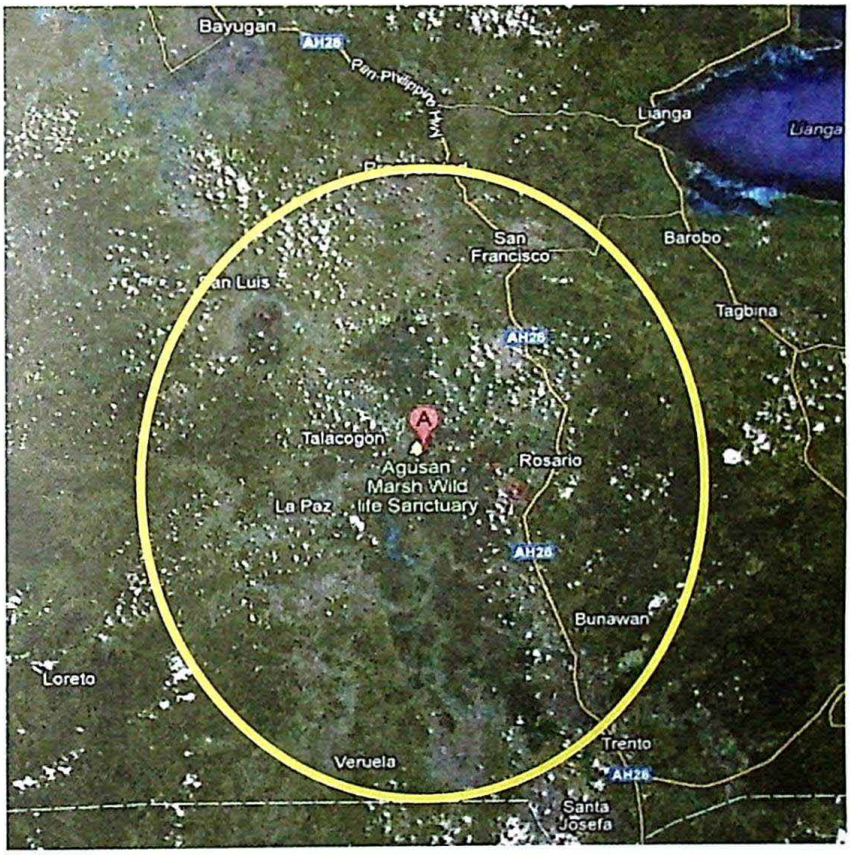

Figure 5. Map of Agusan Marsh.
(http://maps.google.com.ph/maps?q=agusan+marsh+map&hl=en&ll=8.35554,126.033783&spn=0.770384,1.352692&hq=agusan+marsh&t=h&z=10)

The Agusan Marsh Ecosystem consists of swamp forest (~49%), scrub swamp (~14%), peat swamp (~10%), inundated forest (~10%), herbaceous swamp (~7%) and sago area. The peatlands which is considered still "intact" actively accumulates carbon from the atmosphere. The marsh's ecosystem has a unique vegetation assemblage and 45% endemicity for the faunal specimens, which include the Philippine crocodile (*Crocodylus mindorensis*) (Andres, 2012).

The most comprehensive recent study on the biodiversity of fish in Agusan Marsh is that of Hubilla-Travis *et al.* (2007), which shows that from 1953 the number of genera and their species doubled. This could be explained by the heightened taxonomic analysis on this site and the increase in the number of introduced fish species. As of 2007, the number of invertebrate species in Agusan Marsh can be classified as 87% native and 13% introduced. The janitor fish, *Pterogophichthys disjunctivus* is one of the introduced species (Hubilla-Travis *et al.*, 2007).

Socio-Economic and Environmental Challenges

The population in Agusan Marsh can be classified as: (1) people in floating houses who reside permanently around major rivers; (2) people who live in the area during dry season and move out during high peak of rainy season; and (3) people who live within the boundary of the marsh and depend on marsh for daily needs. The population variously practices hunting, trapping, logging, firewood gathering, and harvesting from open fishery and minor aquaculture and agriculture. With population increase in the Marsh, the major and institutional concerns or challenges basically emanate from watershed denudation, resource extraction and agricultural/aquaculture expansion. Sedimentation/siltation of rivers/basins and water pollution from domestic and other anthropogenic activities are also occurring. Flooding and introduction of invasive species have also been recorded (Andres, 2012; Regunay, 2012).

A number of fish kill involving tilapia species was reported in Lake Nato, Esperanza, Agusan del Sur where 50 cages were in operation (Bureau of Agricultural Statistics, http://www.bas.gov.ph). A "fish rain" was also reported recently in Loreto Town, Agusan del Sur as a result of a twister that sucked out a school of mudfish fingerlings from the Agusan Marsh (http://www.philstar.com/Article.aspx? articleId=767997).

Ecotourism has been considered as a potential source of income for the local government units (LGUs) in the Agusan Marsh Ecosystem. The longest crocodile captured in the marsh and named "Lolong" by the local people, has been of the tourist attractions since it has been confirmed by Guinness World Records as the longest/largest crocodile in captivity.

Tabios (2007) has earlier summarized the critical elements of the Agusan Marsh River Basin. For the forest/soil, the critical elements are (1) reduced forest cover due to massive logging from the 1950's to 1960's, with the government and private efforts replace endemic species with exotic species; (2) conversion intro agriculture lands which promotes soil erosion and landslides because increased sedimentation; (3) shallowing of rivers which in turn resulted in low productivity of flora and fauna; and (4) uncontrolled mine tailings, steep slope farming/kaingin. Considering the water, critical elements include (1) competing uses (domestic water versus irrigation); (2) alleviation of flooding in populated areas versus floodwater needs of the marsh; (3) upland water needs versus coastal urban and ecological needs; (4) contamination from mining, agricultural wastes mainly chemicals and pesticides; and (5) urban liquid and solid wastes contamination.

Management of Agusan Marsh

Aside from the Agusan River Basin Organization Development Program, there is an Agusan Marsh and Wildlife Sanctuary (AMWS) Management Program, and an Indigenous People (IP) Development Program. All of these programs are being implemented to take care of water resources development and flood management and watershed management (River Basin Control Office of the Department of Environment and Natural Resources, http://rbco.denr.gov.ph).

Summary and Recommendations

The status/trend of the biodiversity and habitat of the three freshwater bodies can be qualitatively compared using a method modified from Lasco and Espaldon (2005). Table 1 shows that the biodiversity pool of Laguna de Bay and Lake Lanao have been decreasing. On the other hand, that of Agusan Marsh could be ranked as in "mixed condition", i.e. there are areas with "intact" biodiversity and there are those in the decreasing trends. More studies should be undertaken specially in Lake Lanao and Agusan Marsh

where data is lacking or insufficient. Water quantity in Lake Lanao has been reportedly diminishing, as well as in Laguna de Bay where more studies on this aspect should be done, and for Agusan Marsh where a "mixed" status seems to prevail depending on temporal and spatial scales. Water quality studies are needed for all three sites but there are more data sets available for Laguna de Bay where analysis and modeling of these data are needed for management purposes.

Table 1. Comparative summary of the habitat and biodiversity pool of Laguna de Bay, Lake Lanao and Agusan Marsh*

Water body	Habitat		Biodiversity Pool
	Water Quantity	Water Quality	
Laguna de Bay*	↓?	↓?	↓
Lake Lanao	↓	↓?	↓?
Agusan Marsh	↓↑?	↓↑?	↓↑?

Note: ↓ = decreasing; ↑ = increasing; ↓↑ = mixed; ? = research/monitoring insufficient
*The table was constructed using available data and information, following the method of Lasco and Espaldon (2005).

Classification for surface waters of these three basins/wetlands is summarized in Table 2. Laguna de Bay has been classified as having three different types (A, B and C) in three specific sites. "Class A" which can be used for drinking after treatment can be tapped from the central and eastern areas. Lake Lanao waters are unclassified and no quality standard has been established yet specific for marshes (including Agusan Marsh).

Table 2. Classification of surface waters for Laguna de Bay, Lake Lanao and Agusan Marsh.

Lake	Specific Area	Classification
Laguna de Bay	Central and East	Class A *(LLDA 2009)*
	Central and South	Class C *(LLDA 2009)*
	Northern Classified	Class B *(LLDA 2009)*
Lake Lanao	Unclassified *(Philippine Information Agency, Press Release 2010)*	
Agusan Marsh	No water quality standard established yet specific for the marshes *(River Basin Control Office of DENR, http://rbco.denr.gov.ph)*	

Note: A = require conventional treatment for drinking supply
B = contact recreation (e.g. bathing, swimming, skin-diving etc.)
C = fishery, recreation/boating, manufacturing
D = agriculture, irrigation, farming etc.

Available data and information can also be used to qualitatively compare the opportunities (through adaptive management) for ecological (and socio-economic) services of the three bodies of water (Table 3). Most, if not all, of these major freshwater bodies have residents along their shoreline and people even utilize them as routes for movement through, within or around these bodies of water. It is apparent that Laguna de Bay and Lake Lanao can continue to function along these lines at a low/sustainable rate through adaptive management. Agusan Marsh in some areas of its ecosystem can also at a low or very low rate may serve as abode for a regulated number of people. More studies, however, are suggested to estimate the carrying capacity of selected sites in the marsh for this purpose.

Table 3. Comparative summary of the opportunities/services that could be rendered from Laguna de Bay, Lake Lanao and Agusan Marsh through adaptive management

Opportunities/Services	Laguna de Bay	Lake Lanao	Agusan Marsh
1. Residence/Route	↑	↑	↑?
2. Hydroelectric	↑?	↑↑↑?	-------
3. Irrigation	↑	↑↑?	↑?
4. Potable Water Supply	↑↑	↑↑?	
5. Flood Control	↑↑?	?	↑↑?
6. Aquaculture/Fishery	↑	↑?	-------
7. Ecotourism	↑?	↑↑?	↑↑↑?

Note: ↑ = Low; ↑↑= Moderate; ↑↑↑= High; -------- Discouraged; ? = research/ monitoring insufficient

Hydroelectric services from Laguna de Bay and Lake Lanao may continue with opportunities seen as high for Lake Lanao. Research towards adaptive management for this purpose should be undertaken for both bodies because regulation/management in relation to flooding is critical. Utilization of Agusan Marsh for hydroelectric power is being discouraged by the present author because this might bring about irreversible negative impacts to the biodiversity of the marsh.

Irrigation services could be provided by the three wetlands at varying scales and tapping of these waters for potable water supply can continuously be possible, however, Agusan Marsh classification of surface water is lacking.

Fishery/Aquaculture which is highest in Laguna de Bay could be continued at a lower rate to be able to help protect the water resource and biodiversity of the bay. Fishery/aquaculture which is undertaken minimally in some areas of Lake Lanao could be ranked lower than its services as hydroelectric source. Aquaculture is being discouraged for Agusan Marsh especially because most/many cultured species are "invasive".

Basins can be flood control sites, however, research and development for management/co-management of these inland waters for flood control are lacking.

Ecotourism opportunities are highest at Agusan Marsh which seems to have the highest biodiversity of all three and lowest for Laguna de Bay which has the most diverse socio-economic services. Protection of areas used for ecotourism should be carefully considered, however.

Development and Management Directions

Natural and man-made systems are best managed with approaches based on science/knowledge. The Laguna Lake Development Authority (LLDA) through the years has accumulated the most data sets and information via its monitoring and research geared towards enhanced management of Laguna de Bay. This "authority" set-up/framework has not been set-up for Lake Lanao and Agusan Marsh which clearly need research and monitoring for its watersheds and the basins themselves.

Decision-support systems which can consider diverse issues in an explicit framework for adaptive management should be developed for these basins. Ecosystem model/s and socio-economic model/s can be used as inputs to decision-support system specific to each basin. The socio-economic model/s can use changes in population and land use and water use. More modeling can be done that can utilize "feedbacks" or results from the "decision-support system/s" (Figure 6).

The "balance" of economic gains with environmental protection should be adhered to or serve as a guiding principle for management of ecosystems. The ecosystem approach of management should be basin-specific, done over time with consideration of the links to other ecosystem, i.e. a "ridge to reef concept" with the changing climate as an over-arching factor. A continuing

and critical exercise of "assessment → action → evaluation → revision → action" should consider the major "socio-economic factors" and "environmental factors", unique to the basin. This effort should be with adequate manpower and financial support and should be mainstreamed to the government's climate change adaptation and mitigation program.

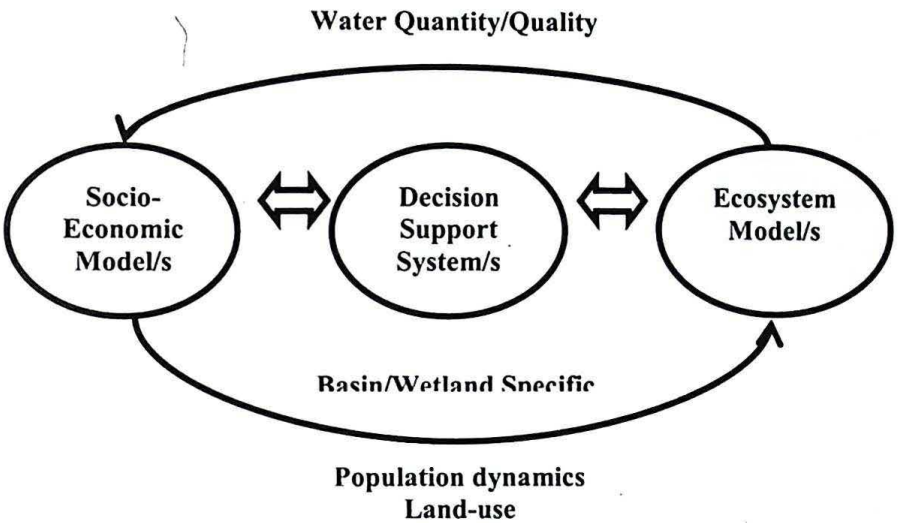

Figure 6. Knowledge-based basin/wetland specific management framework

Localizing wetland management is anchored on the principle that ecosystems are linked but they are unique temporally/dynamically (Figure 7). As proposed by many stakeholders, the government may consider a "Natural Wetlands Committee" that can institutionalize a "National Wetlands Action Plan" where wetland management/authority is localized (as in the LLDA). The academe should be mobilized and supported to undertake research and establish benchmarks for carrying capacity and monitor biodiversity of our major wetlands.

Definitely is that rehabilitation programs to stop or reverse environmental degradation of our major inland bodies of water should be implemented urgently. The development of natural water resources for electric power, generation of potable water supply, etc. should be tempered

by a genuine concern for the protection and conservation of these bodies of water.

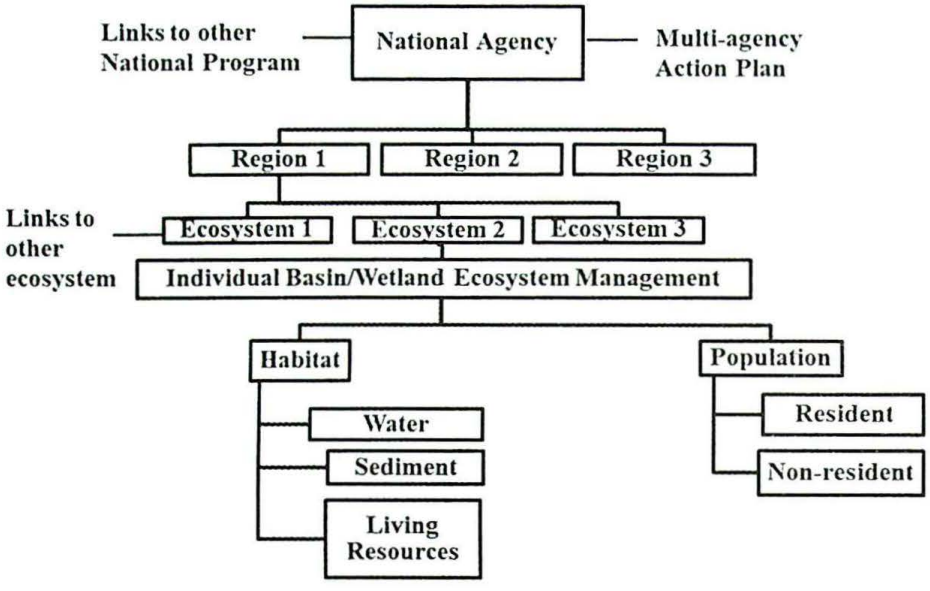

Figure 7. Framework for "localizing" basin/wetland ecosystem management

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