An Ecosystem Approach to Resolving Conflicts Among Ecological and Economic Priorities for Poyang Lake Wetlands

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Ninety-nine percent of the charismatic and Critically Endangered Siberian Crane *Grus leuceogeranus*, as well as 400,000 other waterbirds, depend on wetlands of Poyang Lake in winter. Changes to the ecological character of Poyang Lake would greatly increase risk of extinction for these threatened species.

EXECUTIVE SUMMARY

Poyang Lake has extraordinary importance to Jiangxi Province and to millions of people downriver. Poyang is also recognized internationally for its remarkable biodiversity. The lake's abundant aquatic resources include diverse vegetation and fish, the only freshwater porpoise in the world, and the largest concentrations of wintering waterbirds in East Asia. Construction of a dam at Poyang Lake would transform the ecology of the wetlands, with irreversible impacts on local and global values.

This report recommends an Ecosystem Approach be applied to the management of Poyang. The Ecosystem Approach focuses on structure, processes, and interactions among organisms and their environment. The approach emphasizes the need for adaptive management due to the complex and dynamic nature of ecosystems and the absence of complete understanding of their functions.

The objective for the management of the dam has been described by the Jiangxi Office of the Key Water Projects at Poyang Lake as restoring the natural wetland and its numerous benefits for conservation and development. From an ecosystem perspective, this objective assumes that one maintains (or restores if necessary) the ecological character of the wetland -- including natural water levels and seasonal fluctuations. For example, management would attempt to maintain the historic average winter low water levels at 12 meters above sea level Wu Song at Wucheng and 9 meters at Xingzi (the lake surface naturally slopes downward from south to north through winter), although water would fluctuate within and among winters. International experience indicates that such a strategy maximizes benefits from ecosystem services of wetlands while promoting development.

While the design and operation of the dam have not been determined, water levels that have been proposed for winter at Xingzi - of 12-16 meters above sea level Wu Song -- would cause dramatic changes to the lake's ecological character, with potentially irreversible impacts on ecosystem services of the wetland. Such change would greatly increase the risk of extinction for the Critically Endangered Siberian Crane, Endangered Oriental Stork and other threatened species that have no habitats other than Poyang Lake in winter.

In addition, if water levels were kept at 16 meters throughout the winter, as much as 10 billion m^3 of flood storage capacity could be lost, increasing risk of floods in early summer from the five rivers flowing into the lake. Under normal low water conditions in winter, the lake surface slopes 3-4 meters from south to north at Xingzi, with the result that the lake's annual water exchange rate is 20.9 days. This rapid turnover helps maintain relatively good water quality for Poyang. If the dam kept the water high in winter, however, the annual exchange rate would be greatly slowed. Water quality would decline. The aquatic vegetation of Poyang, highly important for fish and endangered waterbirds like the Siberian Crane, is sensitive to deterioration in water quality. Dongting and other lakes in the mid Yangtze Basin have undergone a sudden transformation from macrophyte-dominated vegetation to a system dominated by phytoplankton, due in part to declining water quality. Such a change at Poyang would be extremely expensive if not impossible to reverse.

Given the global and regional importance of Poyang Lake, and the many uncertainties regarding lake functions and human impacts, we strongly recommend that a decision on construction of the dam be postponed until the steps described below have been completed.

Step 1. The rationale for the proposed dam – that hydrology of Poyang Lake has changed in recent years, to the detriment of natural systems and economic benefits – needs to be rigorously and quantitatively assessed to determine the extent and impact of any change in hydrology.

Step 2. A conceptual model for the system should be developed and tested, that includes the watershed, hydrology, vegetation, fish, Finless Porpoise, waterbirds, the human components, and other important variables, so that complex interactions among these variables can be understood and future changes predicted.

Step 3. If environmental change has occurred, the drivers of this change need intensive analysis, including the effects of other water projects. The various factors probably interact, and in that case their separate and combined contributions need assessment.

Step 4. Information gaps need to be identified and, in some cases, filled through further research before the best choices can be made for Poyang Lake. For example, economic development opportunities and strategies have been elaborated for the dam option, but also need considerable study as part of steps 5 and 6 below for the other (non-dam) options for Poyang Lake. Such studies should examine potential benefits if the funds intended for the dam construction, and for mitigating its negative impacts, were instead spent directly upon improving livelihoods of people living within the basin or its watershed, through a Payment for Ecosystem Services or other development approach.

Step 5. Based on what has caused environmental change at Poyang, a diverse array of management options should be identified. The proposed dam would be one of these options. In order to evaluate the proposed dam as one alternative, the design and operation plan for the dam need to be completed so that their impacts can be fairly assessed.

Step 6. A thorough economic and environmental analysis should compare the various mitigation strategies with one another, in terms of costs and benefits and values of the ecosystem services of the wetland in particular.

Regardless of the decisions made after this process is completed, management of Poyang Lake and its waters is best accomplished by regarding the entire system as a whole, through creation of a management agency that operates across the entire lake basin and its watershed. Such a management body must have the authority, independence, and commitment to assess scientifically the impacts of management actions and to implement adjustments as needed to offset unintended, negative consequences.

Because informed decisions depend on technical information, an inter-disciplinary scientific or advisory council should be established to provide advice to the management body. This advisory council should oversee the monitoring program and evaluate the effects of management actions, so that corrections and improvement can be made.

IUCN is ready to provide technical assistance to Jiangxi Province with regard to training, case studies, the assessments, or implementation of an Ecosystem Approach at Poyang Lake.

CONTENTS

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INTRODUCTION

Poyang Lake is the largest freshwater lake in China, of extraordinary importance to the people of Jiangxi Province as well as millions of people downriver in the Yangtze River Basin. Poyang is also known throughout the world for its extraordinary biodiversity. The lake's abundant aquatic resources - - of great economic importance to local people – include diverse aquatic vegetation, a remarkable array of fish species, the only freshwater porpoise in the world, and the largest concentrations of wintering waterbirds in East Asia. These wintering flocks include 16 species listed as threatened on the IUCN Red List of Threatened Species (Ji et al. 2007), with over 95% of the world's Endangered Oriental Stork *Ciconia boyciana* and 99% of the world's Critically Endangered Siberian Crane *Grus leucogeranus*. The international community has admired China's commitment to conserving this world treasure, including the establishment of 19 nature reserves for waterbirds and other aquatic animals, encompassing a third of the entire lake basin (Qian at al. 2009), and the designation of Poyang Lake National Nature Reserve (22,400 ha) as a Wetland of International Importance under the Ramsar Convention. While management of Poyang Lake is a responsibility of the people of China, the world have much at stake in this unique and priceless wetland. Construction of a dam across the outlet to Poyang Lake has the potential to transform the ecology of the wetlands, with irreversible impacts on local and global values of the wetland.

The International Union for the Conservation of Nature (IUCN) recognizes Poyang Lake to be one of the most important wetlands in the world. Based upon international experience with wetland and water management, we are writing to recommend that an Ecosystem Approach be applied to decisions about Poyang Lake's future. This approach would not start with assessment of whether the dam will benefit or harm the values of the lake that are most important to people. Instead, an Ecosystem Approach begins with an understanding of how the wetland functions and a scientifically based assessment of the challenges to lake management. This scientific understanding leads to a systematic investigation of alternative strategies for solving those challenges. A primary objective of the Ecosystem Approach is to safeguard ecosystem functions of the wetland and to design development strategies that harness their socio-economic potential while sustaining values of the wetland into the long-term future.

This document examines the ecology and conflicts at Poyang, provides a brief conceptual analysis, and advocates a more open-ended process of information gathering, research, and assessment of the diverse ways to meet the development aspirations of the people of Jiangxi. This process should be carried out by Chinese agencies and experts. IUCN is ready and willing to assist or collaborate as desired.

OBJECTIVES

This document has four objectives:

- Provide a clear statement of the current problems or resource use conflicts at Poyang Lake
- Explore strategies to mitigate or stop recent negative environmental changes

- Recommend tools that enable balancing of ecological and economic values
- Propose a process that supports sustainable development while maintaining ecosystem services of the wetland

EXPLANATION OF THE ECOSYSTEM APPROACH TO LAKE AND WETLAND MANAGEMENT

The Convention on Biological Diversity defines the Ecosystem Approach as: a *strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way.*

The ecosystem (in this case, the Poyang Lake system) is seen as a dynamic web of plant, animal, and micro-organism communities and their non-living environment interacting as a unit. Relationships among these components are complex and often not well understood. Consequently, it is important to apply the precautionary approach* during environmental assessment procedures for development projects. One example of such a relationship is Siberian Cranes at Poyang Lake feeding upon underground tubers of the water plant *Vallisneria* spp. These submerged aquatic plants grow during the warm season, requiring a half-meter or more of clear water, sunlight and nutrients, but in winter the Siberian Cranes normally only access tubers of *Vallisneria* if water is < 50 cm in depth or in wet mud. Any number of factors can disrupt this relationship – for example, activities such as sand dredging that make the water turbid and prevent proper plant growth, or significant increases in winter water depth, making the tubers unavailable to foraging cranes.

In implementing management practices, the Ecosystem Approach calls for a focus on the structure, processes, functions, and interactions among organisms and their environment. This focus includes humans and their cultural diversity. The approach also emphasizes the need for adaptive management to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning. Moreover, it is recognized that there is no single way to implement the Ecosystem Approach since it depends on local, provincial, national, regional, and global conditions. Other management and conservation approaches may be integrated into the Ecosystem Approach framework. It is steered by 12 guiding principles together with operational guidance for implementation (see Annex 1).

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The precautionary approach* should be applied in decision-making in cases of scientific uncertainty when there is a risk of significant harm to biodiversity. Higher risks and/or greater potential harm to biodiversity require greater reliability and certainty of information. The reverse implies that the precautionary approach should not be pursued to the extreme; in case of minimal risk, a greater level of uncertainty can be accepted. Guidelines for applying the precautionary principle to biodiversity conservation and natural resource management have been developed under the Precautionary Principle Project at: http://www.pprinciple.net/.

As implied in Ramsar Resolution X.19, Integrated Water Resources Management (IWRM) and, perhaps more appropriately in the context of wetland ecosystems, Integrated River Basin Management (IRBM) provide mechanisms for applying the Ecosystem Approach to water resources management. Definitions of IWRM and IRBM vary, but most reflect the principal philosophy of coordinated, collaborative decision-making across multiple land and water use sectors on multiple, connected scales, in order to ensure that the social and economic benefits of land and water resource use can be sustained and shared equitably, while still protecting vital ecosystems and their services. In general, sustainability is the goal, providing adequate protection from the impacts of land and water uses within and beyond a river basin in order to safeguard the functioning of wetland ecosystems for the benefit of future generations. This protection includes the provision of water allocations for wetland ecosystems.

Some descriptions of IWRM reflect a narrower perspective, with a primary focus on managing the actual water component of water resources within a catchment or basin. In the context of wetland management, the broader perspective offered by use of the term IRBM may be more appropriate, since this term clearly includes both land and water components and allows management to address the role that wetland ecosystems play as the connecting links between land and water systems in a river basin.

The commitment to consider wetland water requirements in water resources management can be a significant first step in moving towards more integrated approaches that encompass land, water and wetlands within the management of river basins. This first step can often catalyze development and application of IWRM and IRBM approaches, since wetlands themselves are integrative in two ways:

- The nature of wetlands as connectors between land and water systems means that considering wetlands in water management is an integrative step.

- The critical importance of wetlands to all sectors of society through the provision of water-related ecosystem services means that people will need to share the benefits of wetlands, and so will need to come together over wetlands, whether in conflict or in consensus, and this process offers opportunities for integration between different sectors and interest groups.

China as a Contracting Party to the Ramsar Convention on Wetlands, has been urged through Resolution X.1 to implement the Ramsar Strategic Plan 2009-2015. Section 1.7 addresses the need to ensure that policies and implementation of Integrated Water Resource Management, applying an ecosystem-based approach, are included in planning activities and their decision-making processes, particularly concerning groundwater management, catchment/river basin management, coastal and marine zone planning, and climate change mitigation and/or adaptation activities (see Ramsar Convention Secretariat 2008b).

THE GLOBAL SIGNIFICANCE OF POYANG LAKE WETLANDS AND WATERBIRDS

Poyang Lake is one of the largest freshwater wetlands in Asia (see Figure 1), characterized by dramatic seasonal hydrological fluctuations. Located in Jiangxi Province, the lake has a catchment of 162,225 km^2, ~98% of the province (Li 2001). The mean annual runoff from Poyang into the Yangtze River is 143.6 million m^3. In addition to the five main tributaries that drain into the lake, Poyang also has a seasonal, reverse-flow system from the Yangtze River which greatly contributes to the complexity of its yearly hydrological variation. This variation, both within and among years, directly contributes to the large biomass of plant life (Li et al. 2004).

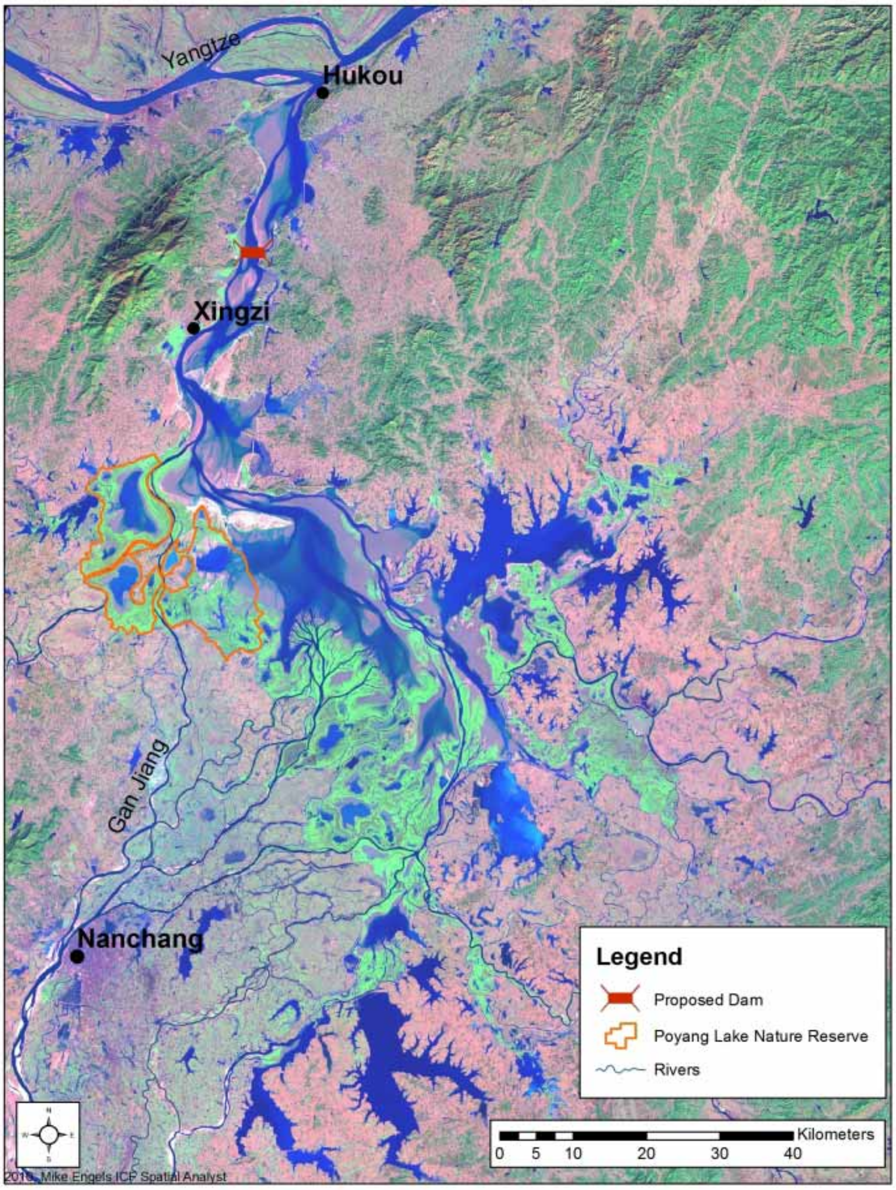

Figure 1. Map of Poyang Lake showing boundaries of Poyang Lake Nature Reserve, the location for the proposed dam, and hydrological station at Xingzi.

In the summer, the lake has a surface area of more than 4,000 km^2 (Shankman and Liang 2003). Falling water levels during autumn months expose extensive mudflats and leave behind isolated sub-lakes (Yesou et al. 2009). These dramatic hydrological variations at Poyang Lake drive the ecological processes within the system and are directly responsible for producing a wide range of habitats that support rich biodiversity. Specifically, the seasonal changes in water levels create two, separate ecological phases of the wetlands at Poyang: one dominated by sub-tropical vegetation that is most productive during the hot summers, and another dominated by temperate vegetation whose primary growth period is during the cool winters (Zheng 2009). Different species make use of these separate ecological phases, resulting in near year-round productivity and a rich diversity of life.

Poyang is internationally famous for its birdlife, and the food resources provided by the emergent and submergent aquatic plant diversity within the system is a major reason that hundreds of thousands of migratory birds travel to Poyang every winter (Li et al. 2005). For example, over half of the world's Vulnerable Swan Geese *Anser cygnoides* and Vulnerable White-naped Cranes *Grus vipio* winter here. Winter surveys at Poyang have recorded 425,000 waterbirds on average, with a peak count of 726,000 birds in 2005 (Barter et al. 2004, Barter et al. 2005, Li et al. 2005, Ji et al. 2007, Qian et al. 2009). In two years of winter waterfowl surveys in the middle and lower reaches of the Yangtze River Basin, Poyang Lake supported 12-15 species with more than 1% of regional waterbird populations. In both years, Poyang Lake was by far the most important wetland for wintering waterbirds.

Poyang Lake supports numerous other aquatic animals dependent upon its wetlands , including the globally Vulnerable Finless Porpoise *Neophocaena phocaenoides* and the Vulnerable Chinese Water Deer *Hydropotes inermis inermis* (Living Lakes 2009). Wu and Ji (2002) report that 122 fish species have been recorded in Poyang Lake, including the Critically Endangered Chinese Sturgeon *Acipenser sinensis* and Critically Endangered Chinese Paddlefish *Psephurus gladius,* one of the largest freshwater fishes species in the world and possibly extinct, and 30 species protected by Jiangxi Province.

CONTEXT AND RATIONALE FOR CONSTRUCTION OF A DAM AT THE OUTLET TO POYANG LAKE

In 2009, the State Council of China approved an Eco-economic Development Plan for the Areas Surrounding Poyang Lake. The plan proposes establishing a special economic zone as a national priority, covering 38 counties and 28 million people, and includes a series of objectives and projects to protect the environment and promote economic development compatible with sustainable use of natural resources. The dam, or water control structure, was proposed as a part of that plan but was not approved by the State Council. Instead Jiangxi was asked to further investigate the environmental impacts of the dam and identify effective mechanisms to address the negative impacts before a decision could be made about the dam.

In response, Jiangxi has contracted with numerous scientists to form six study teams to look at six aspects of the project:

- sediment deposition and its countermeasures;
- flood control and its countermeasures;
- water quality and its countermeasures;

- wetland and migratory birds and its countermeasures;
- aquatic life resources in Poyang Lake and its countermeasures; and
- the linkage between Poyang Lake and the Yangtze River.

Each team is charged with developing a report by May 2010. These reports will then be considered together and consolidated into one document.

This process is to be commended for the range of disciplines and expertise that has been involved. Yet the very short time for the teams to investigate and develop their reports – roughly six months – has precluded any new research that might fill gaps in what is currently known. In addition, the teams were not charged to consider the range of alternative options for Poyang Lake, but only to assess the dam, its impacts and countermeasures, and to then recommend whether or not the dam should be built. The process does not allow for comparison with actions other than the dam that might have a different balance of benefits and environmental safeguards.

A document prepared by the Jiangxi Office of the Key Water Projects at Poyang Lake (2010) summarized the reason behind the need for the dam:

> Poyang Lake no longer possesses its original ecological system and it is undergoing a gradual trend of shrinking. Especially in recent years, the dry season has come ahead of its time and lasted longer, exacerbating ecological problems of Poyang Lake and increasing pressure on the Lake's ecological system.

The document then lists the problems that have arisen: conflict between irrigation water and domestic water, gradual deterioration of wetland and water ecological environment, slow development of shipping and fisheries, deterioration of lake water quality, and prevalence of schistosomiasis due to favorable conditions for the host organism *Oncomelania*.

The project is presented as the restoration of the natural wetland with its many ecological and economic values, so that waterbird habitat will be enhanced, water quality and fisheries improved, navigation expanded, irrigation and water supply needs fulfilled, and disease reduced.

DESCRIPTION OF PROPOSED WATER CONTROL STRUCTURE

At this time, detailed plans have not been developed for the dam, and significant aspects of its design and function await the completion of the reports from the six study teams. Yet the same document provided by the Jiangxi Office of the Key Water Projects at Poyang Lake contains preliminary information.

The dam would be built at the narrowest part of the channel that extends north from Poyang Lake to enter into the Yangtze River at Hukou. The location is approximately 12 km north of Xingzi and 27 km south of confluence with the Yangtze. The length of the dam would be 2,986 meters, of which the discharge width would be 2,195 meters long. A navigation channel would lie on the west side and a fish ladder on the east side. The dam would consist of a series of sluice gates. Currently, a design with sluice gates of 16 to 20 meters in width is being considered. It is not yet decided how these gates would open.

The dam is intended to close the connection between the lake and the river only during the dry season, but would remain open and allow natural flow of water during the wetter half of the year. A tentative operation scheme has been outlined in this document:

- During the river and lake connection period (from April 1 to August 31), all gates are open to connect Yangtze River with Poyang Lake;
- During the water storage period of Poyang Lake (from September 1 to 20), the gates are closed to store the flood tail of Poyang Lake and maintain the water level at 16 to 17.5 meters;
- During the water storage period of Three Gorges (from September 21 to October 31), the upstream water level of the gates is lowered from 17.5 to 16 meters or so; and
- During the compensation regulation period (from November 1 to December 31) and lower water period (from January 1 to March 31), the water level is regulated in accordance with water demand of the lower reaches and the habits of migratory birds to rationalize the utilization of water resources, protect ecological environment and promote social-economic development.

This operational plan does not specify the water levels or fluctuation during the five-month winter period, nor does it consider how to resolve potentially incompatible objectives during that time. Such issues await reports from the six teams, but greater clarity on the goal of this project – is the primary purpose to restore the natural ecology of Poyang or to control and improve the lake? – would make impacts of the project more feasible to predict. The proposed design of the dam does allow adjusting water levels based on varying needs or on evaluation of impacts during its operation.

NEED FOR A CONCEPTUAL MODEL FOR LAKE FUNCTION

The ecological approach relies on an understanding of how a system functions. Poyang Lake is especially complex because of remarkable fluctuations in water within and among years, the size of the lake, and the scale of processes that encompasses not only almost all of Jiangxi Province as the lake's watershed, but also the vast upriver basin of the Yangtze.

The different parts of the system are all dynamically inter-connected, so that changing one element of the system alters other elements often in unexpected ways. Thus careful but separate analyses of the multiple elements of the system cannot simply be added together to make a whole, because these elements mutually interact with one another – this interaction is particularly sensitive to changes in hydrology because in many respects water drives the system.

We already described the example of the inter-relationships linking Siberian Cranes with its food plant *Vallisneria*. The vegetation of the lake is basic to the lake's animal biodiversity and many human benefits including fisheries and livestock production. Vegetation is also linked to the spread of schistosomiasis, for the blood fluke passes from snails to people more easily where livestock are also present; humans and livestock serve as alternate hosts. The grass-sedge zone that grows on the upper margins of the lake, submerged for part of the year, thus favors mixing of snails, livestock and people. As one benefit of raising water levels, this zone of prevalent disease would be inundated for most of the year – a change that would assist in breaking the disease cycle. However, with raised water levels, the sedge-grass zone would move up to higher edges of the basin and probably become much smaller or entirely disappear. With systems thinking, these dynamic relationships alert us to the need to reassess benefits for disease control from higher water levels. Would the 'disease zone" simply shift up the gradient, and lie in closer proximity to people? Would the area of grazing land similarly shrink, reducing economic benefits from livestock?

A conceptual model is even more essential for the basic analysis that must underlie this project. What are the causes of the alleged change in hydrology of the lake, and how do they interact? Without this understanding of the dynamic hydrology of the lake, human interventions such as constructing a dam will almost certainly lead to unexpected, perhaps severe consequences. See case study #1 for an example of the consequences of a large dam project that inadequately accounted for environmental and socio-economic issues.

Without such a conceptual model, assessment of the impacts of the proposed dam on ecosystem functions cannot avoid considerable uncertainty and carry high risk of overlooking significant impacts.

IMPACTS OF A DAM ON ECOSYSTEM FUNCTIONS OF POYANG LAKE

The comments in this section illustrate the complexity of values and ecosystems services at stake, and the needs for further analysis and research to fill gaps in knowledge about the Poyang Lake system.

As described in an earlier section, the precautionary principle – widely applied in international practice for water management projects – indicates that where potential risks from an action are high (as at Poyang), there should be low tolerance for uncertainties in assessing impacts. A decision on constructing the dam should not be made without filling many of the current information gaps.

Changes to the flood cycle, a unique hydrologic feature of Poyang Lake

The hydrological character of Poyang is unique among all China's lakes, very different from Taihu, Chaohu and other lakes (data from Yangtze Science College). The water level at Poyang in different seasons – low water season and average water season – exhibits an obvious significant difference between the upper and lower reaches of Poyang. The lake surface slopes downwards from upstream areas in the south towards its confluence with the Yangtze in the north (Figure 2). The difference in water surface elevation between upper (southern) parts of the lake and Xingzi (located in the north, within the narrow channel and near the dam site) can be >4 meters. In the south, at Kangshan in January, the average water level is 13 meters, and at Wucheng (close by Poyang Lake Nature Reserve) it is 12 meters, while at Xingzi in January the water level averages about 9 meters. When the water level reaches about 15 meters, however, the surface of the entire lake flattens out (the entire basin is flooded). In other words, for water level changes of Poyang Lake, the winter-fall season water surface will slope downward from south towards the north. The process of water increase will exhibit the pattern of flooding that starts in the north then spreads to the south (even when water comes from the south). With a dam, all slopes during the low water will be dramatically reduced if the lake is maintained at 15 meters or higher, and the water level everywhere will become relatively flat.

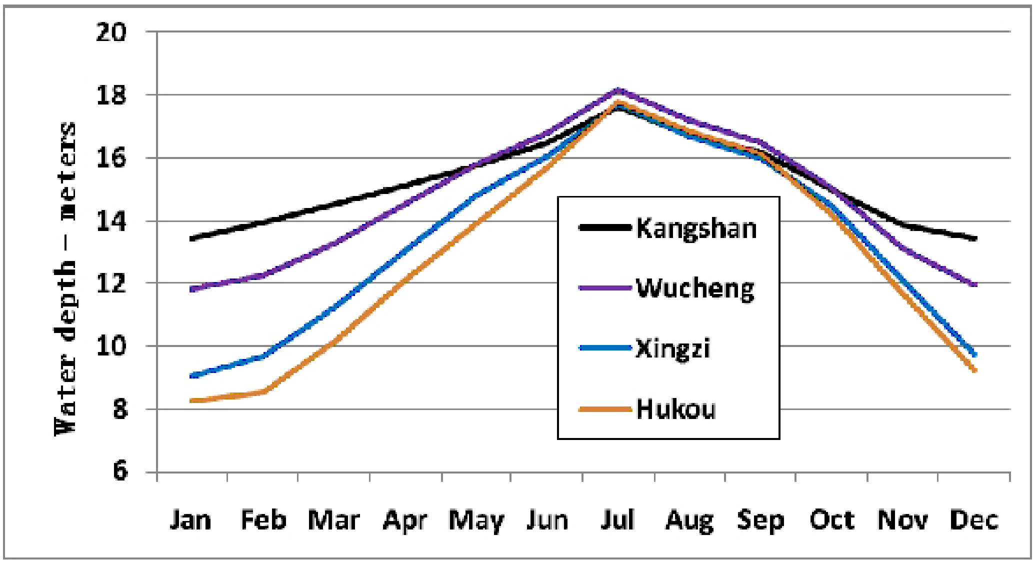

Figure 2. Average monthly water levels (in meters above sea level Wu Song) for four monitoring stations at Poyang Lake, 1952-2007 (Hukou from 1978-2008). The stations are listed in order from Kangshan in the south to Hukou in the north.

In fall, when water drops below 15 meters, water withdrawal will exhibit a pattern from north to south (water will go down first in the north), so the slope will reappear. If the water levels are controlled near Xingzi, this basic and unique characteristic of Poyang Lake will disappear. Repercussions on other elements of the system are unknown, but the next paragraphs illustrate one significant impact.

Changes to the water exchange cycle for the lake, with impacts on water quality

The annual water exchange rate for Poyang Lake is on average 20.9 days (China Academy of Sciences). In other words, the waters exchange in the lake almost 18 times in one year. This exchange rate is only longer than Dongting (18.2 days), so that Poyang has the second fastest rate of exchange for large lakes in the country. The rapid exchange of water is a physical condition that keeps the water clean within the lake, by flushing out pollutants. When the water level drops below 15 meters, with the condition of slope described in the last section, the character of the flow is gravity flow, and the speed is relatively high (1.4 – 2.8 meters/second). When the water level rises above 15 meters, the slope of the lake surface is greatly reduced; at this water level, gravity flow weakens so that wind becomes an important factor; during this period, the speed of wind-driven water is relatively slow, usually 0.1 to 0.8 meters/seconds. Therefore, the water exchange rate is slow. At the end of the five river flood season, when Yangtze River water level increases fast, the flow is small, usually within 0.1 meter/second. The higher the lake water level, the slower will be the speed. At this time, the lake exchange period will be longer than in winter (not considering evaporation). Thus the natural process of flood and water drainage periods each year results in rapid exchange of water for Poyang but at uneven rates among seasons.

The dam will change this seasonal variation in exchange rates and prolong the overall water exchange period, increasing the settlement of nitrogen and phosphorous, concentrating these nutrients in the sediments of the lake. In addition, submerged aquatic plants will die due to inundation (see below) and the new situation will reduce the ability of plants to remove nutrients from the system. After the water level is relatively stable, then the waste from cage nets used for breeding fish will make the lake quality worse. Currently, in lower and middle parts of Yangtze River the use of nets for breeding fish has grown out of control and resulted in serious pollution and degraded ecosystems. After there is a dam and water level control, Poyang's water quality may become a very serious concern. According to 2004-08 data from Jiangxi Environment Protection Bureau, the pollution level is still less than Taihu and Chaohu, but for part of Poyang, the amount of nitrogen was close to Chaohu in 2007, and phosphorous close to Taihu in 2007. In mid August of 2007, at the center of Poyang Lake, there was a substantial algae bloom. Along the dikes, the algae outbreak was 200 meters wide and several kilometers long, a blue color and lasted a week. This incident was a very alarming sign of nutrient enrichment.

Changes to the current hydrology of the Yangtze River, especially with regard to flood control

This project will change the flood pattern for the Yangtze River. The middle reach of the Yangtze has the highest flood risk in China. Poyang Lake is very important for flood control for this area – serving as a natural storage basin for floods and temporarily holding and releasing the five rivers' flood (Cui 2004a and 2004b).

The flood peak caused by the five rivers' flood usually happens between May and June. In late summer, the Yangtze flood can back-flow into Poyang Lake, usually between July and September (Chinese Academy of Sciences). After September, with the flood period ending, the water level in the lake gradually reduces until its lowest levels occur during December or January. During the low water period Poyang Lake is like an empty stomach waiting for storage (the lake is ready to take in a lot of water). This stage is very important. When the water level goes from 8.33 meters (the 1998 lowest at Xingzi) to 16 meters, the storage is 11.75 billion m^3, equal to 50% of Three Gorges Reservoir adjusted storage capacity – this benefit occurs without any dam, a natural flood storage basin with great capacity. This amount (11.75 billion m^3) mainly absorbs and controls the five rivers' flood and reduces the pressure for flood on Poyang Lake and Jiangxi (note, in the flood season even if one would open the proposed dam, the lake mouth is narrow so water outflow would be slow].

The dam has been proposed to stabilize water at 16 meters, resulting in over 10 billion m^3 in lost flood storage capacity. With this loss of capacity, this project will increase flood risks for the Yangtze River system and change the flood control pattern, harming the flood security for middle and lower reaches of the Yangtze River. At the same time, the dam structure will reduce the outflow of floodwater from Poyang Lake to the Yangtze River even when the sluice gates are open. The barrier at the outlet, as well as higher water levels in winter and early spring, increase the risk of flooding in the Poyang region.

Impacts on the distribution and abundance of aquatic plants

The distribution area for aquatic plants between 2006-08 averaged2,012km^2 of the lake (T. Marie, University of Louis Pasteur, unpublished data). While this average is lower than the ~ 2262 km^2, or 80% of the lake, covered by aquatic vegetation in the 1980s (Wang and Dou 1998), the three years 2006-08 showed considerable annual variation; such short-term change seems to account for the difference. Submerged aquatic plants are distributed between 9 and 12 meters elevation, and mainly include *Vallisneria* and *Potamogeton*, with previous area estimates of about 1366 km^2(Chinese Academy of Sciences) The sedge communities (various *Carex* species and other plants) are mainly distributed between 12 and 15 meters elevation, with a total area of 519 km^2. The lake edge elevation between 15 and 16 meters supports reeds and other species including grasses. Above 16 meters is the peripheral upland zone dominated by grass. This pattern of plant communities makes it apparent that if the project controls the water level at 16 meters, all the current submerged and emergent plant zones will be entirely under water all year (all elevations up to 16 meters). At these new water depths, the plant communities could not survive. The sedge zone plants' phenology, for example, matches the timing of hydrological change -- each year, these plants have two times to grow – March to May, and late September. If permanently inundated, these plants will die.

Figure 3 illustrates these plant community zones. With deeper water, if a dam were constructed, these plants might migrate up the vertical gradient, moving toward the periphery of the lake. *Vallisneria* responds quickly to changed conditions, but the sedges and grasses are perennial and may take years to re-establish themselves if at all. They are the primary food for most species of geese (these species form the grazing guild). Tens of thousands of geese will lose their foraging habitat for a period of years before their food plants become re-established.

There is an additional threat to the current aquatic vegetation. Due to changes in water management and water quality, *Vallisneria* appears to be significantly declining in parts of the mid Yangtze Basin such as Dongting Lake and Shengjin Lake (Fox et al. in press). The deterioration in water quality – including nutrient runoff and turbidity – could cause the same process in Poyang Lake. There is ample evidence from research in other regions that changes to a lake system reach a point where the dominant macrophytes such as *Vallisneria* are replaced by phytoplankton characteristic of eutrophic waters (Scheffer et al. 2001). Such a change may be irreversible, and is a serious negative impact of deteriorating water quality that in turn leads to further deterioration. If this happened to Poyang Lake, the main food for Siberian Cranes and other tuber-feeding birds would decline drastically with unknown but potentially very negative effects on these birds. Recent efforts by Jiangxi Province to reduce erosion and untreated waste water within the basin, and to

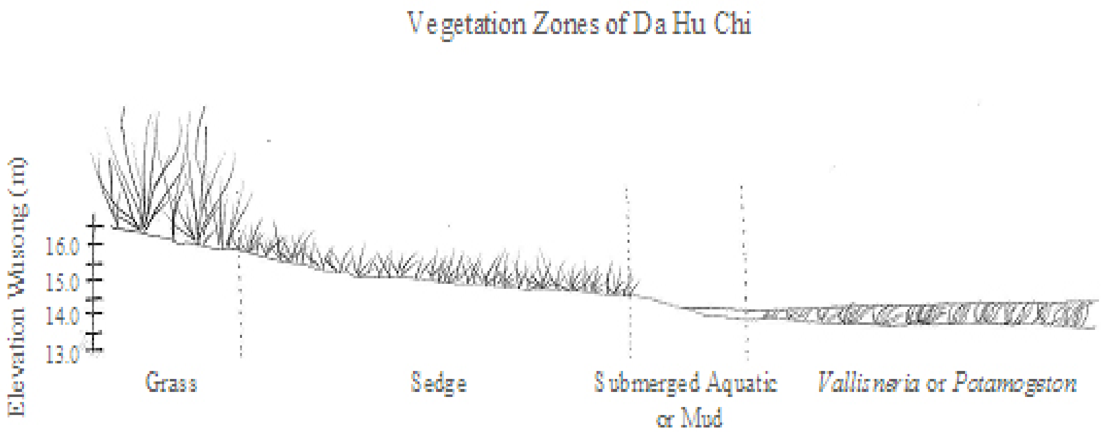

Figure 3. An illustration of different vegetation zones at Da Hu Chi in relation to elevation (Wu Song) moving from high (left) to low (right). In Da Hu Chi the average elevation of the sedge zone was 15.34 m (Wu Song) and of the mud zone was 14.4 m (Wu Song). The zones, as measured at Da Hu Chi, were defined as (Wu Song): Grass Zone >16.0 m, Sedge Zone = 16.0-14.6 m, Submerged Aquatic or Mud zone = 14.6-14.3 m, and *Vallisneria* or *Potamogeton* Zone = 14.3-13.9 m. Da Hu Chi, that separates from the main lake in winter, has vegetation zones at slightly higher elevations than the lake as a whole.

promote eco-friendly industry in areas surrounding Poyang, are very important steps toward maintaining the current ecology. This issue is very complex, but changes to natural hydrology through a dam (especially related to reduced water exchange and flushing of pollutants) could change the flow of nutrients or precipitate other factors that might lead to a crash in macrophyte populations.

<u>Impacts upon waterbirds</u>

Evaluation of risks posed to wintering waterbirds must consider what is happening to these globally important populations more generally in the mid Yangtze Basin and in China and East Asia as a whole. Waterbird numbers in China have declined dramatically (see Cao et al. 2008a and 2008b). Lu (1996) estimated Anatidae numbers in China in the early 1990s at 3-4 million, as compared to a current estimate of 1.1 million (Cao et al. 2008a). Goose populations in particular have declined. All five goose species (Lesser White-fronted *Anser eryphropus*, Greater White-fronted *A. albifrons*, Bean *A. fabalis*, Greylag *A. anser*, and Swan Goose) wintering at Poyang Lake reflect these trends (Wetlands International 2006). Since the mid 1980s, breeding populations of Greater White-fronted Geese and Bean Geese– that migrate from the Arctic to China -- have declined by 80% and 65% respectively (Syroechkivskiy 2006). Swan Geese, breeding in northeast China, southeast Russia and eastern Mongolia, have suffered repeated years of poor reproduction across large parts of the breeding range due to drought and human disturbance (O. Goroshko, N. Tseveenmyadag, and L. Su, personal communications).

Poyang is remarkable for its importance to numerous groups of birds with highly diverse feeding habits. The geese (other than the swan geese) belong to the grazing foraging guild that feeds primarily on grasses and sedges that occur on upper edges of the wetland; these plants grow during the cold season period when they are exposed to the air (see Barzen 2008). Siberian, White-naped, and Hooded Cranes *Grus monacha*, Tundra Swans *Cygnus columbianus* and Swan Geese form the tuber-feeding foraging guild -- all feed on tubers of submerged aquatic plants, primarily *Vallisneria* (although White-naped and Hooded Cranes are less heavily dependent on this food in winter than the other three). Water levels in both summer and winter are critical for foods of these species. Summer water levels must be suited to growth of the plants (unlike the sedges and grasses, they grow during the warm seasons); during winter, *Vallisneria* is senescent, but the birds require shallow water or wet mud so that they can access the tubers. Deep water or dry mud prevents cranes and other birds from utilizing this food. Siberian Cranes primarily feed at water depths < 30 cm, and occasionally up to 50 cm (ICF unpublished data). If water levels were maintained at 14 or 16 meters Wu Song at Wucheng for even portions of the winter in areas utilized by the birds, almost all current habitat would be deeply submerged and tubers unavailable to the cranes (Barzen et al. 2009). The few areas remaining would force the birds to forage near the upper edges of the wetland, where human disturbance is high. Cranes, however, historically do not feed or roost near people at Poyang.

Other birds form the fish-eating foraging guild, including the Oriental Stork. The Oriental Stork specializes in fish injured or trapped where water levels are dropping and shallow. Significant changes in winter water levels could remove this favored habitat as well.

Collectively these species depend on Poyang Lake in winter for survival. The availability and condition of alternate habitats within the lower Yangtze River floodplain is declining. Dongting Lake, for example, has in recent years lost almost all its tuber-feeding birds, while over the last five years, tuber-feeding birds have drastically declined at Shengjin Lake (Fox et al. in press). Loss of Poyang Lake as foraging habitat due to high winter water levels could have catastrophic impact on a suite of threatened and declining species.

If available habitats at Poyang Lake were reduced through dam construction or other development projects, would birds belonging to different foraging guilds find alternate habitats elsewhere? The Siberian Crane is the best known of these species. The most recent waterbird surveys of the lower Yangtze River floodplain have found less than 0.5% of the world's Siberian Cranes utilizing wetlands outside of Poyang Lake (Barter et al. 2005, Cao Lei unpublished data). Tundra Swans, another tuber feeder, occur in other areas of the lower Yangtze River so tubers are likely available elsewhere. Most of these wetland areas, however, have water depths that are too deep for Siberian Cranes to forage efficiently. Extinction of Siberian Cranes in the wild would be a likely event if Poyang Lake were lost as a wintering habitat for this species.

Impacts upon movements of the Finless Porpoise and fish

The Yangtze Finless Porpoise *Neophocaena phocaenoides asiaeorientalis* is the only porpoise that lives in freshwater. This subspecies is endemic to China; it was classified as Endangered in 1996, and a new assessment is underway. While it formerly ranged from the Yangtze River into numerous lakes, all lakes except Dongting and Poyang Lakes have been separated from the Yangtze by sluice gates and embankments. The Yangtze Finless Porpoise has rapidly declined in recent years, from an estimated 2700 in 1991 (Zhang et al. 1993) to 1800 in 2006 (Zhao et al. 2008). These data further imply an annual rate of decline of at least 5% for the entire population in the main stem of the river (Zhao et al. 2008). The estimated 450 in Poyang Lake (Xiao and Zhang 2000, 2002; Zhao et al. 2008) thus represent one fourth of the entire population that faces growing threats from fish nets, boat collisions, pollution and water management projects. The density of porpoises in Poyang Lake is the highest compared to all other water areas.

The Finless Porpoise is an aquatic mammal and depends on sonar reflection to navigate and feed. Therefore they are very sensitive to barriers on their path. At the same time, this animal feeds on fish. When foraging they are very active, often chasing schools of fish. The proposed dam may prevent the Finless Porpoise from moving between the Yangtze River and Poyang Lake, and thus fragment their distribution. If one only designs the dam for the passage of fish, the facility cannot meet the requirements for this species. Even if the sluice gates are open, no one knows if the porpoises will pass through. The dam could be fatal for this flagship species.

Despite the provision of fish ladders, the dam is also likely to impact fish species by blocking migrations and fragmenting their populations. Of 58 species of fish recorded at Nanjishan National Nature Reserve during 2003-2004, 20 were migratory (Wu et al. 2006). Many fish, including commercially important species, utilize the sedge zone for spawning so that the impacts of higher water levels – that affect distribution and abundance of the sedge communities -- will have complex influences on fish populations. Populations for the Critically Endangered Chinese Paddlefish, and other rare fish species once found in Poyang, have experienced precipitous declines across the Yangzte Basin (Dudgeon 2010). Aside from the impact of the physical barrier, changes brought to water quality and water flow may have significant impact on some species. Given the intense negative pressures on many fish restricted to the Yangtze Basin, the precautionary approach indicates that very thorough assessment of these impacts should be completed before a dam could be approved.

RECENT ENVIRONMENTAL CHANGES AND THE FACTORS THAT MAY BE RESPONSIBLE

Poyang Lake has gone through many changes – the region has been intensively used and managed by people for thousands of years – yet over recent decades Poyang Lake has consistently been highly productive with extraordinary biodiversity and immense human benefits. Data collected over the past 50 years provide a baseline for evaluating current changes.

Recent data for Poyang Lake need to be tested rigorously against that baseline to determine if there have been recent changes in winter water levels. We lack the data to do this thorough analysis, but the limited data available suggest that the lowest water levels in recent winters are comparable to other periods in the recent past. Figure 4 is a time series (1956-2009) of measured monthly average water-levels in Poyang Lake at Xingzi, not far from the proposed dam site. Figure 5 shows a similar time series of flows from the lake into the Yangtze at Hukou. The figures illustrate both the seasonal and the inter-annual variability in water-levels and flows. Both graphs also suggest longer cycles of up to approximately 10 years, during which mean discharge and water-levels are higher or lower than average. It is likely that these reflect natural cycles in rainfall and hence flow in the rivers discharging into the lake.

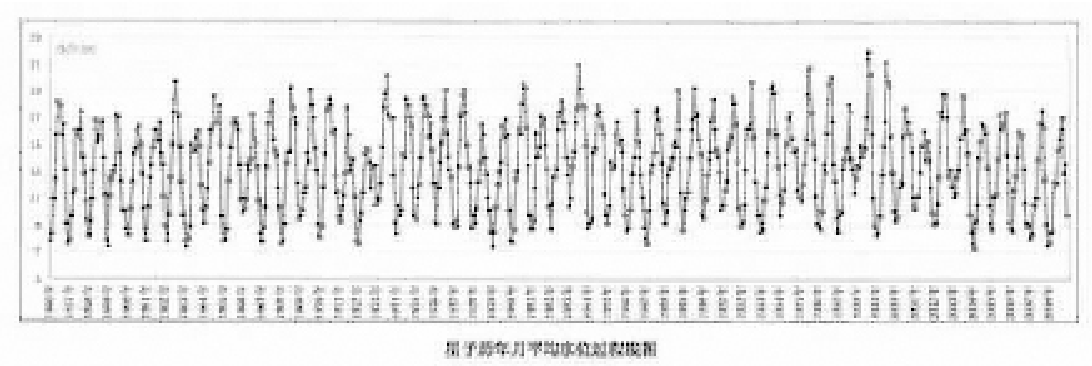

Figure 4. Average monthly water levels for Poyang Lake (masl Wu Song), measured at Xingzi, 1956-2009.

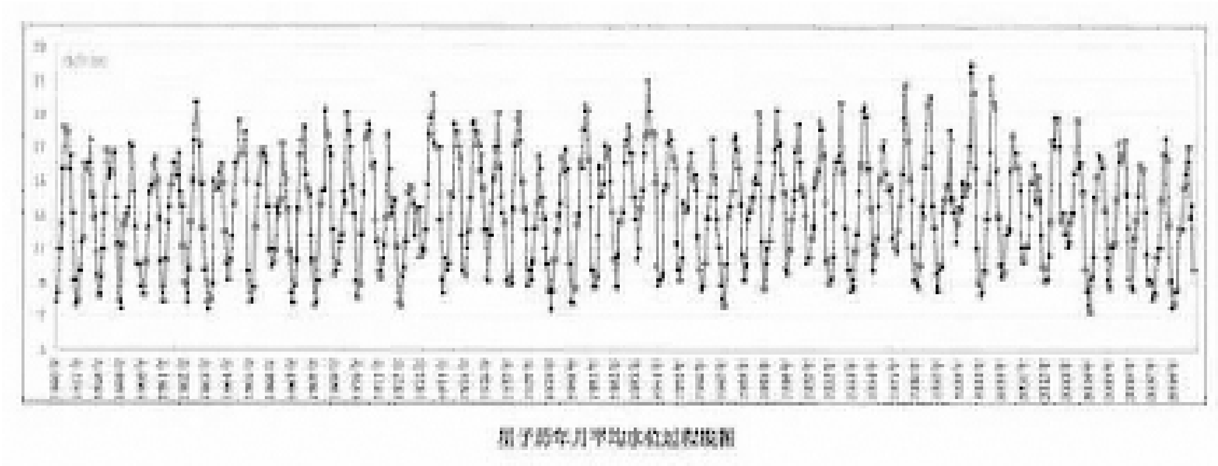

Figure 5. Average monthly flow (m^3s^{-1}) from Poyang Lake into the Yangtze, measured at Hukou, 1956-2009

Figure 6 presents average monthly water levels on the Gan and Xiu Rivers at Wucheng from 1955-2008, in close vicinity with Poyang Lake Nature Reserve, together with monthly variability. If the management objective is to restore natural hydrologic conditions to the lake, this figure provides a quantitative measure for achieving that objective. Water levels exhibit larger variation during the summer months than in winter. While there is significant variability within months, winter water levels that have been proposed for operation of the dam (of 16 meters, or even just 14 meters) would represent major change to this wetland -- 14 meters is more than two standard deviations higher than average water levels for the months December to February. Stated another way, 14 meters is two meters higher than the average December-January water levels for the two rivers. It should be remembered that if water levels of 12 meters were maintained by a dam near Xingzi, due to the sloping lake surface in winter, water levels at Wucheng would likely match or exceed 14 meters, two standard deviations higher than the 53-year average.

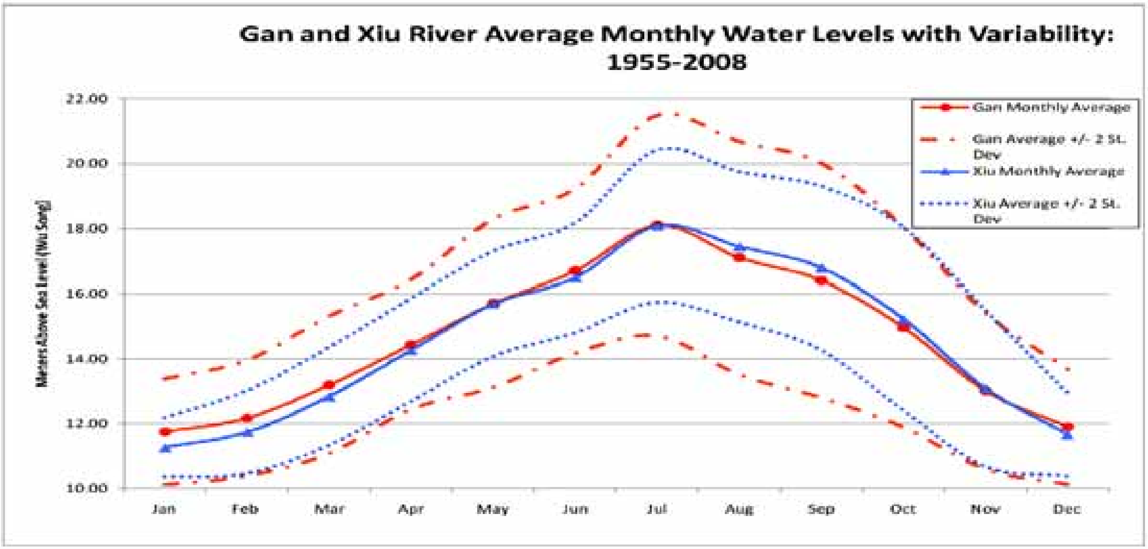

Figure 6. Average monthly water levels by month with variability for Gan and Xiu Rivers at Wucheng, 1955-2008

Standard deviation measures the variability of a data set. In a normal distribution, approximately 68% of all the data present will fall within one standard deviation from the mean. Two standard deviations from the mean typically account for 95% of all the data present. In many statistical tests, any point beyond two standard deviations of the mean is considered beyond the range of most variability. Within the context of hydrological fluctuations at Poyang over the last 53 years, two standard deviations from the average appear to provide a boundary for "normal" fluctuation within the system. Maintaining water levels above or below this two standard deviation boundary for prolonged periods could be considered highly abnormal, likely with dramatic effects on the system.

For Poyang Lake Basin, as part of the Yangtze River Basin, alternating flood and drought are natural phenomena. Currently, the Yangtze River has exhibited gradual drying. Yet the river has not reached the lowest record compared to historical data. For example, for the low water year 2006 at Xingzi water monitoring station, the lowest water level was recorded on 31 December at 7.85 meters. That level is still higher than 7.32 meters (recorded on 20 December 1956).

These data do not indicate whether or not the low water period in winter has lengthened. An earlier and longer low water period would have significant impact on natural ecology and on human communities.

We next consider potential factors that might be contributing to recent changes in low water periods at Poyang.

Reduced water in the Yangtze River due to operation of Three Gorges Dam

The Three Gorges Dam project started in 1993. In 1997 the dam was closed. From 26 May to 10 June 2003, water was stored behind Three Gorges Dam up to 135 meters. In 2006, Three Gorges Reservoir raised the water level up to 156 meters. The storage water period began on 20 September 2006 and ended on 27 October, it totaled 37 days and stored 11.1 billion m^3.

The published operating strategy for Three Gorges Dam indicated that the main changes to the Yangtze would be lower water levels in October and November, when the Three Gorges Reservoir is being refilled, and higher levels during January to May, when water is being released. The patterns recorded at three Yangtze water level monitoring sites (Chenglinji, Hukou, and Huangpen Sluice; the latter is at Shengjin Lake, an important national nature reserve for wintering waterbirds in Anhui Province) were quite different than the operating plan. They included a delay in spring flooding, a decrease in peak summer water levels, and an earlier drop in autumn water levels (Zhang et al. 2010).

Changes in water levels in the Yangtze are known to affect Poyang Lake water levels, but the extent of those changes needs to be assessed. Changes to Yangtze water levels since Three Gorges Dam began operation (2003) coincide with the period when the significant changes have been reported for Poyang Lake. The data suggest that these impacts, however, are not nearly as significant as the next factor to be discussed.

Changes in inflow of waters from the five rivers that feed Poyang Lake

From the 1950s until 2001, 9603 water reservoirs, including 25 large reservoirs, 211 middle-sized and 9367 small-sized reservoirs, have been constructed within the Poyang Lake drainage area in Jiangxi Province. The total volume of storage reached 27.9 billion m^3. Most of these reservoirs were utilized for flood prevention and irrigation as well as water supply (Liu et al. 2009).

In addition, many artificial irrigation channels have been established such as Jinlin canal in Fu River Basin and trunk diversion channels in Ganfu Plain. With the rapid socio-economic development of Jiangxi Province and population growth, the water demand for industry, agriculture and daily life has increased proportionately. These water projects have become important factors affecting Poyang Lake and its watershed and their combined impacts are expected to grow.

Since the primary sources of water for Poyang Lake are these five tributary rivers, impacts of water development within their watersheds probably greatly exceeds impacts from Three Gorges Dam, but these impacts need to be assessed.

Sand dredging within Poyang Lake Basin, especially near the outlet area

Intensive dredging in Poyang Lake started around 2001, after it was banned from the Yangtze in 2001. Dredging further increased due to the rapidly rising demand for sand in order to support construction in the lower Yangtze River economic zone. In addition, benefits to the local economy likely have persuaded the local government to allow and possibly promote dredging in this lake (Zhong and Chen 2005). The dredging-related vessels have been mainly concentrated in the region between Hukou and the Sand Hill in the northern Poyang Lake. It was estimated that very few vessels were detected in 2000, but the vessel number grew to about 140 in 2001, and quickly increased to about 230, 430 and 450 in 2002, 2003 and 2004 respectively, while about 380-390 vessels were found in 2005 and 2006 (Wu et al. 2007a, Wu et al. 2009a).

Recent reports (Zhong and Chen 2005, Fok and Pang 2006, Wu et al. 2007a, Wu et al. 2008, De Leeuw et al. 2010) suggest that sand dredging has had negative impacts. Zhong and Chen (2005) indicated that the noise, oil pollution, turbidity and decreased habitat caused by dredging could seriously affect the propagation, growth and subsistence of fish in the lake. Poyang Lake is also significant habitat for rare animal species such as the IUCN Red List Critically Endangered Chinese Sturgeon, and the Vulnerable Finless Porpoise. The increased water turbidity from dredging activities (Wu et al. 2007a, Wu et al. 2007b) may decrease the available light for photosynthesis of *Vallisneria (Wu* et al. *2009b)*, and consequently cause a decrease or disappearance of the food source of Siberian Cranes. Dredging also modifies the topography and removes the sediments of the lake, and may reduce the winter water levels and result in increased hydrological gradient and stream velocities upstream. Increased stream velocities in turn might enhance erosion upstream (De Leeuw et al*.* 2010).

Climate fluctuation and change

The climate of Poyang Lake shows a slight degree of change since 1950 and more significant change since 1990, with the same variation tendencies as for the whole Yangtze River Basin, such as increasing temperature and precipitation, torrential rain and flood incidents.

The average temperature in 1990 was higher than during 1961-1990 by 0.27^{o} C and the average temperatures of 1991-2003 and 1998-2003 were 0.42^{o} C and 0.75^{o} C higher than for 1961-1990 respectively (Guo et al. 2006, Fan et al. 2009). The temperature increase is significantly concentrated in the northern region, with the Rao River basin increasing most significantly, followed by the Poyang Lake area, and lower reaches of its tributary rivers (Guo et al. 2008).

Rainfall at Poyang Lake is plentiful, with 1426.4 mm of annual precipitation, but distributed unevenly. The precipitation from April to June accounted for 47.4% of the annual precipitation, while precipitation during the wintering period of migratory birds (November to March) was small, especially during November to mid-January, with only 9.9% of annual precipitation. The meteorological data (1961-2006) showed a slight overall increasing trend in annual precipitation, but the trend of uneven distribution of precipitation in time has intensified. Since 1990, the heavy rains in summer increased significantly (Wang et al. 2009).

ALTERNATIVE RESPONSES TO UNDERLYING CAUSES FOR NEGATIVE CHANGES

Conditions in 2006-07 reflect the mix of inputs from all of these factors and, as noted above, may also reflect short term cycles normal over the past 50 years. The dam for Poyang Lake has been proposed to solve these recent problems. As the causes for changing hydrology of the lake are assessed, however, it may become clear that alternative measures may more directly address these underlying causes. In the event that a water control structure were to be approved, it is probable that it should be accompanied by a suite of other measures to counter these underlying causes and that approval of the dam itself would necessarily require mitigation measures and strict operational guidelines in response to the dam’s substantial impacts upon the ecological functions of Poyang Lake.

Adjustments in operation of Three Gorges Dam and dams upstream in Poyang Lake’s watershed

Two sets of related studies are needed, one for Three Gorges Dam and the other for the dams upstream on the Gan and other rivers that feed into Poyang Lake. First, the impact of water management due to the operation of these dams should be assessed. Second, alternatives for adjusting the operation of the dams should be evaluated. These two studies are linked but alternatives may exist for adjusting operation of dams even if they are not the primary cause for hydrological change at Poyang. For example, even if the Three Gorges Dam is not significantly affecting the length of the low water period in winter at Poyang, it is possible that delaying the water storage period at Three Gorges during the autumn period could help mitigate the early lowering of water at Poyang.

Water conservancy measures within the watershed and lake basin

Operation of these dams affects the timing for water inflows to Poyang. Related studies should examine the extent that water is drawn off from the five rivers and from Poyang Lake for human use and thus removed from the system. If growing water use, either upstream or within the lowland areas surrounding Poyang Lake has led to water shortages, it may be important to improve the efficiency of water use – for example, by promoting a different mix of industries, improving the efficiency of irrigation, recycling water, or phasing out wasteful uses of water.

Development of a mitigation plan related to sand dredging

Several strategies could be implemented to decrease the negative impacts of sand dredging on the Poyang ecosystem, including controlling the dredging magnitude, limiting the dredging period, and regulating the dredging region. The locations used for sand dredging within Poyang Lake should be evaluated, and consideration given to eliminating sand dredging from sensitive areas such as the outlet channel where it passes from the main lake toward the Yangtze River.

The demand for sand is likely to continue to grow and it is appropriate to explore alternative ways to satisfy this demand while decreasing the negative impacts. More environmentally friendly dredging techniques and methods might be carried out, and more marine sand resources could be utilized to fulfill demand for sand.

Creation of climate change adaptation plan for Poyang Lake

Whether or not a dam is constructed at the outlet to Poyang Lake, short-term climate cycles and long-term climate change will affect water availability, natural ecosystems, and human livelihoods in Jiangxi. Accordingly, a climate change adaptation plan is needed for Poyang Lake. This plan can help reduce the impact of short-term events – such as extreme weather periods – or long term changes such as increasingly uneven distribution of precipitation through the year or warmer temperatures.

This plan should be comprehensive in scope. Parts that will link specifically to the wetlands include:

- The enhancement of protection and restoration of wetlands. The small size lakes, hill ponds, branching streams, and rivers could be protected and any illegal encroachment by development activities prohibited. Consolidate the achievements in returning reclaimed farmland to the lake, grazing lands to grassland and wetland, and maintain the natural flood retention capacity. These actions would allow the natural wetland vegetation to recover and implement wetland ecological restoration projects to enhance the functions and services of Poyang Lake wetland. Wetlands are the kidneys of the landscape, providing some resilience against extremes of climate for people and animals.

- Establish an ecological buffer area to improve the water quality of Poyang Lake. While controlling industrial and agricultural pollution and treating domestic sewage before it goes into Poyang, establish an ecological buffer area outside the shoreline of the lake corresponding to the highest water level, while changing the traditional farming methods (which use large amounts of chemical fertilizer per unit area) to improve the water quality. Regulate land use activities within the ecological buffer, and restore natural vegetation, to minimize run-off into the lake.

- Environmental flow support. Adjusting to the annual change in run-off water volume, a basin-wide system for water management and timed releases of water from the many impoundments on the tributary rivers could be developed. In addition, measures are needed to reduce unreasonable water consumption in the area -- for example by improving irrigation infrastructure, recycling water, or phasing out industries highly wasteful of water in favor of more water-efficient industries -- in order to ensure the normal survival and reproduction of species and ecological communities, and to maintain the ecosystem services of the wetland. For instance, in the dry season, the depth and volume of water should be maintained and water capacity should be increased by minimizing diversions of water from the five rivers or Poyang itself. These measures would enhance the capacity of the wetlands for water purification (e.g., maintain beds of natural vegetation, unimpeded flows through the system) and maintain the alternative states of water and land resulting from fluctuating water levels.

TOOLS AND ALTERNATIVE DEVELOPMENT STRATEGIES

Recognition of ecosystem services in development planning for water resources

Investments in water infrastructure have long been a major component of the budgets of governments and development agencies. While clean and regular water supplies are seen as underpinning economic growth, as well as key to achieving long-term poverty reduction, such investments have conventionally ignored one vital – and economic – part of water infrastructure. They have omitted the natural ecosystems which safeguard and maintain water quality and supplies, protect against water-related hazards and disasters, and generate many other goods and services that are critical for human and economic wellbeing. The consequences of inadequate accounting of environmental and social issues during development planning are illustrated in case study 1 (see below).

The Poyang Lake system provides a range of ecosystem services that underpin the local economy, including: **Provisioning Services** such as water supply, natural fisheries and aquaculture, grazing and fodder for livestock, and harvesting of other plants for fuel, food and medicines; **Regulating Services** such as water regulation, natural hazard regulation (e.g., flood mitigation), water purification and waste treatment, and climate and air quality regulation; **Supporting Services** such as sediment retention, nutrient cycling, maintenance of genetic resources (biodiversity), and the underlying primary production that supports life (plant growth); and **Cultural Services** such as recreation, nature-based tourism, research and education. These ecosystem services are connected to varying degrees and are ultimately dependent upon the functioning and integrity of the overall ecosystem.

Particularly important functions of Poyang Lake include water storage and flood mitigation, which are expected to assume greater importance due to climate change predictions. There have been various attempts to estimate the economic value of natural flood control by wetlands – usually based on calculating the construction and ongoing maintenance costs of the engineered structures that would need to be built and maintained if an existing wetland's water regulation functions were lost or impaired. For example, the annual economic value of the remaining Danube River floodplains, including their flood mitigation function, was assessed in 1995 at EUR650 million (Ramsar Convention Secretariat 2010).

Development strategies compatible with sustaining ecosystem services of wetlands

Many features of the Eco-economic Development Plan for Poyang Lake already support a future based on continued benefits from healthy wetland ecosystems at Poyang Lake. Jiangxi Province is to be strongly commended for recognizing its relative advantage for future development due to its good environmental quality including the lake and wetland environment.

Significant aspects of that development plan include or could be modified to emphasize:

- investment in treatment of sewage and other waste in areas surrounding Poyang Lake;
- commitment to improved management of the uplands portions of the watershed through restoration of diverse forest systems and other measures that reduce soil erosion and nutrient run off;
- improvement of irrigation and other water infrastructure to make water use more efficient and productive;
- encouragement of new industries that use less water and have low pollution impacts;
- promotion of land uses appropriate to safeguarding ecosystem services through zoning, regulation and incentives– for example, keeping intensive development away from sensitive wetland areas, reducing use of hillsides or wetlands for croplands, and providing incentives for soil conservation in watershed areas;
- concentration of key industry and infrastructure within designated zones located away from environmentally sensitive areas, providing more efficiency for communication, transportation and pollution control; and
- enhancing capacity of the people to undertake high value economic activities with low environmental impact.

International experience has shown that the high quality of natural environments, including maximizing benefits from their ecosystem services such as maintaining water quality or water supply, are best achieved when comprehensive development strategies as well as environmental protection efforts encompass the entire lake system and its catchment (Bao 2009). Thus the Poyang Lake Eco-

economic Development Zone can play a strong positive role by reconciling the many, sometimes conflicting objectives of stakeholders in the basin and ensuring that development policies, strategies and plans include the maintenance of ecosystem services and natural values.

In the case of Poyang, development of the area surrounding Poyang Lake needs to be linked to land use and conservation efforts across the watershed – which in this case includes almost the entire province. The fact that the province and the watershed so closely coincide is a strong advantage for integrated wetland, water, and watershed management. Current efforts of Jiangxi Provincial Government already are deriving benefits from a broad view of lake and environmental protection.

The recent establishment of the Poyang Lake Eco-economic Development Zone, as a special, national level priority, also allows the province to channel development money where it can make the most positive difference and balance diverse objectives. These factors are important advantages for ensuring protection of the lake and wetland ecosystems as part of a strong sustainable development strategy.

A range of economic and financial tools available

Economic and financial tools can be used to prioritize ecosystems so as to strengthen investment decisions in the context of water infrastructure development and river basin management. Case studies, data and evidence generated under IUCN's Water and Nature Initiative (Emerton 2009) and elsewhere underline the wisdom of an approach that counts and invests in natural ecosystems as key water infrastructure – and shows that the returns from such investments are typically substantial in economic, development and human well-being terms.

One market-based instrument in particular has good potential to improve the integration of ecosystem values into water investments and river-basin management: **payments for ecosystem services**. These payments can provide a powerful tool for encouraging sustainable ecosystem management, and reward stakeholders for the provision of economically-important ecosystem water services. Various other analytical frameworks and decision support tools can also be applied to use valuation data in support of water management decisions. IUCN could provide additional information if desired.

Payment for ecosystem services

This analysis has made clear that maintaining or restoring the ecological character of Poyang Lake wetlands makes incompatible certain economic development options such as increased capacity for navigation by larger ships within Poyang Lake and its rivers. The deeper water levels needed for such expanded navigation capacity would drastically and negatively impact plant and waterbird communities dependent on Poyang, and also affect other ecosystem services such as flood prevention and enhancement of water quality. Other foregone opportunities might include expansion of irrigation during early autumn periods when withdrawing additional water from the lake could negatively affect water levels at a sensitive time for other lake users.

In recent years, innovative financing mechanisms and, more specifically, payments for ecosystem services (PES) have been recognized as essential for addressing some of the identified failures in environmental management. PES can reward providers of benefits that have so far been taken for granted (e.g., water utility companies pay for protecting water catchments – see case study #2). PES provides land users with incentives to protect natural environments. They typically apply to water, carbon, soil protection or biodiversity actions (offsets, restoration and enhancement of quality). At Poyang, PES might be targeted to very specific actions, such as compensating farmers to adjust agricultural or aquacultural practices in areas immediately adjacent to wetlands to protect water quality, or to compensate selected water consumers in order to reduce demand for water in early autumn. Another variant could be for the Central Government (or downriver provinces) to make annual payments to the Poyang Lake Eco-economic Development Zone as a lump payment for ecosystem services of the wetland, establishing a fund that Jiangxi could then disperse or invest as it saw most effective for sustainable development.

PES schemes make it possible to take into account environmental externalities. In a situation of high environmental concerns and limited financial resources, PES can generate additional alternative resources, divert funds to environmentally friendly management practices and sustainable production patterns, create incentives for investment, and increase the involvement of the private sector in environmental protection. They have the potential to be an environmentally effective, economically efficient and socially equitable tool for implementing integrated water resources management (IWRM). PES schemes complement other approaches, such as command and control.

PES is adaptable and can be flexibly linked, for example, to environmental challenges like water management, or protected area networks. There already exists a wide range of experience that can be relatively easily replicated and adapted for use in other countries (TEEB 2009). For further examples, see Smith et al. (2006) and Emerton (2009), or visit http://www.watershedmarkets.org/.

Experience with eco-compensation in China

Research on eco-compensation in China can be traced back to the 1980s, but did not receive a high degree of interest until the 1990s, when theoretical research and practice gradually expanded. In general, the establishment of an eco-compensation mechanism and corresponding policy framework is still at a preliminary exploratory stage in China. Yet Chinese forestry and watershed conservation fields already have relatively mature case studies of eco-compensation as implemented in the field.

Eco-compensation for forests and natural reserves started relatively early and received more governmental investment, resulting in comparatively visible achievements. Besides a compensation fund system to protect the ecological benefits of forests, six major eco-projects including natural forest conservation and the Grain to Green program also used compensation methods to deal with ecosystem degradation due to long-term damage. Relevant governmental policies and measures include: the Notice on Key Issues of Economic System Reform in 1992 (GF [1992] No. 12) issued to the National Development and Reform Commission by the State Council clearly called for “the establishment of a forest price system and eco-benefit compensation system, as well as a system of payment for use of forest resources;” the Notice on Strengthening Afforestation and Greening Work (GF [1993] No. 15) issued by the State Council in 1993, pointed to the need to “reform the investment mechanism for afforestation and greening funds, and to gradually implement eco-benefit compensation payment system;” the Notice of the State Environmental Protection Administration on Determining Pilot Site of Eco-environment Compensation Payment (terminated in 2002); Article 6 of the Forest Law, revised in 1998, expressly declared that “the State will establish eco-benefit forest compensation fund to foster, tend, conserve and manage forests protecting ecological benefits, forest resource and trees with special uses.” The period from 2001 to 2004 was designated as the pilot stage for a forest eco-benefit subsidy program. In 2004, the forest eco-benefit compensation fund was officially established by the Central Government. At the same time, the Ministry of Finance and the State Forestry Administration collaboratively issued the Management Measures for the Central Forest Eco-benefit Compensation Fund. The establishment of a forest eco-benefit compensation fund marked the substantive creation of a forest eco-benefit compensation fund system in China.

For watershed eco-compensation, local practices mainly focused on conservation of urban drinking water sources and inter-jurisdictional eco-compensation between upstream and downstream sections of medium and small watersheds, such as the collaboration for water conservation between Beijing and headwater areas in Hebei; eco-compensation along the upstream sections of the Dongjiang and other rivers in Guangdong Province; and eco-compensation along the Xin’an River in Zhejiang Province. Among the main policies that have been adopted is a method by which a higher level of government would transfer funds to local government entitled to receive compensation. Another method pools all relevant funds to be used in areas receiving compensation. A third policy allows for the horizontal transfer of compensation funds between governments at the same level of hierarchy. Meanwhile, some areas have also developed market-oriented eco-compensation models, for example a water resource trading model. In Zhejiang Province, Dongyang City and Yiwu City successfully launched a trading procedure for water use rights. After negotiations, Dongyang transferred permanent use rights for 50 million m^3 of water in the Hengjin Reservoir to the downstream city of Yiwu. There are similar water resource trading schemes in Ningxia and Inner Mongolia, through which upstream irrigation areas sold excessive water to hydro-power stations downstream after upgrading to water-saving equipment.

From the practices in Zhejiang and Guangdong, an eco-compensation model of “trans-regional development” was created. To avoid serious upstream pollution due to industrial development and to account for corresponding economic development losses in upstream areas, Jinhua City in Zhejiang Province set up the “Jinpan Economic Development Zone” which was to be used as the production lands for Pan’an County, a water conservation area. The plan also provided policy and infrastructural support to Pan’an. In 2003, the industrial production value of the production lands reached 500 million RMB and 50 million RMB in tax revenues, accounting for 40% of Pan’an County’s finances. Five other cities and counties in Zhejiang Province also carried out or will carry out similar practices.

Example: PES, erosion and the Giant Panda: rewarding local communities in China

China runs one of the largest PES schemes worldwide, the Grain-to-Greens Programme (GTGP). Its main objective is to tackle soil erosion, believed to be the principal cause of the extreme flooding in 1998, by planting trees or maintaining pasture on cropland with steep slopes to prevent soil erosion. By the end of 2006, the GTGP had contributed to the conversion of 9 million ha of cropland to forest.

The GTGP is expected to generate conservation benefits and improve degraded ecosystem services, especially in regions that are global biodiversity hotspots such as Wolong National Nature Reserve (one of the largest reserves for endangered Giant Pandas *Ailuropoda melanoleuca).* Participating households receive an annual payment equivalent of US$ 450 per ha for a fixed 8-year period for converting cropland to forest and keeping the converted plots forested. The GTGP has already generated positive impacts on panda habitat (source: TEEB 2009, adapted from Chen et al. 2009)

INTERNATIONAL CASE EXAMPLES

Much can be learned from international experience in management of complex water systems. In the Annexes 2 and 3, we provide two case studies.

Case Study 1: The environmental, social and economic impacts of the Akosombo Dam on the River Volta in Ghana. This case study provides an example of how social and environmental issues were inadequately considered during planning for a large dam project. Lack of an Ecosystem Approach as the project was designed led to major, unforeseen residual impacts including loss of agricultural lands, shellfish industries and biodiversity, soil erosion and infertility, eutrophication, spread of invasive waterplants blocking navigation, increased water-related disease incidence, increased poverty, loss of livelihoods and social disruption, and downstream coastal erosion. The Akosombo Dam illustrates the dangers when planning, design and impact assessment do not account for the complex interrelationships linking aquatic and terrestrial environments, and the combined effects of the human response to an unexpectedly changing environment. The values of ecosystem services were not considered. Integrated water resource management for the transboundary Volta River Basin is now under development to improve environmental and socio-economic conditions including some remedial measures. But the costs of solving the problems now affecting all aspects of this major river system are immense, and these interventions will not be able to offset much of the damage to natural and human communities.

Case Study 2: Sustainable water management in the Catskill and Delaware watersheds to supply clean water to New York City, USA. This case study demonstrates how valuation of watershed services was used in planning investment decisions by New York City, saving billions of dollars on water treatment infrastructure while improving the environmental conditions in the watershed through an urban-rural partnership guided by local leadership. In this case, alternative solutions to deteriorating water quality were compared: construction of a water filtering facility for the New York City water supply, as contrasted with safeguarding or restoring the watershed so that the waters it supplied did not need treatment. The Ecosystem Approach – focused on enhancing a diverse area of land use and economic activities across the watershed – proved to be far less expensive and provided numerous benefits to local people living within and using the watershed. Although costs for this alternative were much lower, an evaluation of ecosystem services led to significant investment targeting activities within the watershed that would benefit ecosystem health and water quality.

Numerous other case examples are relevant to the process and decisions underway for Poyang Lake. IUCN could provide additional case study materials if desired, or assist with arranging study visits by Jiangxi Government management and technical staff to some of these locations.

RECOMMENDED PROCESS FOR SUCCESSFUL OUTCOMES FOR POYANG LAKE

This section synthesizes contents of this report as recommendations for a holistic process that balances maintenance of Poyang Lake's ecosystem services with socio-economic development. This process differs markedly from the current process that takes one solution (the outlet dam) and attempts to resolve its negative consequences. Such a narrow focus is likely to under-estimate the negative consequences of the proposed dam and overlooks alternatives that might avoid these impacts while offering other advantages.

Given the global and regional importance of Poyang Lake, and the many uncertainties involved regarding lake functions and human impacts, it is extremely important to postpone a decision on the dam until the steps outlined in Table 1, and described below, have been completed.

Prior to the decision process, a clear statement is needed of the objectives for water management at Poyang Lake. The objective has been described as restoring the natural wetland and its numerous benefits for conservation and development. From an ecosystem perspective, this objective assumes that one maintains (or restores if necessary) the ecological character of the wetland -- including natural water levels and fluctuation within and among years. For example, management would attempt to maintain average winter low water levels at 12 meters above sea level Wu Song in the Wucheng area (and at 9 meters near Xingzi) even though the water would not remain constant at this level but would fluctuate both within and between winters, sometimes going below 12 meters and sometimes going above. International experience indicates that, especially in the case of globally important wetlands like Poyang, such an objective will maximize continued benefits from the diverse ecosystem services of wetlands while allowing considerable compatible development.

Yet the current proposal for the dam appears to arise out of two conflicting objectives in Jiangxi: restoring the natural hydrology of Poyang Lake and managing water levels to enhance economic benefits from irrigation, fishing, navigation, etc. In that case, the objectives should be explicitly expressed as two objectives that are both important but not fully compatible. The task then becomes to identify and assess ways to combine them, with the various options being valued and compared as long-term strategies for Poyang Lake wetlands.

Table 1. Recommended steps for a decision process for Poyang Lake management

Step 1. The rationale for the proposed dam – that hydrology of Poyang Lake has changed in the past several years, to the detriment of natural systems and economic benefits – needs to be rigorously tested.
Step 2. A conceptual model for the system should be developed and tested that includes the watershed, hydrology, vegetation, fish, Finless Porpoise, waterbirds, the human components, and other important variables.
Step 3. If environmental change has occurred, the causes for this change require intensive analysis, including the effects of other water projects.
Step 4. Information gaps need to be identified and, in some cases, filled through further research before the best choices can be made for Poyang Lake.
Step 5. Based on the causes of environmental change at Poyang, a diverse array of management options should be identified. The proposed dam would be one of these options. • Step 5a. In order to evaluate the proposed dam as one alternative, the design for the dam needs to be completed so that its impacts can be fairly assessed.
Step 6. A thorough economic and environmental analysis should compare the various mitigation strategies with one another, in terms of costs and benefits and in particular, values of the ecosystem services of the wetland.

Steps to be taken prior to making management decisions for Poyang Lake

These steps should be holistic, applying an Ecosystem Approach that encompasses Poyang Lake together with its entire watershed. IUCN would be willing to offer technical assistance to Jiangxi Province with regard to training, case studies, the assessments involved in these steps, or implementation of an Ecosystem Approach to Poyang Lake.

Step 1. The rationale for the proposed dam – that hydrology of Poyang Lake has changed in the past several years, to the detriment of natural systems and economic benefits – needs to be

rigorously and quantitatively tested through comparison with data on the lake collected over the past 50 years. Data should also be collected and analyzed for additional years before a decision on the dam is made, to avoid reacting to what may be a short-term cycle rather than a long-term change.

Step 2. To successfully analyze environment change and impacts of alternative management scenarios, a conceptual model for the system needs to be developed and tested that includes the watershed, hydrology, vegetation, fish, Finless Porpoise, waterbirds, human components, and other important variables. This model is especially important due to the complex hydrology of Poyang Lake. The model will help ecologists (who think in terms of complex systems, feedback loops, and ecological constraints) to collaborate effectively with engineers (who focus on key variables in the system and how to control or adjust them). These groups need a framework for building mutual understanding of the issues involved, how to address them, and the ways that perspectives on both sides can evolve in the decision process.

Step 3. If environmental change has occurred or is likely the various causes for this change need intensive analysis, including the effects of other water projects. The various factors probably interact, and in that case their separate and combined contributions need assessment.

Step 4. Given the importance of Poyang Lake regionally and globally, information gaps need to be identified and, in some cases, filled through further research before the best choices can be made for Poyang Lake. Time must be provided to identify and complete this research. For example, economic development opportunities and strategies have been elaborated for the dam option but also need considerable study as part of steps 5 and 6 below for the other (non-dam) options. Such studies should examine potential benefits if the funds intended for the dam construction, and for mitigating its negative impacts, were instead spent directly upon improving livelihoods of people living within the basin or its watershed through a Payment for Ecosystem Services or other development approach.

Step 5. Based on what has caused environmental change at Poyang an array of strategies should be identified and assessed. If multiple causes are responsible for negative environmental changes, then mitigation strategies likely need to be considered in various combinations (e.g., adjustment in water releases from upstream dams combined with water conservancy measures such as improving irrigation infrastructure). This step is crucial, as the dam appears to have many negative impacts that could be avoided through other more effective, and potentially much less expensive options.

Step 5a. In order to evaluate the proposed dam as one of the alternatives, the design for the dam and water management plan needs to be completed early enough that its impacts can be fairly assessed. The proposed dam could have very different impacts depending on how it operates; therefore its operating plan needs to be specified and evaluated as part of this alternative.

Step 6. A thorough economic analysis is needed to compare the various mitigation strategies with one another in terms of costs and benefits. Values of ecosystem services for the wetland in particular, either sustained through the option in question or requiring expensive infrastructure to replace, must be assessed. Earlier sections of this report suggest that the costs to replace flood storage capacity, water quality amelioration and fisheries values of Poyang would be immense.

Recent changes to Poyang Lake water levels in early autumn might be much more cheaply solved through an IWRM approach to the catchment as a whole through modifying the operation of more than 9,000 dams and upstream water diversions. A payments for ecosystem services scheme -- utilizing funds that might have gone toward the dam and mitigating the resultant loss of the ecosystem services of the wetland -- might be highly effective at compensating upstream water users at a far lower economic and ecological cost than for the dam option.

Other features of an effective assessment and decision process

As has already been recognized, the process for effective assessment and decision-making requires diverse teams of scientists across multiple disciplines. The effort to integrate information about different elements of the Poyang Lake ecosystem, and the human activities that depend on the lake, is especially important and should occur through an open process that invites external scientific comment.

Regardless of the options selected for future action, management of Poyang Lake and its waters is best accomplished by regarding the entire system as a whole, through establishment of a management committee or agency that can operate across the entire lake basin and its watershed. The creation of the Mountain, River and Lake Development and Management Project (MRL) in 1980 demonstrates that the Jiangxi Government has long recognized that issues surrounding Poyang Lake do not stop at the lake's boundaries. MRL, however, does not have regulatory authority over activities occurring within the lake basin.

Institutional mechanisms should place that regulatory authority within one agency, to reflect the large scale at which analysis and decisions should occur, and will need to involve the diverse stakeholders as members of the management body. After the selected responses to environmental change at Poyang have been put in place, such a management body must have the independence, commitment, and authority to conduct rigorous assessments of the impacts of those actions and to implement adjustments as needed to offset unintended, negative consequences. Such a body needs to be committed to following the approved operating plan, if a dam is constructed, as changes in the operation of the dam could transform the ecological character of the wetlands, an eventuality that might bring major short-term economic benefits to some stakeholders at significant cost to many other interests. Furthermore, failure of proper oversight will likely reduce the longer-term productivity and economic value of the system.

Because informed decisions depend on diverse technical information, a scientific or advisory council should be established to provide advice to the management body. This advisory council should oversee the monitoring program and evaluate the effects of management actions, so that corrections and improvements can be made.

Monitoring and evaluation

Monitoring and auditing are used to compare the actual outcomes after project implementation has started with those anticipated during the planning and approval process. Monitoring and auditing also serve to verify that the proponent is compliant with the design and operating conditions specified when the project's environmental impact was evaluated and the project approved. In the

Ramsar Convention's context, monitoring is largely focused on measuring changes in ecological character of internationally important wetlands, such as Poyang Lake (Ramsar Convention Secretariat 2008a).

The recognized international importance of Poyang Lake for biodiversity, especially its populations of migratory waterbirds, mean that post-project monitoring against baseline information collected before the project, using comparative methodologies, will be critical in determining the actual impacts of proposed developments (including the operational phase if a dam is constructed) and the effectiveness of planned mitigation measures. The monitoring program specified in the project document should measure changes in ecosystem processes as well as effects on biodiversity over a long enough time (ideally 10 years or more) to adequately document the overall impact of the development and to guide management responses.

For Poyang Lake, inter-disciplinary teams should be formed to assess the monitoring data and to determine required adjustments in the monitoring regime. Institutional mechanisms are required that will allow recommendations of these teams to be implemented through adaptive management procedures.

Given the global, national and local importance of the resources at stake, it is critical that institutional mechanisms respond rapidly to unforeseen or underestimated environmental impacts to manage the environmental risks posed by this project.

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ANNEXES

Annex 1. Twelve guiding principles for ecosystem management

Annex 2. Case Study 1: The environmental, social and economic impacts of the Akosombo Dam on the River Volta in Ghana

Annex 3. Case Study 2: Sustainable water management in the Catskill and Delaware watersheds to supply clean water to New York City, USA