

Technical report from Phase 2 of the USAID GCP-funded initiative (FY07)

Integrating Biodiversity and Hydrological Processes into Conservation Planning at the Landscape Scale



(photo by David Mitchell)

Summary of discussions from the *Workshop on Integrating Hydrological, Biodiversity and Socio-economic Analyses for Conservation Actions*

Chilika, Orissa province, India
March 12-15, 2007



I. Background

While networks of conservation areas are the most effective tactic for preventing species extinctions in the short-term, the long-term persistence of both threatened species and sites also depends on the maintenance of critical ecological processes at a sea/ landscape-scale. Complex hydrological processes create the conditions for a range of habitats (e.g., floodplains, lakes, shorelines) that are of critical importance to threatened species. Hydrological processes also generate important socioeconomic benefits by supplying water for daily needs, agriculture, fisheries, hydroelectric energy and other industrial uses, and by contributing to flood defense and supporting harvestable biodiversity resources (e.g., fish, crabs). Disruptions to hydrological processes (e.g., due to dam development, deforestation, or pollution) have been identified as significant threats to both biodiversity and sustainable economic development.

Integrating hydrological processes into conservation planning at the landscape scale is a technical challenge that requires the close collaboration of both biodiversity conservation and hydrological expertise. Over the past two years (2006-2007), Conservation International has led a collaborative learning initiative to bring together conservation partners and centers of freshwater expertise, including the African Wildlife Foundation, The Nature Conservancy, the Wildlife Conservation Society, the World Wildlife Fund, the IUCN Freshwater Program, Wetlands International and the Commonwealth Scientific and Industrial Research Organisation. The initiative enables partners to share expertise and lessons learned on the integration of hydrological processes into conservation planning at the landscape scale to address the following key questions:

- How do changes in hydrological processes impact on globally threatened species and/ or conservation priority sites (such as KBAs) and the ecosystem services they provide?
- How do we map and quantify hydrological processes and patterns and identify clear targets or thresholds for hydrological processes to ensure the persistence of globally threatened species, priority sites, and the ecosystem services they provide?
- How do we value the biodiversity and ecological benefits of functioning hydrological processes to the wider economy and society?
- How do we integrate hydrological information with biodiversity and socioeconomic data to support the design of effective conservation strategies at the landscape scale and how do we integrate these conservation strategies in sustainable development planning?

As a first step in this collaborative initiative, CI-Brazil hosted a workshop at the Fazenda Rio Negro in the Pantanal (April 21-25, 2006), the world's largest contiguous wetland. This first workshop focused on the identification of targets for maintaining hydrological processes and key threats to those processes, drawing upon experiences gained through several case study analyses being conducted in the field and providing lessons for the other projects about to embark on similar analyses (refer to the CI FY07 Technical Report to USAID/GCP under this initiative for a summary of the workshop discussions).

A second workshop was held at Chilika, India (March 12-15, 2007) and hosted by Wetlands International South Asia and the Chilika Development Authority. Chilika lagoon is a RAMSAR site that consists of a unique assemblage of marine, brackish and fresh water ecosystems, and supports the livelihoods of over a million fisherfolk in the area. The objectives of this second workshop were to examine processes and approaches for defining threats and pressures on the hydrological system, engaging with the relevant stakeholders, identifying the types of conservation interventions that might be most effective given the local/ regional contexts, and identifying the types of analyses required to properly implement those interventions. The case study teams were to integrate the various layers of biodiversity, hydrological and socio-economic analyses to develop a cohesive strategy for conservation.¹

¹ All presentations and resources from both workshops will be posted on the CI Corridor Learning Portal and available for download by workshop participants in November 2007 (<http://corridors.conservation.org/>).

II. Key discussion points from the Chilika workshop

While the first workshop in Pantanal explored questions of mapping and linking biodiversity targets and hydrological processes, much of the discussions at this workshop steered towards questions of understanding the social context and development pressures, and managing these large hydrology-driven regimes to meet both conservation and social goals.

Chilika Lake provided an inspirational backdrop for the workshop. A major restoration effort to open a new mouth between the lake and the Bay of Bengal in 2000 was extremely successful in restoring the lake ecology and regulating the salinity gradient in the lake waters. This has resulted over the recent years in the regeneration of native lake vegetation, increase of fish, prawn and crab resources and thus, improvements in fish incomes, and return of migratory bird and fish species, most notably the Irrawaddy dolphin (CR).

There were two clear messages from the Chilika experience:

1. In conservation planning for large complex systems such as the Chilika lagoon, it was emphasized while holistic planning for the entire hydrological system (for example, the entire river basin from upland catchment to coastal lagoon) is preferable from an ecological point of view, it is quite impossible to do so practically from an institutional and resources perspective.

Figure 1 below illustrates the model of adaptive and decentralized management that the Chilika Development Authority has applied to the broader Chilika ecosystem. This model has distinct temporal and spatial scales. There are two nice features of this approach: i) spatial scales are based on natural ecological boundaries nested within each other, and the variables of analyses and monitoring are clearly linked together; and ii) the conservation and/or restoration activities can be successive from smaller to larger spatial scales and timing can be determined either through threat intensity (e.g. in terms of impacts) and/or opportunity (e.g. resource availability, partner and local stakeholder interest). This provides a structure for working in manageable chunks, whilst still thinking holistically and keeping an eye on the broader picture.

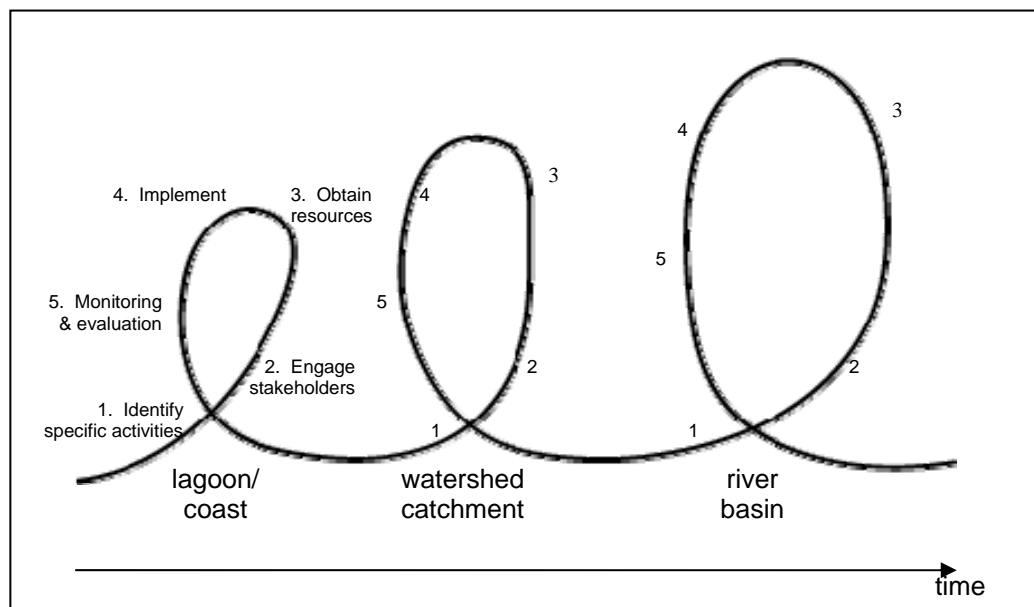


Figure 1: A model of adaptive and decentralized management for the Chilika Lake system

- Similarly, it is obvious that one cannot afford to understand *all* the root causes of ecosystem degradation because the socio-economic context is typically very dynamic and threats and drivers can adapt quickly to fluid economic and political situations. Rather, through consultations with local experts and stakeholders, knowledgeable conservation managers should be able to make informed decisions and invest in targeted scientific studies that are geared towards finding solutions.

Methods and approaches on integrating socio-economic information by external experts

The three invited experts provided interesting applications of different methodologies and modeling approaches to how socio-economic information were incorporated into their conservation planning approaches in three very different regions:

- Chris Baker (Wetlands International) presented the use of ecological cost and benefit analyses to influence decision-making on development of new dams in the Inner Niger Delta (Mali). The first stage of the analysis was to understand/ quantify the relationship between the extent of flooded areas and biodiversity (i.e. migratory waterbirds and breeding grounds), and production (i.e. hydro-electricity, livestock and rice production). The second stage is to quantify the expected impact of dams on flooding patterns and water flows, and the resulting impact costs and benefits to biodiversity and production. An examination of just benefits was not particularly helpful as the results show that more dams provide increasingly higher cumulative benefits. However, once costs were considered (see Figure 2 below), results show that it is actually preferable to maintain status quo (Scenario 2 – currently two dams in production), rather than to develop another new dam (Scenario 3). An interesting conclusion of this study is that increasing dams will produce *net costs* and suggest that the priority is to develop adaptive strategies for both people and biodiversity in the Inner Niger Delta as the hydrological system becomes increasingly fragmented.

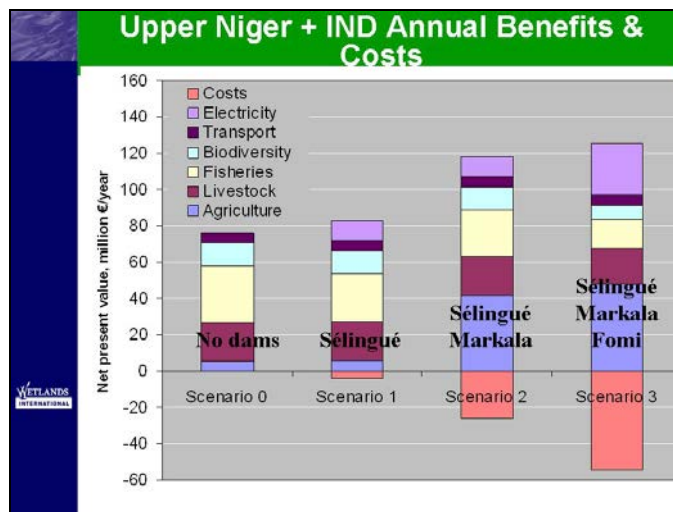


Figure 2: Illustration of costs and benefits from various dam scenarios in the Inner Niger

- Bob Smith (University of Kent) applied a systematic conservation planning framework to identify an effective conservation reserve network (and including linkage areas) in the Maputaland, a region which encompasses part of Mozambique, Swaziland and South Africa. The study used transformation risk/suitability for agriculture as a planning unit cost, so that the conservation software tool (MARXAN) identified priority areas that met the targets whilst minimizing its impact on areas that were most suitable for agriculture. The study highlighted difficulties with measuring cost, and suggest that the types of cost data to use should depend on the implementation possibilities. Three distinct types of economic costs and benefits were considered within the conservation planning framework:

- Conservation opportunity, which consists of privately and communally owned game reserves. These were to be considered as potential for inclusion into the PA network;
 - Potential game ranch profitability based on the presence of game species and their market values;
 - High likelihood of agricultural transformation based on geophysical suitability. These are areas that were excluded from the PA network due to its high opportunity costs and inevitable threat of land conversion. Areas that were already highly transformed were excluded from the analysis.
- Frederieke Kroon (CSIRO) presented work with designing a conservation strategy for the Tully catchment (northeast Australia) and application of the *Landscape Toolkit*, an integrated biophysical and socio-economic modeling approach to land use analysis. The framework for this modeling approach (see Figure 3 below) applies a systems approach to understand the complex interactions between land use and management, and ecosystem states, properties and functions. It is also, however, very complex and demands intensive data and high analytical capacity. In this case, the Landscape Toolkit is used to inform landscape management and protection to improve water quality run-off into the Great Barrier Reef. There are many advantages to the approach and one of interest to the group is how it compares the current state with local stakeholder-defined future land use scenarios to examine land use, economic, ecological and biodiversity impacts. By incorporating the local priorities from the beginning, this helps ensure that proposed policy measures will gain buy-in from the stakeholders.

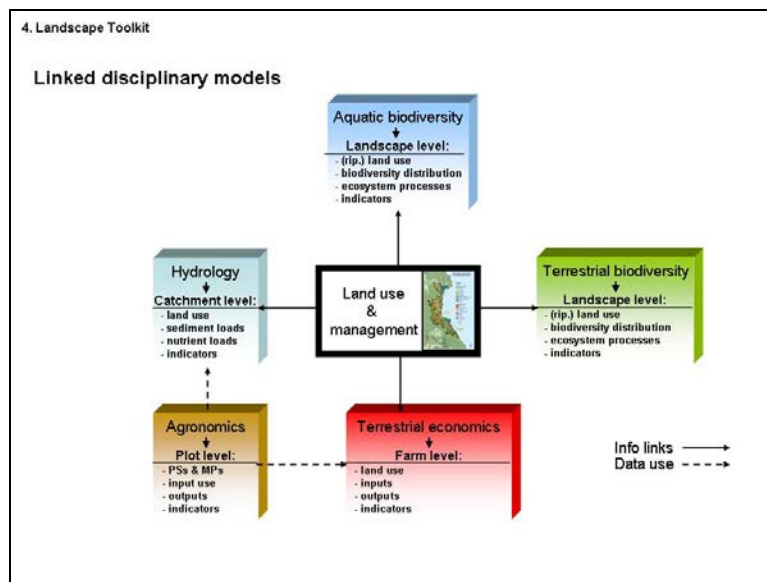


Figure 3: Modeling framework for the Landscape Toolkit

Questions raised and discussion points

“Species and ecosystems are legitimate users of water” was a phrase that resonated throughout the meeting. While this statement has equivocal agreement/support from all present, it raised numerous questions and lively debate on how conservation managers can implement strategies that balance water for species’, ecosystem and human needs.

- How to define “sustainable thresholds” for water use?
 - The WCS case study from Rungwa-Ruaha (Tanzania) is attempting to quantify water needs/demands by key species in the region (for example, water buffaloes,

elephants, hippos, freshwater molluscs), measure the relationship between water flows and productivity of rice fields, and understand the balance/allocation between the two. This is readily acknowledged as a daunting task as there remain many uncertainties related to both parts of this equation.

The program has implemented an innovative approach to encourage rice farmers' to conserve and save water since a substantial portion of water use is to irrigate rice fields out of the rainy season in order to maintain subsistence livelihoods. The WCS program studied the market chain between rice farmers and the market, and learned that the overwhelming profit is captured by middlemen. WCS is now trying to implement a program of "conservation dividends" to provide more equitable prices for rice in return for water conservation practices.

- Dr. Trisal (WI-SA) also noted the challenges in trying to relate links between flows and species. Despite the wealth of research and studies in Chilika over the past decade, this still remains a gap in the scientific knowledge.
- How to measure or quantify the link between landscape resiliency and ecosystem processes (such as hydrology)?
 - The graphic below (Figure 4) illustrates an obvious relationship between the collapse of an ecosystem function and the socio-economic from the Rungwa-Ruaha landscape. The Mtera wetland plays an important regulating function across the broader Ruaha river system and the construction of a dam in 1984 disrupted the natural functioning of the hydrological system. In February 2006, hydroelectric turbines were shut down for over 100 days, resulting in a loss of \$200,000 daily revenues from electricity, and Tanzania went into country-wide power rationing, with power provided for only 12 hours/day. The local fishery industry also shows a similar collapse, illustrating the tight correlation between the ecosystem function and socio-economic resiliency.

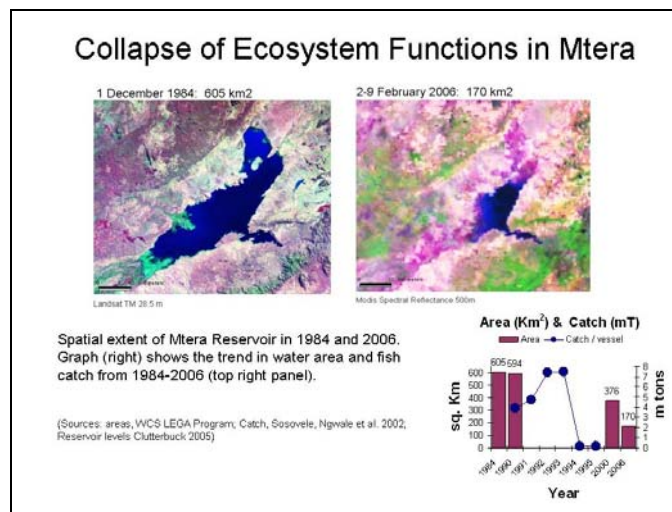


Figure 4: Correlation between ecosystem and socio-economic collapse in the Mtera

- In the Maputund study, Smith et al. incorporated targets for ecological processes which included areas large enough to maintain natural fire regimes, and natural herbivory patterns for elephants, and a range of connectivity linkages that cover altitudinal ranges, longitudinal ranges, and wet/dry seasonal patterns. These targets are considered as critical for maintaining ecosystem functions. There were, however, not quantified and were determined based on expert opinion. There are plans to incorporate specific hydrological features in the next stage refinement of this work.

- There was also some discussion about the role of “hidden water” (i.e. groundwater) in regulating landscape function. The use of this resource by crop plantations and smallholder agriculture is largely ignored in conservation planning exercises but is a prevalent practice throughout Africa and India.
- The case study presented by Wetlands International South Asia (WI-SA) on Wular Lake in Kashmir (India) provided a striking case of how a conservation manager would not be able to parse out the intricate linkages between people, biodiversity and ecosystem needs in a vast wetland that is on the verge of ecological collapse. In their suggested management plan for the area, WI-SA relies on an *ecosystem-based management approach* that tackles the most critical pressures simultaneously, namely catchment conservation and water management; biodiversity conservation; and livelihood improvement (through ecotourism and fisheries development). This is accompanied by a study of policies to guide coordination at the larger river basin level, and development of effective institutional mechanisms for management.

All the case studies relate to the need for analyses to be *more integrated and finely tuned to development needs in the region*.

- Part of the conservation planning process in Milne Bay (Papua New Guinea) involves the identification and quantification of economic trade-offs between development options and biodiversity values. In order to make a meaningful analysis about trade-offs from the perspective of the community (who have traditional ownership of the land and are largely subsistence farmers), the CI program carried out a participatory exercise with communities and other stakeholders to have them prioritize the relative importance of several possible development options (large scale oil palm, logging, timber plantations, subsistence gardens, smallholder oil palm and mining) using an Analytic Hierarchy Process. The process of weighing options forced many to consider the status of their natural environments (forest, water) and helped the CI program incorporate these values into the planning process for prioritizing conservation actions.
- The modes of communication with policymakers and development planners have to be finely tuned to their perspective. For example, in the Inner Niger case study on cost and benefit analysis for dams, Wetlands International also provided information on the distribution of benefits to present a very convincing case against development of additional dams - Scenario 3 shows that higher proportion of benefits will flow to regions/ countries outside of the Inner Niger/ Mali (see Figure 5 below).

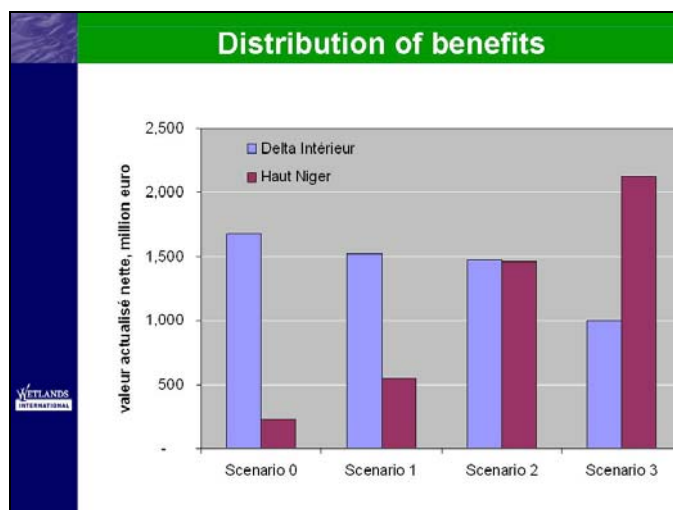


Figure 5: The distribution of benefits from dam development scenarios in the Inner Niger

- Conservation groups must strive to find approaches/mechanisms to collaborate with the development sector to achieve mutual benefits for both biodiversity and human well-being. Larry Gorenflo presented a framework that CI is using to examine the synergies between biodiversity conservation and the water development priorities, what he terms as the *common geography* – common in terms of location and mechanics for collaboration, while recognizing that both groups are likely to lead separate and independent (though ideally, temporally coordinated) projects.

Some examples of where conservation and development priorities may merge include watershed management/conservation to support development of water delivery systems; Payment for Environmental Service (PES) mechanisms for managing land and resource use to maintain water quantity and quality; and development of compensatory offsets from dams and other disruptive hydrology infrastructure towards water and biodiversity conservation.

A few final points to ponder

Several major questions dominate this work as we progressed in this initiative over the last two years and are worth re-iterating here as critical gaps in the current scientific knowledge, and which should be considered as research and implementation priorities by the GCP NGOs and partners involved in tackling the biodiversity conservation and hydrology intersection.

- The challenge to properly measure and map the linkages between biodiversity, hydrological processes and other ecosystem functions continue to dog the group; and this is a serious limitation when identifying a proper suite of conservation targets/features within the conservation planning framework. Flow regimes and hydrological connectivity continue to be under-represented in conservation planning.
- Socio-economic studies should be designed with an eye on the range of implementation possibilities and the policy framework. Conservation has to fit within the broader development priorities in the region and the objective of analyses is to support informed decisions on the point of intervention to influence political and social will.
- Much of the socio-economic analyses of hydrological-driven systems are static, while the processes that being studied are inherently dynamic in nature. Studies of the social and economic systems should include development of future scenarios and risk analyses.
- Issues of scale inconsistencies as they relate to the hydrological system (lagoon, catchment, basin), biomes (marine, coastal, freshwater), stakeholders, institutional boundaries, implementation strategies, funding possibilities and timing.
- All levels of stakeholders should be engaged in the planning process from the onset and where possible, also in the analytical process. It is also important to incorporate local and traditional knowledge where there are data deficiencies, and to aid in the design of locally relevant actions that support conservation objectives.
- Recognize that this work necessarily requires multidisciplinary knowledge and an integrative approach – and thus requires a network of experts with differentiated skills, but a common conservation vision, to achieve the broad goals.
- The importance of an adaptive and decentralized management strategy for managing these large complex systems cannot be underscored enough, yet it is not widely applied either by conservation or development groups.

Useful products/resources that the group thought should be produced from this initiative (although this is only dependent on available future resources)

A flow diagram that describes the step-by-step process for this work to allow field programs that are in various stages of conservation planning to pick up the process and integrate hydrological components within their planning framework.

A short review paper for publication in a scientific journal that summarizes the wealth of discussions from both workshops in Pantanal and Chilika; illustrates challenges and lessons from the case studies and organizations that have participated; and identifies remaining scientific gaps with integrating hydrological processes in biodiversity conservation efforts.

Please refer to Annex I for the Workshop Agenda and Annex II for a List of Participants.

III. Outputs from the GCP Biodiversity and Hydrological Processes initiative

Progress of CI case studies

Part of the strength in this initiative is the lessons gained through the application/test of conservation planning approaches in the case study programs over the course of the two-year initiative. Unfortunately, of the six learning case studies that participated in Pantanal in 2006, only three made it to the workshop in Chilika in 2007 – these are the CI case studies from 1) Maracaju-Negro, Pantanal; 2) Milne Bay, Papua New Guinea and 3) Mamberamo catchment, Indonesia. Fortunately, the participation of Wetlands International South Asia and CSIRO provided important continuity and linkages between the two workshops as the conservation planning process within the case studies evolved/ progressed over the course of the year.

Aside from WCS' Rungwa-Ruaha program, the other GCP partners were either unable to participate due to lack of funding resources or had to pull out of the initiative at the last minute due to scheduling conflicts.

Interim reports from the Maracaju-Negro and Mamberamo corridors, the two CI case studies under this USAID-GCP initiative, are attached in Appendix III. The reports describe how both CI programs attempted to adapt methodologies discussed at both workshops into their conservation planning process, and the challenges and gaps faced with trying to integrate the biodiversity, hydrology, climatic and socio-economic data layers.

The interesting thing to note is the widely differing approaches employed by the two programs. The Pantanal program applied the systematic conservation planning framework and used optimization software (CLUZ) to identify an effective network of reserves to meet their conservation targets. The Mamberamo program, on the other hand, relied on participatory community assessments to tease out traditional knowledge of the relationship between species, hydro-ecological processes and how local resource use patterns adapt to changing seasonal fluxes in the hydrological system.

The different approaches used are obviously related to specific regional contexts. Although both are classified as hydrologically-driven wilderness areas, the Pantanal has had a strong research and scientific presence with CI-Brasil and the research center in Rio Negro, EMBRAPA/Pantanal, UFMS, and Earthwatch Institute, among others. Their collective analytical results make possible the program's attempt of a data-driven systematic conservation planning approach. On the other hand, the Mamberamo is vastly under-studied and its remoteness has long been a key contributing factor to its conservation. The region is sparsely populated (approximately 11,000 people in close to 8 million hectares), and the inhabitants are seasonal nomads who depend on natural resources for their subsistence livelihoods. As such, the program has applied the Multidisciplinary Landscape Assessments methodology (developed by CIFOR) to extract information on the relationship between species, habitats, hydrological processes and resource use from indigenous knowledge.

For both case studies, the complexity of the hydrological system presents a key challenge to understanding and quantifying its relationship with biodiversity. Both are works in progress and expect to have an integrated conservation plan developed for their region by Spring 2008.

Lessons gained from the initiative and its contribution to CI's corridor planning framework

In part due to the tremendous amount of thinking in biodiversity and hydrological processes over the course of this two-year GCP project and to the huge need on the ground, CI has invested into an initiative to “*integrate hydrology, freshwater priorities and ecosystem services in corridor planning*” in FY08. By integrating watershed management and resource planning at this scale, and through having a better understanding of hydrological processes as they impact biodiversity and

service flows, this initiative aims to contribute towards CI's work in understanding, adapting and mitigating threats to biodiversity. This initiative builds on the lessons learned from the implementation of systematic analyses and planning processes initiated in the two CI corridors (Maracaju-Negro and Mamberamo), as well as from the various partner implemented case studies that were part of this GCP learning project. CI regions that are involved in this new initiative include China (Pingwu-Yujiashan landscape), Southern Africa (Kavango-Zambezi), Philippines (Eastern Mindanao Corridor), Cambodia (Cardamom Mountains) and Indonesia (East Java).

The GCP initiative has also facilitated technical collaborations between CI and CSIRO and Wetlands International. Over 2008, the CI corridors planning unit and Wetlands International South Asia will be working together on an adaptive systematic conservation planning approach in the Chindwin-Manipur hydrological corridor within the Irrawaddy river basin of northeast India. The objective of this collaboration is to test the applicability of an integrated planning approach within a large complex system, with the expectation of developing a model for replication in other similar systems. This type of collaboration was identified as a desired follow up activity during both workshops.

Annex I: Workshop Agenda

Day 1, March 12

- 10.00-10.30 Welcome (Chilika Development Authority, Wetlands International-South Asia)
- 10.30-10.45 Introductions and discussion of the agenda
- 10.45-11.15 Workshop objectives (CI) – overview of the Hydrological Processes learning initiative, the different approaches of partner organizations to conservation planning at the landscape-scale, and the workshop goals
- 11.15-12.00 Freshwater development and biodiversity conservation: A case for collaboration between the conservation and development sectors – Larry Gorenflo (CI)

Learning case study presentation, part 1: Biodiversity and hydrology (20 mins presentation + 20 mins discussion)

- a brief overview of the biodiversity, hydrology regime and socio-economic context in the region;
- progress made since the Pantanal workshop last April with identifying species, sites and other focal biodiversity targets, and their link/ dependence on hydrological flows;
- an initial analysis of the key drivers and threats to biodiversity and the hydrological system, and identification of the changes in behavior and/or policy needed to mitigate the threats.

- 12.00-12.40 1. Pantanal, Brazil – George Camargo (CI Brazil)

LUNCH

- 2.00-2.40 2. Milne Bay, PNG – David Mitchell (CI Melanesia)
- 2.40-3.20 3. Rungwa Ruaha Landscape, Tanzania – Festo Semanini (WCS)
- 3.20-4.00 4. Mamberamo, Indonesia – Hugo Yoteni (CI Indonesia)
- 4.15-5.30 Presentation on Chilika Lake: biodiversity, socio-economic context and the development of a conservation plan – A.K. Pattnaik (Nandankanan Zoological Park)

Day 2 , March 13

Presentation of various methodologies/ approaches used in analyzing the socioeconomic and policy drivers affecting hydrological processes and biodiversity, and the development of conservation strategies and actions (30 mins + 15 mins discussion):

- 9.00-10.00 Incorporating socio-economic data into a systematic conservation planning framework: case study from Maputuland – Bob Smith (DICE, University of Kent)
- 10.00-11.00 Case study of the Cardwell Shire Floodplain Program, Australia – Frederieke Kroon (CSIRO)
- 11.00-12.00 Analyses of ecological costs and benefits from dam development in the Inner Niger Delta – Chris Baker (Wetlands Intl)

Learning case study presentation, part 2: Integrating socio-economic pressures and priorities in conservation planning (40 mins presentation + 20 mins discussion):

- ongoing socio-economic and policy analyses;

- discussion of the types of integrated analyses/approaches that is relevant to support policy and behavioral changes within the local socio-economic context, and the incentive structures necessary to catalyze those changes;
- a brief outline of next steps in the development of actions and strategies for conserving biodiversity and hydrological regimes.

12.00-1.00 1. Pantanal, Brazil (CI Brazil)

LUNCH

2.00-3.00 2. Milne Bay, PNG (CI Melanesia)
 3.00-4.00 3. Rungwa Ruaha Landscape, Tanzania (WCS)
 4.00-5.00 4. Mamberamo, Indonesia (CI Indonesia)

Day 3, March 14

Field trip to the Bengal Bay and sites of various conservation projects in and around Chilika

Day 4, March 15

9.00-10.00 Understanding river dolphin biology for conservation – Dr. Panda (Chilika Development Authority)

10.00-10.45 Migratory birds of Chilika Lake and management implications – Mr. P. Sathiya Selvam (Chilika Development Authority)

11.00-2.00 Case study clinics
 Case study teams to consult external experts for input on socioeconomic analyses and methodologies to support the maintenance of hydrological processes for biodiversity conservation and local needs in their region.

LUNCH

2.00-3.00 Case study on the development of a conservation management plan in a large wetland basin: Lake Wular, Kashmir – Ritesh Kumar (Wetlands Intl South Asia)

3.00-5.00 Discussion on the appropriateness of various socio-economic methodologies/ approaches to the different scale of threats/ pressures on biodiversity and hydrology (i.e. dam development, land use/ cover change, over-fishing, climate change, etc.), challenges (i.e. data constraints, capacity), and opportunities.

Discussion of the types of tools, guidance materials and other resources/ products that would support ongoing lesson-learning (bearing in mind, resources etc. that already exist).

Discussion on the development of a joint paper for publication.

Discussion of possible next steps for the biodiversity and hydrological processes initiative.

Annex II: Participant List

Name	Institution
Chris Baker	Wetlands International
George Camargo	Conservation International-Brazil
Larry Gorenflo	Center for Applied Biodiversity Science, Conservation International
Siddarth Kaul	Ministry of Environment and Forests India
Frederieke Kroon	Commonwealth Scientific and Industrial Research Organization (CSIRO)
Ritesh Kumar	Wetlands International- South Asia
N. Sanajaoba Meitie	Loktak Development Authority
David Mitchell	Conservation International-Melanesia
S. Panda	Chilika Development Authority
A.K. Pattnaik	Nandankanan Zoological Park
R.N. Samal	Chilika Development Authority
P. Sathiya Selvam	Chilika Development Authority
Festo Semanini	Wildlife Conservation Society
Bob Smith	DICE, University of Kent
Chaman Trisal	Wetlands International-South Asia
Grace Wong	Conservation International
Hugo Yoteni	Conservation International-Indonesia

Annex III: Case study summary reports

1. Maracaju-Negro Biodiversity Corridor, Pantanal, Brazil

INTEGRATING BIODIVERSITY TARGETS, HYDROLOGICAL PROCESSES, AND HUMAN DEMANDS FOR SYSTEMATIC CONSERVATION PLANNING OF PANTANAL WETLANDS, BRAZIL: MARACAJU-NEGRO BIODIVERSITY CORRIDOR STUDY-CASE

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Background

The Pantanal is a 140,000 km² south American central floodplain surrounded by a highland belt of Cerrado (Appendix). Recent literature compilation reveals the floodplain harbors at least 3,500 species of plants, 325 fishes, 463 birds, 124 mammals, 177 reptiles, and 41 amphibians (Harris et al. 2005). It has extremely high densities of several large vertebrate species that are unsurpassed anywhere on the South American continent, such as hyacinth macaw, giant river otter, marsh deer, tapir, and bush dog, all of them are globally threatened species. Brazil share the Pantanal wetlands with Bolivia (12,5%) and Paraguay (5%) and effective conservation planning and actions must be implemented in collaborative efforts among them, including governments, NGOs and stakeholders from these three countries. The main ecological factor determining patterns and processes in floodplains such as the Pantanal is the periodic flooding, or flooding pulse (Hamilton et al. 1996; Junk et al. 1989; Junk & Da Silva 1996; Oliveira & Calheiros 2000; Tomas et al. 2001). The annual flooding pulse in the Pantanal is relatively predictable and corresponds to an annual hydrological cycle (Junk & Da Silva 1996), with amplitudes from 2 to 5 m. However, this flooding regime is not uniform in space or time: whereas some areas are permanently inundated, others have a relatively short flooding period. In some transitional areas, the flooding period may be longer than four months. In some areas with occurrence of Cerrado vegetation, the flooding may be due solely to rainfall and poor drainage, with no influence of river overflow.

The Serra de Maracaju-Negro River Biodiversity Corridor is located in the eastern part of the Pantanal region, on the border between floodplain and plateau areas in the Upper Paraguay River Basin (UPRB) (Appendix). This corridor has close to 3.17 million ha and includes 10 municipalities territories in Mato Grosso do Sul state (Corumbá, Rio Verde de Mato Grosso, Rio Negro, Corguinho, Aquidauana, Terenos, Bandeirantes, São Gabriel do Oeste, Rochedo, and Dois Irmãos do Buriti), but it has just four towns (Aquidauana, Corguinho, Rio Negro e Rochedo). The population of all of these 10 municipalities is around 223,000 inhabitants, and the main human activities are cattle ranching and agriculture. Deforestation is the main threat to biodiversity conservation in this area (Figure 1). Some municipalities such as São Gabriel do Oeste and Corguinho have already cleared more than 70 percent of their territories (Harris et al. 2006). Human pressure is extensive on the borders of this corridor and in some parts of the floodplain (Harris et al. 2005). Large deforested areas can compromise the Pantanal's natural flood pulse, and the important role the Negro River plays to maintain its natural dynamic.

Biological Context

The Maracaju-Negro Biodiversity Corridor is located in the central region of Mato Grosso do Sul, with its major portion located in the Negro River hydrographic basin, one of the regions with the best conservation

status in the Pantanal plains (Figure 1). Most of this Corridor is found in the Pantanal region known as Nhecolândia, whose most evident hydrographic characteristic is the presence of thousands of lakes known as bays and salines. Because of this lake system, Nhecolândia is often considered one of the most beautiful regions in the Pantanal (Figure 2).

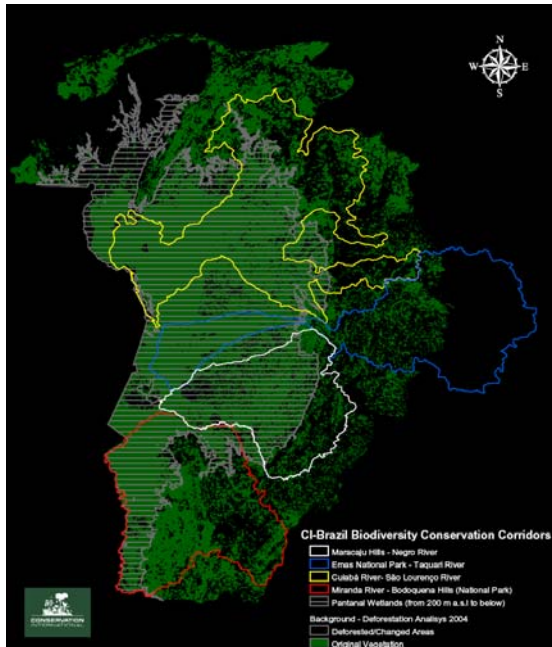


Figure 1. Deforested areas happened up to 2004 in the Upper Paraguay River Basin and Pantanal floodplain (see Harris et al. 2006) and conservation biodiversity corridor of CI-Brazil, Pantanal Program.



Figure 2. Overview from Pantanal of Nhecolândia, which regional landscape is represented partially in the Serra de Maracaju-Negro River Biodiversity Corridor, Brazil.

The Negro River, the main river in the Corridor, flows for approximately 530 Km, with its headwaters located in the Maracaju Mountains (*Serra*) at an altitude of about 400 m. Along its upper reaches, it presents characteristics typical of tableland rivers, such as bedrock and a great amount of falls and rapids. But when it enters the Pantanal plains, it forms wide swampy areas, a pattern that is repeated in some of its main tributaries, such as the Taboco and Vermelho rivers.

Most of this region is flooded at the beginning of the rainy season by the Taquari River, whose waters flow southwest into the Negro River (PCBAP 1997). However, the Negro River's flood is delayed and prolongs the period of flooding; it may also cause the so-called "re-inundation," known as a "backwater effect." Aside from the typical complex hydrological system of this Corridor, other landscapes can be found in the region, ranging from savannas and grasslands to semi-deciduous forests, especially in the upper reaches of rivers that spring from the higher parts of the Maracaju Range and in the tablelands.

The biodiversity of the Maracaju-Negro River Corridor is the most studied in the Pantanal. Several research projects have been conducted at Fazenda Rio Negro private reserve and at neighboring farms, which, together with the State

Park of Rio Negro Pantanal, comprise the core region of this corridor. Although there is great diversity of landscapes and environmental complexity in the area, wildlife diversity and endemism are not particularly high. Nevertheless, the region does contain several important threatened species, in particular relatively large and healthy populations of the giant otter *Pteronura brasiliensis*, hyacinth macaw *Anodorhynchus hyacinthinus*, and the threatened jaguar *Panthera onca*. More than 60 percent of all species registered for the Upper Paraguay River Basin are from this corridor (1,671 registers). Of the 21 (globally and nationally) threatened vertebrate (mammals and birds) species found in the Maracaju-Negro Corridor, six were exclusive to it (*Leopardus tigrinus*, *Chiroderma doriae*, *Clyomys bishop*, *Polystictus pectoralis*, *Alectrurus tricolor*, and *Oryzoborus maximiliani*).

Institutional Context

There are many institutions working in the region of the Maracaju-Negro Biodiversity Corridor, such as organizations connected to the municipal and state governments, NGOs, landowner associations, and educational, research, and extension institutions.

Acquired information for the CI-Brazil's work in this region was made possible by partnerships with different educational and research institutions, such as EMBRAPA/Pantanal, EMBRAPA/Beef Cattle, UFMS (Campo Grande, Corumbá and Aquidauana Campi), and Earthwatch Institute, as well as NGOs such as the Forpus Institute, Manoel de Barros Foundation (FMB), and the Foundation to Support the Educational Development of Mato Grosso do Sul (FADEMS). These partners in the Corridor played a fundamental role in consolidating and obtaining results. The presence of the UFMS campus in Aquidauana is important institutionally, because its undergraduate courses in Biology and Geography and Master's programs in these areas have supported much research in subjects related to Ecology and Conservation.

Information produced by part of the studies developed in the region, combined with an analysis of data on municipalities' multi-temporal deforestation, was used to support a regional environmental program. Two actions provided the basis for this project: 1) support for the creation and implementation of private or public CUs (Conservation Units); and 2) reclamation of Permanent Preservation Areas (APP). The first is being done through support for the creation and management of private reserves, in partnership with the Association of Private Reserve Owners of Mato Grosso do Sul (REPAMS). Besides contributing to creating and strengthening the association, the project envisages technical and financial support for creating other reserves and managing existing ones. CI-Brazil, in partnership with the Environment State Secretariat of Mato Grosso do Sul (SEMA-MS), supported the creation and contributed to the implementation and management of Pantanal Rio Negro State Park, the Corridor's largest public protected area.

Socioeconomic Context

Cattle's breeding is the main economic activity in the region, both in the lowlands and on the plateau. In the plateau region, part of the productive land is also used for monoculture, mainly soybean and corn. Some companies are involved in agribusiness, such as slaughterhouses, meat packing plants, dairy plants, and tanneries. Commerce and industry sectors depend a lot on these activities, and fluctuations in agribusiness have a direct impact on the economy of the region. In Aquidauana, there is an iron ore smelter, to which part of the coal produced in the region is sold, and which has suffered lawsuits due to licenses and environmental control problems. In Corumbá, there is also a manganese factory, and other entrepreneurs are planning an expansion of this activity.

Deforestation has become a constant threat to biodiversity, and in the majority of cases is associated with the expansion of cattle breeding and agriculture areas, sometimes with severe consequences to the natural environment. But now deforestation is a critical problem within the floodplain itself. More than 40% of the forest and savanna habitats at Upper Paraguay River Basin (UPRB) have been altered for cattle ranching through the introduction of exotic grasses, 17% in the floodplain and 63% in the surrounding cerrados tablelands (Harris, et al. 2006). Although the Pantanal wetland is a Biosphere Reserve and is considered a Wetland of International Importance, only 2.5% of the UPRB is formally protected. Inadequate soil management practices, the non-observance of environmental laws regarding licenses for some activities, and the lack of protection for Permanent Preservation Areas, often cause erosion and siltation of watercourses, both with particulate material and agrochemicals. Biological contamination due to the introduction of invasive exotic species, such as those belonging to *Brachiaria* genus, is another impact originating from cattle breeding activity.

More recently, the creation of various charcoal camps in the region has caused great concern, especially because of the association of this activity with the opening of pasture and monoculture areas. The lack of control and supervision of the activity and the increase of the demand for charcoal in the internal markets of Mato Grosso do Sul and other states have been identified as the main causes for the increase of charcoal exploration in the region, with various impacts on the local biodiversity. However, the good news is that, at least for this corridor, many landowners are concerned about preserving this region.

Serra de Maracaju-Negro River Biodiversity Corridor as a study case for Learning Initiative on Hydrological Process

CI's work over the past five years has focused on designing the Corridor and has included the following activities: biological assessments, threat assessments, development of monitoring capacity, creation of a Corridor information system and assistance to planners, engagement of stakeholders in managing the landscape to connect the corridor, and the development of educational and communication initiatives that create awareness and generate support for Corridor operations and policies. In a very appropriated and theory-based way, the key biodiversity areas (KBAs) delineation has been done lying hydrological sub-basin boundaries, which localities where global threatened species were registered. Therefore, the corridor approach is currently incorporating this design in order to be more comprehensive in terms of analysis and more effective in implementing conservation actions.

In a first moment, the challenge of Learning Initiative in this study case has been integrate CI's biological targets as global threatened species and protected areas with hydrologic cycles features of the Serra de Maracaju-Negro Corridor, responsible for the high productivity still encountered in the region but highly threatened by the current alterations of hydrological cycles in the Rio Negro watershed. By gathering data on the hydrological cycle using modeling tools, the first aim of this initiative was identify priority areas within the Corridor to maintain flooding cycles and its water pulse and to integrate these information to biodiversity and socioeconomic data to refine the Corridor strategy and KBA effectiveness. The choice for the Marajacu-Negro Biodiversity Corridor is due it remains as one of the most intact areas in whole Pantanal wetlands. There is an important ecological gradient in this corridor, linking Cerrado and Pantanal biomes, with the first one starting in eastern which highlands rich soils plateau with several savanna forest types, following a decreasing altitudinal smooth variation till reaches the flooding plain where vegetation and geomorphological traits are completely different. This linkage is crucial for ecological integrity of whole Pantanal system. To reach the goal, several organization and expertise's' centers were invited to participate in workshops, which some results were positively incorporated here, for example, annual precipitation and water demand by humans and animals.

To meet the objectives of this Learning Initiative, two workshops was taken in place in order share experiences among experts on integrating and analyzing biodiversity, hydrological process and socioeconomic data. A brief summary of the shared ideas, discussions and experiences during the workshops are given below, specially the most applied procedures into CI's way of work.

Lessons learned though the accomplished workshops in order to improve de corridor management approach

Local, regional and global partners were represented (see detailed information in the respective report) by their high level experts. Consequently, long and productive discussions came up during the workshop days. Find below a synthesis of the main presentations, which are the most aligned with CI's outcomes.

Integrating biological targets and hydrological processes - 21 to 25 April, 2006 – Fazenda Rio Negro (CI-Brasil), Aquidauana, MS, Brazil

- Among the shared experiences, the conservation systematic planning in landscape scale exposed by Christopher Margules (CSIRO) was very innovative and elucidative, in terms of how to be assertive for allocating scarce resources in high priority areas for conservation biodiversity. Using and implementing a well-structured framework, gaps can be filled by: biodiversity relative measures (surrogates), setting clear outcomes, targets and objectives and the development of flexible tools for implementing them, considering

the costs trade-offs and other spatial constraints. Biodiversity surrogates (sub-sets of species, species assemblages and environmental classes - vegetation types, environmental domains) or surrogate combinations (e.g. environmental domains, vegetation types, threatened and rare species - Papua New Guinea - and; critically endangered species, ecological communities and ecosystems processes - Bay Milne Province) must be used with the bests available datasets. Anyway, the greatest challenge is to achieve the same level of biodiversity representation with lower social impact (fewer people) in almost the same total area. Related to opportunity cost trade-offs, some priority areas for conservation may be deselected if cost trade-off is too high, using systematic planning methods to identify areas that could be used for industrial complexes, urban development, etc., defined in multi-criteria analysis, finding out sustainable development levels for both environment and livelihoods. David Mitchel (CI-Papua New Guinea) presented the Milne Bay Province Planning Outcomes Experience where all these steps showed by Margules have been taken in place thought a joint initiative between CI-Papua New Guinea, CSIRO and CI/CBC-Melanesia.

- Another important experience was presented by David Harrison and Karin Krchnak (TNC) who is concerned with freshwater biodiversity conservation. Freshwater ecoregions drainage systems are defined by patterns of biotic composition at a continental scale, usually based on biogeography of fishes. Second Harrison, this ecosystem approach fits targets better than species, because little reliable information is available for species. The ecoregional perspective offers comprehensive information about targets and threats. The main goal is not to create optimal conditions for all species all of the time, rather, they want to create adequate conditions for all native species enough of the time. Some methods and models have been developed to analyze alternative flows and limits of hydrological alteration.
- Methods for defining important sites of freshwater biodiversity was presented by Anna McIvor (SSC/IUCN - Freshwater Biodiversity Assessment Programme) in order to show how to assess the distribution and status of freshwater species, using the IUCN Red List criteria for identifying important sites of freshwater biodiversity and investigating the links between biodiversity and livelihoods. The basic method is based on the same set of criteria of Important Bird Areas and Key Biodiversity Areas (IBAs/KBAs), e.g., threatened species (1st), for restricted range species (2nd), biome restricted species (3rd) and life history stage and/or congregatory species (4th), which threshold or combinations must be evaluated as available data and tested.
- Brian Smith presented a very interesting natural history study of dolphins of Ganges-Brahmaputra-Meghna river system, suggesting that knowledge of habitat selection and the potential effects of declining freshwater supplies should be incorporated into the design of protected area networks for aquatic biodiversity. In the same way, Sustainable Management of the North Rupununi Wetlands was presented by Indranee Roopsind (Iwokrama Forest) and Curtis Bernard (CI-Guianas), and Mamberamo Basin Study-Case was presented by Nev Kemp (CI-Indonesia).
- Based on the affirmation that hydrology is probably the single most important determinant of the establishment and maintenance of specific types of wetland processes, and that an understanding of rudimentary hydrology should be in the repertoire of any wetland scientist, Ward Hagemeyer (Wetlands International, Netherlands) presented the technical aspects that must be studied to reach a well-knowledge of any wetland. Second Hagemeyer, sites can be defined through its importance for specific species, based on their occurrence, but as hydrology drives many of the processes and abiotic factors which in turn create the local conditions for the species. The conclusion is that whole ecosystem, with all its functions and services depends on the abundance and quality of water, on hydrological processes, and to understand how to manage this system and the impact of alterations in the system for biodiversity, it is necessary to integrate the requirements of all stakeholders and a socioeconomic valuation of ecosystem services needed to be a partner in the planning process.
- Chaman Trisal and Ritesh Kumar (Wetlands International, India) showed their experienced with the Loktak Lake where a preliminary socioeconomic assessment has been incorporate in the biodiversity and hydrological integrative study already well done and where a management action plan for is being implemented.

Integrating biodiversity, hydrological processes and socioeconomic analyses for conservation actions - 12 to 15 March, 2007 – Chilika Lake, Bhubaneswar, India.

- Robert Smith (DICE/University of Kent) presented the conceptual framework and the use of softwares Marxan and CLUZ for incorporating socioeconomic costs into a systematic conservation planning, using the Maputaland, Africa as a applied study.
- Chris Baker (Wetlands International) showed the decision making analysis for development and biodiversity in the Inner Niger Delta, where cost effectiveness scenarios were modelled to show the economic gains versus conservation gains in building dams.
- Frederieke Kroon (for Chris Margules/CSIRO) presented the landscapes toolkit for the Great Barrier Reef Lagoon, where a consortia has been implemented to halt and reverse the decline in water quality entering the reef within 10 years and to reduce diffuse sources of pollutants into the reef through implementation of sustainable land management practices and better land use decisions. They believe the rehabilitation and conservation of areas of the reef catchment have a role in removing water borne pollutants. Development of a 'Landscapes Toolkit' is allowing the spatially explicit assessment of the impacts of land use and management change on social, environmental and economic values.
- David Mitchell and Hugo Mamberano (both from CI) presented the trade offs against KBAs protection. Currently they are estimating the percentage of protected areas and KBAs needed to conserve still living endangered species and to maintain key eco-hydrological processes. Present patterns and acceptable hydrological changes are being investigating in order to safeguard species, habitats and the livelihoods of communities.
- Larry Gorenflo (CI Headquarter) presented the case for collaboration for freshwater development and biodiversity conservation around the world. The greatest challenge is conserving biodiversity in areas of poor human conditions and he provided examples where human engagement and conservation investments can contribute to reduce poverty.
- The Wula Lake, Kashmir case study was presented by Chaman Trisal and Ritesh Kumar (Wetlands International, India) where also the most challenge is biodiversity in areas of poor human conditions, mainly in areas where water and its associated biodiversity is by far the most crucial resource.
- Festo Semanini (WCS – Tanzania, Africa) – presented the Ruaha Study-Case and showed that development assistance without direction is being carrying out and feeding serious human problems in Tanzania.

Introducing workshop insights into Serra de Maracaju-Negro River Biodiversity Corridor study case

The main objective is to refine the biodiversity corridor approach for wetlands areas thought inserting hydrological dynamics analysis, which are crucial for wetland-dependent species. Thus, the project needs to make the following steps:

1. Identify key areas to maintain hydrological integrity in the Corridor;
2. Identify priority areas for biodiversity conservation (dry areas functioning as refugia for terrestrial fauna);
3. Develop a planning tool to be applied in other Corridors in the Pantanal and in others wetlands where CI works;
4. Gather data on the most important abiotic features of the Pantanal - the water regime.

Technical approach

The technical approach has been determined in collaboration with experts from partner organizations like Wetlands International, The Nature Conservancy and others workshop attendants. This has been a joint effort between CI-Brasil Pantanal team and CI-DC Protected Areas and Corridor Planning Support.

Deliverables

Effective integration of hydrological processes into Corridor design and protected areas network.

Finally, the proposal should clearly identify the Deliverables. These should include:

- a key component of the broad-scale conservation planning process completed;
- recommendations of the analysis and planning process implemented;
- a detailed write-up of the analytical process produced, including specific recommendations for future application of the technical approach.

The major challenges for conserving the Cerrado and Pantanal regions is to find socioeconomic models that allow for conservation and economic uses of the land in association with the development of specific environmental legislation, adapted to the unique characteristics of these regions. As the Pantanal biodiversity and hydrological cycles are highly dependent on the integrity of upstream Cerrado habitats, that harbor the headwaters of the large tributaries of the UPRB, large scale conservation approaches are crucial for biodiversity persistence in the Cerrado/Pantanal contact region. In a local context, biases due different sampling efforts, lack of biological inventories in large and hard-access area, and the lack of knowledge of ecological requirements of species are the most difficulties. Thereby, the questions we have in mind before the first workshop accomplishment were:

- How hydrological processes affect species behavior and its area of occurrence in order to help the KBAs delineation and to support right decisions to propose creation of protected areas?
- What is the feasible scale and methods in order to promote a right temporal data collection to do the appropriated analysis?
- Will more clear patterns be seen if new variables are considered (vegetation, flood data, etc.)?
- What are the suitable variables that can be used to describe habitat requirements for terrestrial species? And for aquatic species?
- Records collected in a non systematic way can be used to link species occurrences with environment variables?

Thereafter, some helpful abiotic information was gather on Serra de Maracaju-Negro River corridor as it has high and fast runoff, low infiltration (rocky soils), and consequently high drainage density in its surrounding highlands. In the other side, the corridor flooding plain has slow an low runoff, high infiltration (sand soils), and consequently low drainage density (Figure 3). Besides, Negro river sub-basin, as an endorheic one, there is no outflow of water from the watershed, and it acts as a large sinking swamp. For that reason adding the fact of having such poor soils (alluvial sand soils), this sub-basin is poorly studied and it isn't priority for governmental water monitoring programs, mainly due the impossibility of livelihood transportation.

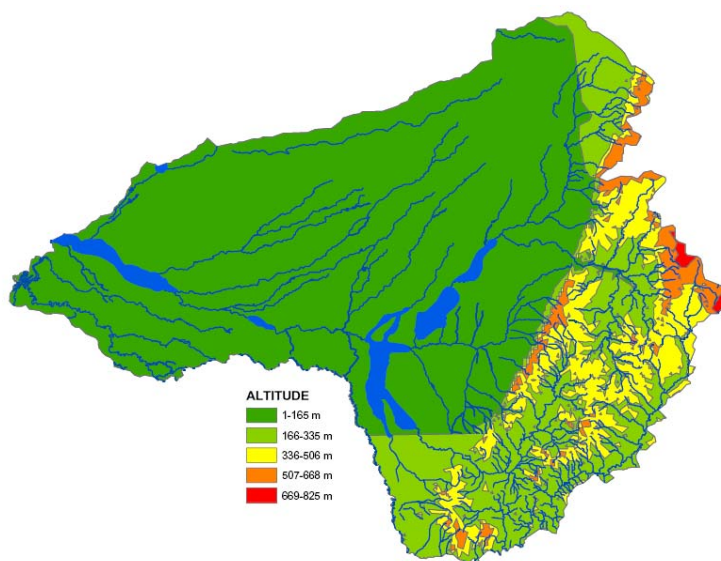


Figure 3. Rivers, permanent flooded areas and altitude classes in the Serra de Maracaju-Negro River Biodiversity Corridor, Pantanal wetlands, Brazil.

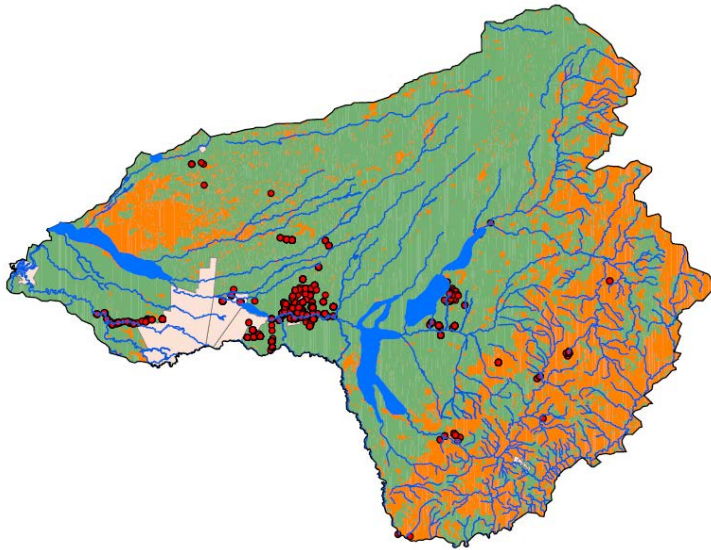


Figure 4. Threatened species point records (21 species), protected areas (11 - 160.936,00 hectares – 4,4% of corridor) and remained original vegetation (68,5 %) of total area of Serra de Maracaju-Negro River Biodiversity Corridor, Pantanal wetlands, Brazil.

The temperature and precipitation data obtained from WorldClim site, the overall database of Maracaju-Negro corridor gathered by CI-Brazil/Pantanal Program staff is illustrated in Figure 4. Besides, a preliminary first steps of systematic conservation planning has been outlined (Figures 5, 6, 7, 8), using 10K ha as planning units (not sub-basin yet for a preliminary assessment), for early data, plus opportunity costs (Figure 5A), primary productivity growth (Figure 5B), headsprings (meaning important recharge catchments areas – Figure 5C) and irreplaceability (Figure 5D).

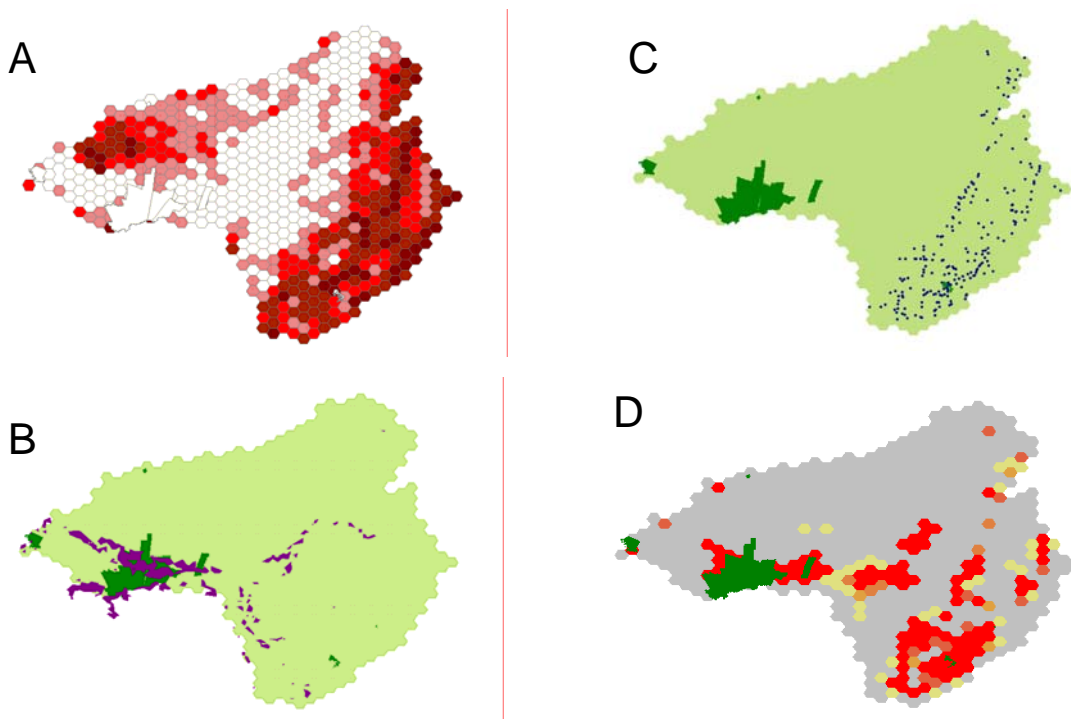


Figure 5. Spatial database of performed preliminary gap analysis for Serra de Maracaju-Negro River Biodiversity Corridor. Pantanal wetlands, Brazil. Spatial data (10K ha cells) for opportunity costs (A), primary productivity growth (B), headsprings (C) and irreplaceability (D).

The performed preliminary gap analysis revealed that only 10% of threatened species quantitative targets were fulfilled, 52% are partially protected and 38% are non-protected.

Methods

Biological data for this proposal was those from globally threatened species, which means the preliminary identification of key biodiversity areas (KBAs). Water data was obtained from WorldClim (www.worldclim.org), clipping annual and seasonal precipitation for Maracaju-Negro Biodiversity Corridor. Therefore, social and economic data was obtained through governmental data available in internet, such as those for counties (municipalities' extent, population densities, human development indexes, livelihoods, types of industries and others economic activities). Further analysis will be performed through mapping of past and present land use to identify opportunities and threats to contribute for Corridor design and priority areas identification and delineation.

Work in Progress

Climate and Hydrological Data

As data gathered from WorldClim and considering 1 mm of rain/year meaning 1 liter/m² or 1 liter/0.0001 ha, the annual mean precipitation is more than 250.000 GLiters in this corridor. A little more than a half of this amount drops in corridor highlands, while the rest drops down in the flooding plain portion of the corridor.

Socioeconomic Data

Official available data reveals that ca. 80,700 inhabitants are currently living in the Maracaju-Negro Corridor area. In spite of plantation is not too significant (banana, sugar-cane, soy, corn, manioc, fruits), the cattle ranching reaches 1.8 billions of heads, representing ca. 22 cattle-heads per inhabitant. Cattle are responsible for ca. 90% of total water demand for both humans themselves and its livelihoods in the corridor. If it a mean of 120 L and 60 L amount of water demanded everyday by human and cattle is respectively considered, there is a deficit of about 315 GLiters in the inflow/outflow water balance during the dry season. It means the aquifers' water is required periodically, without a clear understanding about its effects on the next season, which fluctuates 'naturally'.

Next Analytical Steps

We will perform analysis on landuse expansion and economic tendencies to build future and alternatives scenarios through multi-criteria analysis as set up by systematic conservation planning (Margules & Pressey 2000), taking into account the spatial distribution of biological and hydrological data on areas that support critical ecological processes – threatened species, protected areas, watersheds, rivers, mangroves – and their vulnerability to planned development. The alternatives zones will be useful to negotiate with local and regional stakeholders, synthesizing and delivering information in formats relevant to local stakeholders, regional and national decision-makers.

Conservation Perspectives

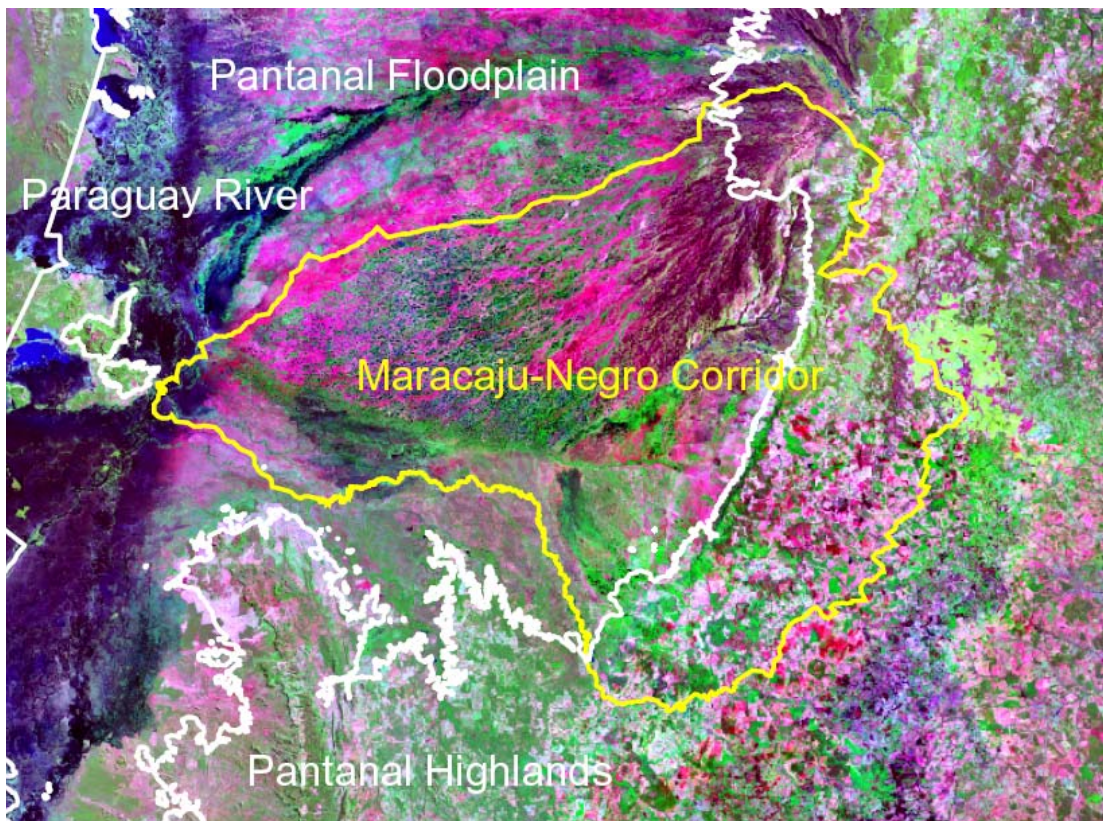
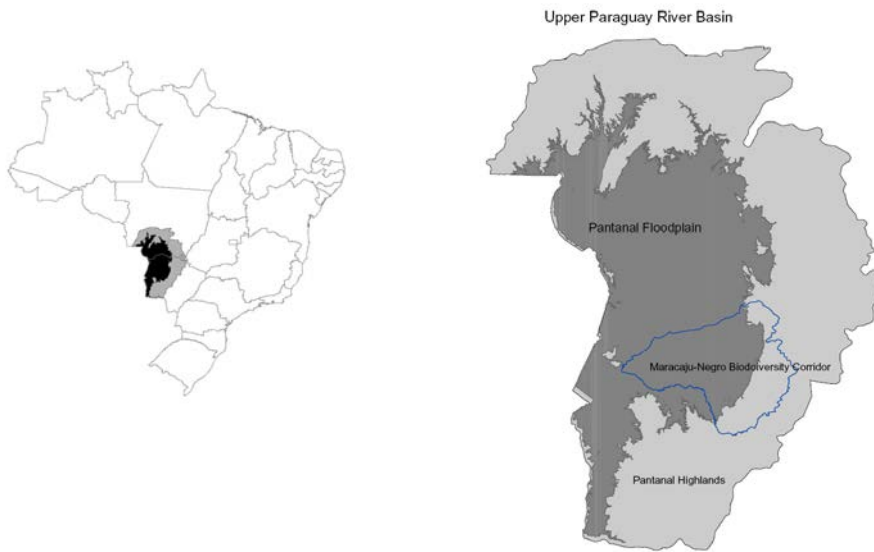
With this project we intend to take key areas (KBAs and catchments for water recharges) in a local system of protected areas. The approaches of representativity and complementarity will be useful in identifying and protecting those species and environments poorly included in the current set of protected areas. CI and local partners will conduct biological surveys and analyze spatial patterns of natural ecosystem distribution in order to promote a regional gap and multi-criteria analysis for further scientific studies on biodiversity and negotiation with stakeholders, respectively. CI will actively monitor the project's progress for a systematic adaptive management process that is both flexible and driven by science, that will strength partnerships and will focus on the connections among biodiversity conservation, hydro-ecological processes and human welfare.

Future actions demand for systematic conservation planning of corridor

- Implement good hydrological features monitoring network to build a flow modeling, hydrograms and permanence curves and to compare it with other well-know UPRB sub-basin in hydrological matters (Taquari River sub-basin, a human deep-explored one, for example);
- Monitor official data about cattle ranching and demography in both cities and rural areas (real densities) and its respective real and seasonal water consumption;
- Continue monitoring water quality (in partnership with EMBRAPA) at Rio Negro sub-basin;
- Monitor pollution (though heavy metal accumulated at caiman bodies?);
- Monitor water and habitat requirements directly related to biodiversity (fishes, giant otters, high primary productivity areas, etc.);
- Influence stakeholders to build and implement water resources policy;
- Build a better understanding about water input and human use with the water monitoring;
- Create a method to quantify water output through artesian wells used for agriculture and cattle ranching.
- Improve investigations on ecological needs of area demanding species, supporting inventories in knowledge gap areas and checking target species current occurrence in the field and testing models generated by the spatial and multi-criteria analysis.

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Appendix. Localization of Upper Paraguay River Basin which includes the Pantanal wetlands (white-line delimited), highlands and Maracaju-Negro Biodiversity Corridor (yellow-line delimited), state of Mato Grosso do Sul, Brazil.

2. Mamberamo Biodiversity Corridor, Papua, Indonesia

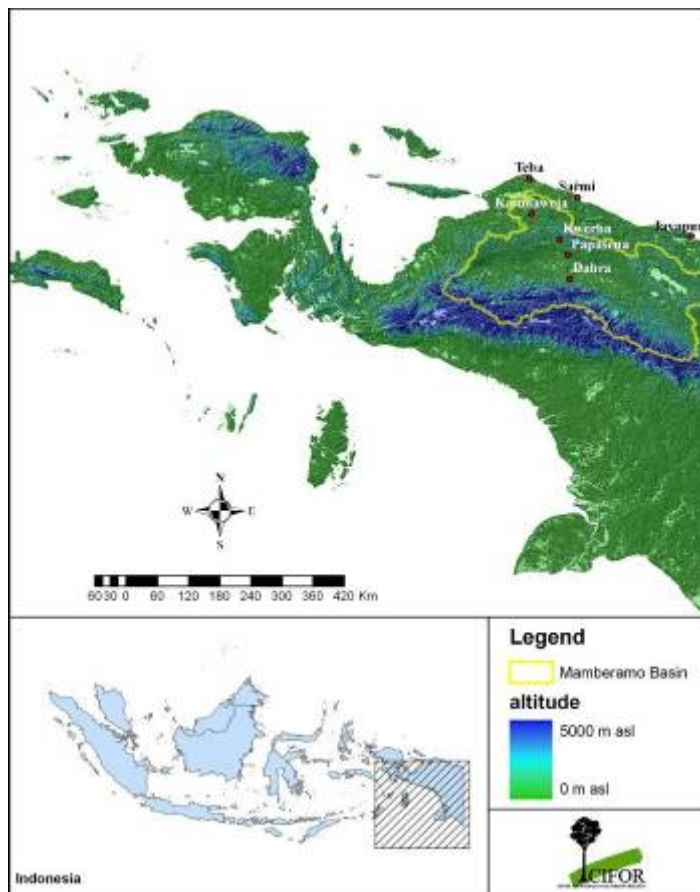
COMMUNITY BASED ASSESSMENT OF HYDRO-ECOLOGICAL PROCESSES AND ITS INTEGRATION INTO CONSERVATION PLANNING IN THE MAMBERAMO BIODIVERSITY CORRIDOR, INDONESIA

Neville Kemp, Hugo Yoteni
CI Indonesia, Mamberamo Program

1. Introduction to the hydro-ecological Work in Mamberamo

1.1. Background

Papua is Indonesia's largest and least populated province. Three million people live in an area of around 42 million ha, of which 80% is still forested (BAPLAN, 2002). This is equal to approximately 35 million ha of original forest cover intact (FWI, 2004).



The Mamberamo Biodiversity Conservation Corridor Program of the Conservation International (CI) in Papua recognizes that large-scale conservation is essential for the long-term survival of rich biodiversity and while networks of conservation management areas are the most effective strategy for preventing species extinctions in the near-term. The long-term persistence of both threatened species and sites will also depend on the maintenance of *critical ecological processes* at the landscape level. Landscape scale conservation is especially relevant to the Mamberamo region which contains a large number of wide-ranging, low-density, threatened species that cannot be effectively conserved and managed at the site scale.

One of the most crucial biophysical processes at landscape scale in the region is *eco-hydrology* and also one of the most complex. These processes are though unique in the case of the Mamberamo since the vast flat region of the basin may be influenced by and particularly sensitive to a complex flooding and sedimentation regimes. The maintenance of habitats and species is thought to be determinant of these regimes, and hence the livelihoods of people as hunters and gatherers may be potentially greatly affected.

In addition change in land-use will have an affect on these processes, however, the areas that are at most risk from potential changes in eco-hydrological regimes are those outside rather than inside the Mamberamo Basin. This is due to the sparse population pressure compared to the highlands as well as natural resources-based development plans in those areas (which include road construction, extractive industries (logging and some small scale mining concessions), and large-scale plantations in the uplands of the Mamberamo. These human-induced activities should take into account the environmental and social consequences, which to large extent irreversible.

1.2. Objectives of the Community based assessment of Hydro-ecological Processes

Integration of hydrological processes into conservation planning at the landscape scale and the maintenance of critical hydrological processes for sustainable landscape conservation planning highlights a number of questions, primary

- How do changes in hydrological processes impact on globally threatened species and/ or KBAs and the ecosystem services (to communities) they provide?, and
- How do we map and quantify hydrological processes and patterns and identify clear targets or thresholds for hydrological processes to ensure the persistence of globally threatened species, KBAs, and the ecosystem services they provide?

In order to understand more about how the eco-hydrological processes affect species (especially threatened and restricted range species), habitats and socio-economic livelihoods that these species and habitats support in the Mamberamo lowlands, a community based assessment of hydro-ecological processes was part of a month long assessment of local knowledge combined with field observation was carried out (to answer question 1 above).

The survey used Multidisciplinary Landscape Assessments type methodologies to study indigenous knowledge, and was designed to document preliminary information about the benefits communities derive from the maintenance of hydro-ecological processes for socio-economically important species and habitats in the Mamberamo. This information is essential background data that can support *specific corridor scale targets* decisions for landscape conservation within the Mamberamo Biodiversity Conservation Corridor when combined with a rapid technical study and profile assessment of the biophysical variables of Eco-hydrological processes (to answer question 2 above – but not reported on here as still in progress). These targets will ultimately aim at setting targets of habitats that must be conserved or managed sensitively to ensure the hydrological status quo, and continue to support species and sites of importance.

By addressing these questions, the work provides guidelines for the specific issues that affect policy and spatial planning in the Mamberamo - How do we integrate hydrological information with biodiversity and socioeconomic data to support the design of effective conservation strategies at the landscape scale and how do we integrate these conservation strategies in sustainable development planning?, and how do we value the biodiversity and ecological benefits of functioning hydrological processes to the wider economy and society, in order to influence policy?

1.3. Specific aims

Working with communities to ascertain indigenous knowledge about specific attributes required testing hypotheses in order to focus discussions. The follow were tested -

1. Seasonal fluctuations in hydrological processes significantly influence the distribution, composition and population of aquatic and swamp forest species for the benefit of local population
2. Seasonal fluctuations in hydrological processes significantly influence the distribution, composition and extent of socio-economic important habitats.
3. An increase in the degradation of upstream habitats will affect the distribution, composition and population of aquatic and swamp forest species.
4. An increase in the degradation of upstream habitats will affect the distribution, composition and extent of socio-economic important habitats.

2. Overview of Mamberamo

2.1. Geography, Geology and Lithology

The geography of the Mamberamo region is unique. With a total catchment area of about 7.7 million hectares (the largest in Papua province) over 90% undisturbed, and dominated by a vast flat inland ‘Lakes-Plains’ basin or depression with many natural lakes, surrounded on all sides by high and steep hills and mountains. The Lakes-Plains depression and surrounding mountains have been formed by a complex geologic history with plate tectonic movement of New Guinea, Australia and the Pacific regions (see Hall 2002). The elevation of the basin ranges from about 0 m asl in the northern parts of the basin to about 5,000 m asl in the southern part (Figure 1).

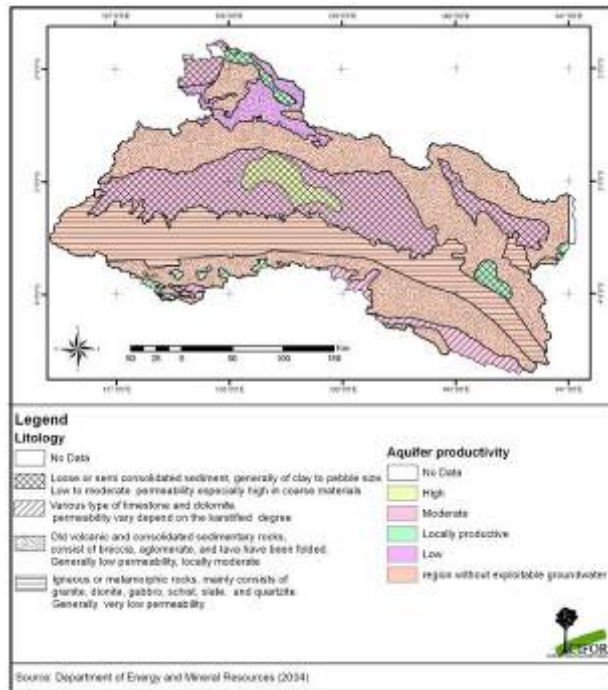


Figure 2. The hydrogeological map of the Mamberamo catchment indicating lithology and aquifer productivity (this map also shows that the aquifer productivity - in most areas of the region the aquifer productivity of the basin is without exploitable groundwater).

The surface geology of the areas comprises resistant, intrusive plutonic and metamorphic rocks surrounded by arenaceous or argillaceous sediments in the Foja Mountains and Van-Rees mountains. The Lakes-Plains depression consists of alluvium and terrace deposits from sedimentary deposits of the Tariku and Taritatu rivers (Petocz, 1989).

The lithology in the basin is dominated by old volcanic and consolidated sedimentary rocks, which is located in the southern and northern part of the basin (Figure 2). This formation where Kwerba sampling site is located has low to moderate permeability, but high in coarse materials. In the middle part of the basin where Papasena is sitting on semi consolidated sediment, which are composed from clay to pebble size with low to moderate permeability. Dabra is located in the igneous or metamorphic rocks, mainly consist of granite, dionite, gabro, schist, and quartzite with very low permeability.

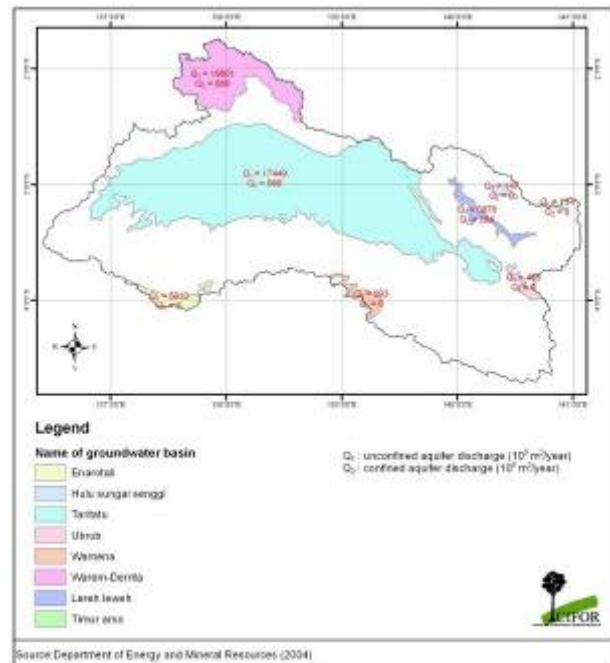


Figure 3. Groundwater basins and their confined and unconfined aquifer discharge of the Mamberamo Basin

2.2. Climate (from draft CIFOR Hydrological assessment of Mamberamo)

The monthly rainfall data recorded from 77 rain gauges within and around the basin (Figure 4) are obtained from the Water Resources Management and Flood Control Project of Papua (Department of Public Works (1997). The period of rainfall record is from 1950 to 1995 with the length of the series data in each station varies from 4 to 40 years. The lowest annual rainfall of about 600 mm was recorded in the northern part of the basin with the gentle topographical condition. The highest annual rainfall of approximately 5,300 mm was recorded in the mountainous

areas in the southern part of the basin. It is an indication that the rainfall formation was very much affected by topography, usually called orographic rainfall. The minimum monthly rainfall of about 220 mm was recorded in October while the maximum monthly rainfall of more than 300 mm in March (Figure 5). Monthly rainfall varies little. Interpolation of rainfall throughout the year is being calculated, but due to the patchiness of the data and lack of rainfall data for large parts of the watershed this should be an approximate guide only to trial hypotheses and assumptions.

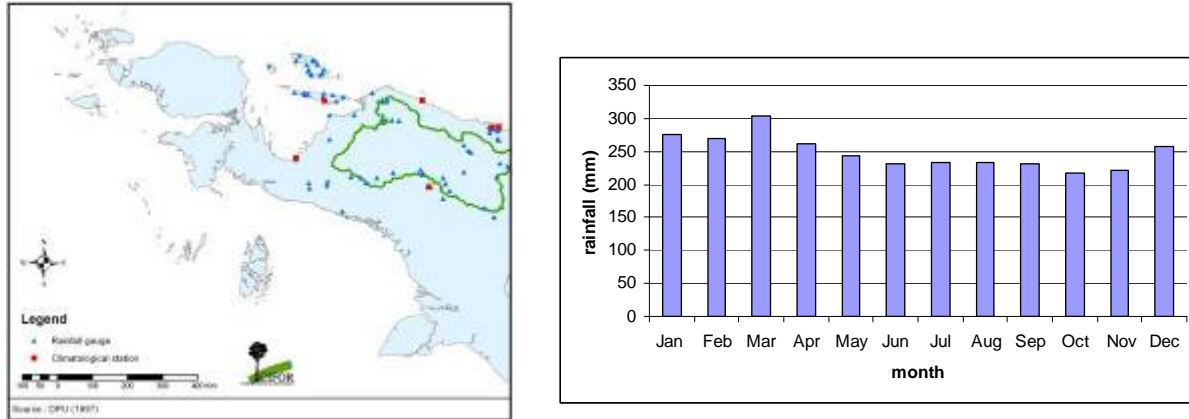


Figure 4. Location of rainfall and climatological stations within and around the Mamberamo Basin.
Figure 5. Mean monthly rainfall (1950 -1990) in the Mamberamo Basin averaged over 77 stations.

Seven climatological stations around the region were maintained by the same project. The temperature data was available for the period of 1971 to 1991. Based on the elevation map, a spatially explicit temperature distribution was generated for the entire basin (Figure 6). Digital data is available.

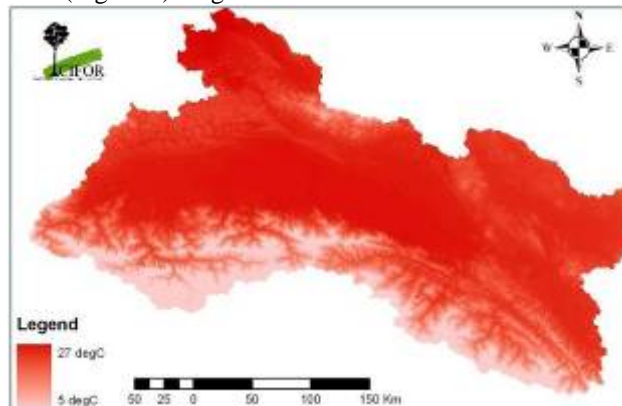


Figure 6. Mean annual temperature distribution in the Mamberamo Basin.

2.3. River systems

The main rivers in the Mamberamo Basin is shaped like a giant inverted “T” with two major branches, the Tariku River (previously known as the Rouffaer River) in the west, flowing eastward and the Taritatu River (previously known as the Idenburg River) in the east, flowing roughly westward. They meet in the Lakes-plains to form the main Mamberamo River (Figure 7). Beyond the confluence of the Tariku and the Taritatu, the Mamberamo turns abruptly northward, flowing for 175 km to the coast at Cape D’Urville on the northeast margin of Cenderawasih Bay. The lower reaches of the river pass through a deep gorge in the Foja/Van Rees mountain chain containing several sets of navigable rapids, the most famous of these being the Batavia Rapids. With a stream flow of 4.50 km/hour, this river can be sailed throughout the year (by ships with up to 30 ton weight) up to 100 km from the river mouth. There are also some lakes such as Rombebai Lake (13,749 ha) in the Lower Mamberamo and Bira Lake in the Middle Mamberamo (8,350 ha).

The upper Tariku branch rises at elevations above 4000 m in the Pegunungan Tengah (Nassau Range), with most of this headwater drainage feeding into rivers that follow the east-west strike of the Derewo Fault Zone. The two most significant of these drainages are the Delo, or Hitalipa, in the west, and the upper Tariku itself in the east; these two

branches meet at a confluence below the rugged peak of Mt. Gulumbulu (4041 m), which marks the ancient boundary between the country of the Moni people to the west and the Dani people to the east. Below this confluence the Tariku flows north through a gorge for approximately 50 km, then turns east as it enters the Lakes-Plains depression, where it receives several large tributaries from its southern bank, including the Van Daalen and Swart Rivers in its final 125 km before joining the Taritatu (CI, 2000).

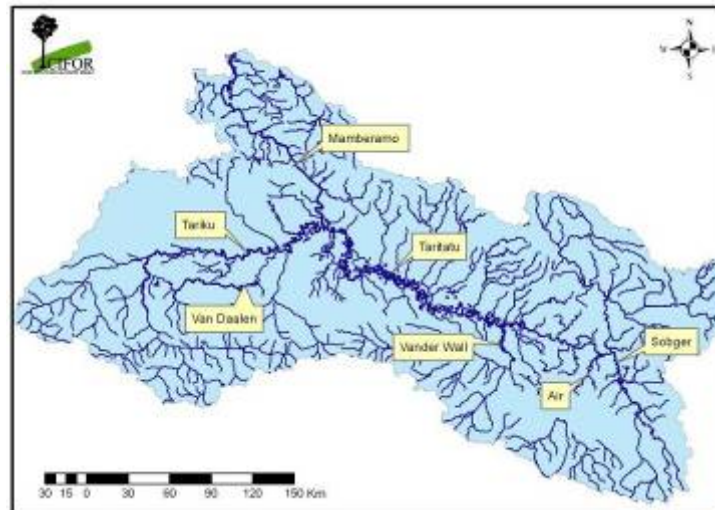


Figure 7. River systems in the Mamberamo Basin with inverted “T-shape” of the main rivers of the Tariku, the Taritatu and the Mamberamo

The Taritatu River rises in poorly mapped country north of Puncak Mandala (4700 m), one of the highest peaks in Papua. It is an area of fractured karst topography with many structurally controlled drainages such as the Kloof, Borne and Sobger rivers which form incised, reticulate networks with the main trend of flow toward the northwest. Near the village of Hulu Atas this complex of rivers coalesces with southward flowing drainages from the flanks of the 30 and 60 Mile Hills between Lake Sentani and the Lakes-Plains depression, forming the westward flowing Taritatu River. Beyond Hulu Atas the Taritatu flows across the Lakes-Plains depression in sinuous bends for nearly 200 km, receiving several major south bank tributaries. Most notable is the Van de Wal, which drains the eastern limb of the Derewo Fault Zone and contains Archbold Lake in its upper reaches.

2.4. Vegetation

Outlying mountains of the Foja and Van Rees not connected to the central mountains that form the spine of New Guinea, contain many rare and endemic forms of wildlife and plants. The vast freshwater swamp-forests, lowland and hill forest, and marshes, lakes and rivers contain many globally threatened species with very healthy populations. The land cover in Mamberamo basin is dominated by lowland evergreen rain forest area that covers an area of about 58% of the entire basin (Figure 8). The swamp forest, swamps, swamp brush and water bodies (BAPLAN definitions of vegetation types) is also a significant vegetation type 16.2% coverage within the catchment (over 1.25 million hectare represented).

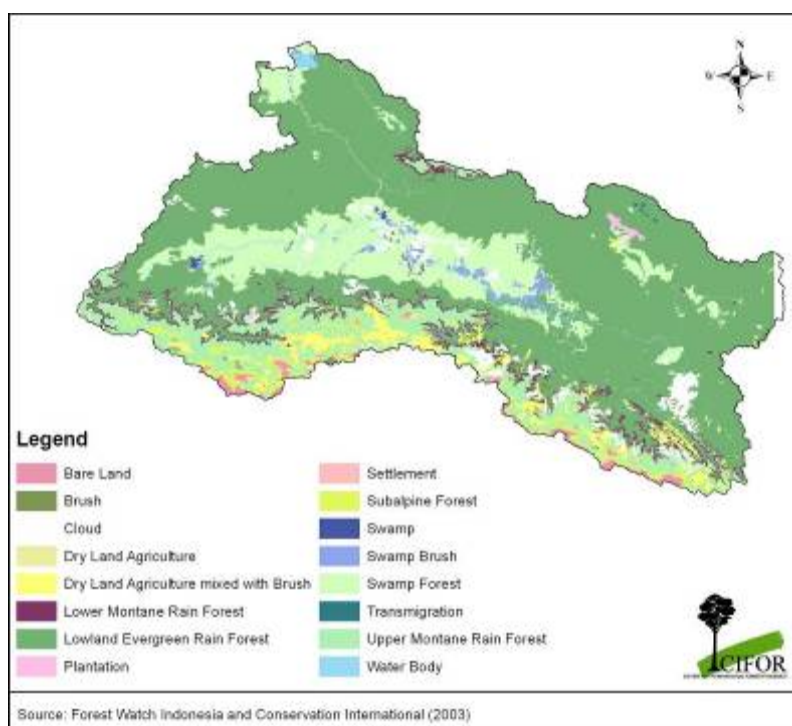


Figure 8. Land cover map of the Mamberamo Basin

2.5. Over view of wildlife and their habitats (focusing of the low lake-plains depression)

Mamberamo was one of the objects of Archbold's famous 1929-30 expedition on which they discovered the Dani people in the Baliem valley. As the expedition used a flying-boat for logistic supplies and aerial exploration, the Mamberamo with its many hundreds of ox-bow lakes and long meandering rivers provided the perfect base camp from which to proceed further into the interior. During this expedition, biological forays were made into the northern slope of the central ranges and in the lower parts of the Mamberamo river.

The Archbold expeditions provided the best information on species that were found in the Mamberamo, which focused mostly on terrestrial mammals and birds, until the 2000 RAP (Rapid Assessment Program) carried out by CI. The program was meant for training purposes carried out in Dabra.

The Mamberamo region supports an incredible 35% of all Papuan avifauna. Among the 250 species recorded in the entire region, at least 11 are endemic and 6 are globally endangered. A total of 13 Birds of Paradise have been recorded (include one species that is heavily associated but not confined to Swamp forest), 11 species of fruit pigeon numerous parrots including Salvadori's Fig-Parrot (*Psittaculirostris salvadori*) (VU) and cassowaries (which are abundant in the area and frequent swamps as one of their preferred habitats).

The Mamberamo Basin has an exceptionally rich herpetofauna. A number of reptile species including the Saltwater Crocodile and the New Guinea Freshwater Crocodile, a giant softshell turtle (*Pelochelys cantori*) and a number of smaller turtles, goannas (*Varanus*) and large snakes have economic or subsistence value for local communities. The basin is home to an extremely rare aquatic snake, the Mamberamo River Watersnake (*Heurnia ventromaculata*), known only from the Mamberamo River system; and is the eastern-most extreme of the range of the spectacular Sail-finned Lizard (*Hydrosaurus amboinensis*).

2.6. Socio-economy

The Mamberamo is very sparsely inhabited with approximately 11,000 people living in the lowlands along major rivers. Due to the remoteness of the region, communities continue subsistence livelihoods and maintain a close attachment to the forest, swamps, lakes and rivers and their natural resources. Education, health and communications are poor. Small scale economic activities do exist but all rely on exploitation of natural resources. Hence, traditional Mamberamo communities live a semi-nomadic life and support their livelihoods through harvesting sago palms, agriculture, fishing and hunting.

In Mamberamo, sago is confined to the swamp areas. Sago is staple food for people in Mamberamo and the area

has the largest stocks of this valuable starch-producing palm in the world. In a conservative estimate, almost pure stands of sago (sago forest) comprise 60,-100,000 ha with the Mamberamo watershed.

Fishing in the rivers and lakes provides a large proportion of protein consumed by communities. Fishing techniques include the use of spears, hook and line, nets, and occasionally poison. The main varieties of fish caught include Fork-tailed Catfish (*Arius uturus*), Carp (*Cyprinus carpio*) and Tilapia (*Oreochromis mossambicus*). Many villagers are starting to extract the swim-bladders of the Fork-tailed Catfish (*Arius* spp) which are sun-dried and sold to traders (use in Chinese medicine) for relatively high prices. This is a new industry, and an exploitative one. It is uncertain whether the stocks of these large New Guinea endemic freshwater fish have started to decline, and populations need to be surveyed in the future. Fishing as an activity to secure protein for consumption is being by economy.

Hunting is also an important livelihood strategy to provide protein. Hunting grounds are usually defined by management decisions about abundance of wildlife stocks and the location of ‘good places’ (that are often connected to flood regime in the basin).

Species hunted include wild pigs, crocodile, cassowary, cuscus and possums, tree kangaroo, bandicoots, large rats, monitor lizards and freshwater turtles. Practically all animal proteins are eaten. Crocodile (*Crocodylus novaeguineae* and *Crocodylus porosus*) hunting for trade started in 1960. Most communities with access to the main Mamberamo river now carry out this economic activity which has become a mainstay of cash income.

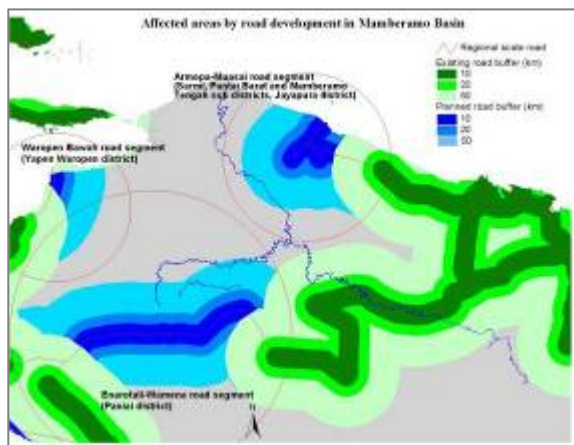
2.7. Regional development activities and plans that will impact the Mamberamo

2.7.1. Mamberamo Mega development project

In 1996, a project termed “Environment, Innovation, and Development (EID) of Intensive Energy Industries” was created for the Mamberamo. The thrust of the envisioned project was to exploit the hydropower potential of the Mamberamo River, estimated at about 10 GW out of the total hydropower potential of 100 GW throughout the entire watershed. The power was planned to be used to meet the needs of the industrial, commercial, residential and all other supporting activities. Sectors to be developed would include metal and mining industries, petrochemical, agricultural, forestry, services, and trade. Study on hydro power plant development and potential capacity (overestimated at 14,000 MW) were carried out which ironically provide much of the climatic and spatial data for this assessment. The potential impact of the proposed development would be catastrophic. All swamps in the Lake-Plains would be inundated, species and habitats lost and communities displaced. However, for the present, this project has since been shelved.

2.7.2. Road construction

Existing and provincial government planned regional-scale roads are illustrated in Figure 9. The provincial and district governments also plan to extend the existing road networks in the future. The government of Sarimi District wishes to pursue a plan to open up the Mamberamo by constructing a road from Kasonaweja over the Van-Rees mountains to Sikari. Due to lack of funds, the government is pursuing a “logs-for-roads” deal where 5km either side of the road is logged in return for road development (1,000 ha forest logged for every 1 km road constructed). This in itself has major implications for conservation in the Mamberamo region. While easier access to the Mamberamo will vastly increase communities’ access to services and markets for some sustainable managed natural resources, there will be negative impacts on biodiversity through exploitation of natural resources. If not well-planned, the development could provide a driver for significant Land-use change and increased threats to biodiversity and



wildlife habitats in the Mamberamo. Loss of habitat due to land clearing, will cause increased erosion, landslides and sediment loads which may have the potential to significantly alter the hydrological processes within the watershed and threaten habitats and species by drying up of inundating potentially large areas of land.

Figure 9. Affected areas by road development in the Mamberamo Basin

2.7.3. *Logging industries*

The only logging concession directly operating with the Mamberamo river catchment is PT. Mamberamo Alas Mandiri (located in Sarmi District). This is the biggest concession in Papua with the total area of 677,310 ha. This logging operation transports lumber by both road and river. Road construction until March 2000 totaled about 61.79 km for main roads and 100.80 km for branch roads. As construction of roads is expensive, rivers play significant role in the transportation of lumber to the sawmill. As the Mamberamo River itself is impassable to large timber barges, the areas logged within the Mamberamo catchment are limited to the lower extremities near the coast, and have not entered the Lakes-Plains depression. However, the government is encouraging a resumption of logging activities in the Mamberamo to develop the road networks into the Mamberamo (described above) which will present an even greater threat to biodiversity and a potential threat to the eco-hydrology of the plains if not managed to minimize impacts.

2.7.4. *Plantation development*

The area with agricultural potential in the region is about 1.2 million ha (1,135,137 ha for rice plantations and 110,126 ha for oil palm plantations surrounding the Rombabei Lake (Sheng , 2003). Low productivity and efficiency, security risks, traditional land tenure, and lack of educated labor force were sited as major constraints to the development of the agricultural sector in the region. Currently, there are two active oil-palm plantations around the area of the Mamberamo Region that belong to PT. Sinar Mas II covering an area of about 23,000 ha in the Mamberamo Corridor.

Transport is the main factor determining whether a plantation is viable or not. Spatial analysis shows that plantation and timber estate in Papua areas seem closely related to the main road network and are in close proximity to the main population centers such as Jayapura, Merauke and Sorong (Mertens, 2002) so is not a threat until the planned road network is developed.

3. **Community knowledge and utility of hydro-ecological process, the species and habitats that they support.**

CI Mamberamo Project started this assessment of community knowledge with a substantial amount of background knowledge that has been documented through Multidisciplinary Landscape Assessment; about the livelihoods strategies, species of importance, places and habitats of importance to local communities. However, this general information did not tell us specifically about *how* and *when* the community use the swamps, swamp forest and lakes – the focus of this study and the dominant area within the Lake-Plains. We also wished to find out more information from the communities about the hydrological processes within each of these formation, the species that they contain (if known) and how hydrological processes impact on habitats and species of conservation importance. We started with the following assumptions that would then be tested through interviews and focused MLA type methodology.

- Changes in flow rates, timing and quality and levels of flooding influences the composition of species with various habitats in the Mamberamo.
- Communities take advantage of the changes in species composition between habitats caused by fluctuations in rates, timing and quality.
- The normal fluctuations in rates, timing and quality maintains specific habitats; extreme fluctuations may change habitats.

The output of this study was therefore testing these assumptions by documenting processes that affect important habitats and their species composition (especially in regard to threatened and restricted range species).

3.1. **Local monitoring of Flow, Timing and Quality within the Mamberamo Basin**

Accurate flow rates for the Mamberamo are not available from any source and monitoring flow, timing and quality of water within the Mamberamo is fraught with difficulties (even though communities live along side the river). This is because excessive dry or wet periods tend to be over exaggerated using participative techniques and the methodology is not sensitive to peaks and trough that the river may experience throughout the year. Therefore the figure represented below is for illustrative purposes only and explains the “phases” that the community use to describe hydrological variable in the river.

The local communities confirmed CI general observations that the Mamberamo Basin undergoes several seasons (often marked in some years). As the area experiences rainfall throughout the year (see above), it is difficult to define a “rainy” season *per se*. The driest seasons occur in the months of May-August when the river levels drop. Seasonal temperatures are at their highest during this time also. This period is known as Tiguwaig. The rest of the

year falls into Aridogkwariwai when rainfall increases (and temperatures decrease due to cloud cover) and the river once again become full. During this time the Mamberamo river and tributaries regularly floods their banks replenishing the swamps and lakes. During peak flooding, tributaries reverse their flow resulting in some of the flood waters being pushed back into swamps and lakes. The resistance in the lower parts of the tributaries also causes smaller tributaries to flood and thus swamps receive flood waters from a variety our sources as well as from rainwater.

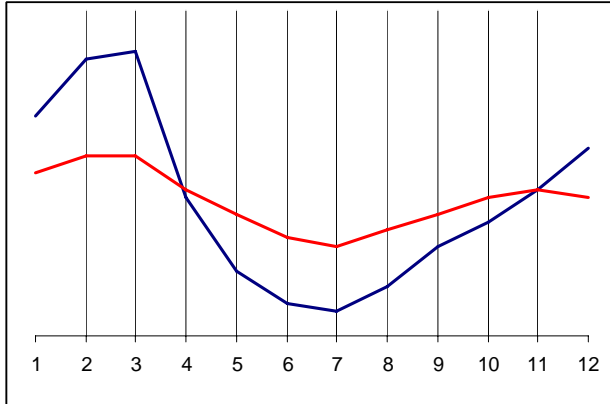


Figure 10. Representation of Flow Rates and Timing of the Mamberamo. (communities perception) .Red line = average flow throughout year. Blue line = maximum and minimal that can happen occur periodically during peak and driest months

Akhu koripira is an exceptional flooding event that occurs approximately 5-7 years. During this period the entire lakes-plain area become inundated. This coincides with excessive rainfall that is experienced in the year following an El Nino event (such as that occurred in 2006, thus a Akhu koripira flood was experienced in 2007. The communities believe that the Akhu koripira events are the Mamberamo resetting itself and replenishing nutrients and sediment throughout the swamp ecosystem. Whilst this maybe true to some extent, Akhu koripira events are dramatic and can drastically alter habitats, strand populations of wildlife (terrestrial) and affect the communities ability to make a living.

Whilst we cannot accurately measure the flow rates it is still useful to have the pattern of flow so that a correlation can be made with livelihood strategies. that are closely linked to the distribution of many socio-economically important species.

3.2. *Local classification of habitats in the Mamberamo.*

The local communities distinguish habitats as swamps, swamp forest, lakes and rivers. The table on the following pages, is a summary of the information received from communities and from field visits to the sites. This information is complemented with aerial photos of the habitat types at the end of this report.

Swamp formations	Hydrological Characteristics	Geographical characteristics	Dominant Vegetation	General use by communities
Mixed Swamp Forest (Akhu) – Peatland forest.	<i>Poor drainage, usually inundated for 6+ months of year. This swamp forest is characterized by many open areas surrounding the mixed swamp forest (consisting of swamp scrub) which lie in depressions and therefore inundated for longer. Watered from adjacent rivers when in flood but few rivers draining it. Water retained in the swamp become black /brown</i>	<i>This form of swamp forest is extensive and the most common form of swamp habitat in the Mamberamo. Mixed Swamp forest lies behind Open Riparian Forest.</i>	<i>High diversity of trees (list in prep), generally of small stature (10-15m occasionally 20m), mixed with sago – very often with open areas dominated with shrubs, low trees, palms and rattans. Key Families: Lecythidaceae, Clusiaceae, Capparaceae, Dilleniaceae, Rubiaceae, Pandanaceae, Myrtaceae</i>	<i>Areas are large, and used by communities year round. However, many communities target these areas for hunting at peak flood times as wildlife congregates in the drier, higher part of swamp (those dominated by trees).</i>
Sago Swamp (Pi Akhaku)	<i>Often inundated from flooding but quickly absorbed into the body (soil) of the swamp. Organic rich soils have very poor drainage (some drainage channels) at largely retain all water content even in driest months. Water retained in the swamp in muddy and brown for the fine organic matter.</i>	<i>Usually located away from to river courses (except where shifting river course cuts into this habitat type, behind Open Riparian Forest</i>	<i>Dominated by Sago palms, with some tree species. Key Tree Families: Lecythidaceae, Combretaceae, Rubiaceae, Euphorbiaceae, Myristicaceae, Datisceae, Apocynaceae, Fabaceae, Clusiaceae</i>	<i>Extensively used by communities for sago extraction, hunting, building materials.</i>
Swamp Grassland (Durekha)	<i>Swamp grassland is always inundated and wet underfoot, however, water level within the swamp grassland varies greatly. Drainage of these areas is moderate. They usually outlets to Mamberamo and other major rivers</i>	<i>Often extensive habitats and usually associated with old river courses or lakes. A successional habitat from shallow lakes. Also occur in depressions sometimes close to other lakes.</i>	<i>Dominated by Grasses and Pandanus sp. Which forms floating mats of vegetation. Species poor. Very few trees can grow in these conditions. Key Families : Poaceae, Pandanaceae.</i>	<i>Usually difficult troublesome to access , but often used by communities for hunting game (such a pig and cassowary) that may feed on pandanus fruit.</i>
Swamp scrub (Akakhu akeikia)	<i>As swamp scrub is always inundated but levels vary greatly with season. Is located in depressions and therefore receives water draining from other swamp types. Water in the swamp is brown.</i>	<i>Swamp scrub is thought to be a successional stage between grassland and mixed swamp forest and usually found adjacent to above.</i>	<i>Swamp scrub is a successional forest type consisting of scattered trees and sago, a very dense shrub, climbers, sedges and grasses. Key Families : Poaceae, Tiliaceae, Moraceae, Combretaceae, Lecythidaceae, Malvaceae, Datisceae, Rutaceae</i>	<i>Due to the dense undergrowth swamp scrub is rarely visited by local communities and therefore can be a refuge of many globally threatened and economically important species.</i>
Riparian forest (Warutudai)	<i>Seasonally inundated, moderate drainage. Not essentially swamp forest but included here due to proximity to swamp forest and impact this has on various swamps types.</i>	<i>Forest type only found along mid- to large rivers.</i>	<i>Highest diversity of vegetation of the forests in Mamberamo. Key Families: Rubiaceae, Lecythidaceae, Dilleniaceae, Verbenaceae, Fabaceae, Moraceae, Combretaceae, Malvaceae. Dominant species</i>	<i>Many species commonly hunted are found in these forests – due to their accessibility, communities in the Mamberamo favour using this type. It provides hunting materials, building materials, some sago, fruits, canoe</i>

			include <i>Ficus spp.</i> , <i>Intsia spp.</i> , <i>Pterocarpus indicus</i> , <i>Ochtomeles sp.</i> , <i>kayu merah</i> , <i>Pandanus sp.</i> <i>Sago in wetter areas</i>	<i>materials as well as an important source of games.</i>
Lakes				
“Ox-Bow” Lakes (Karu Tapai)	<i>There are several local definitions of Ox-Bow lakes which describe various stages / age of the ox-bow lakes. These lakes generally retain an outlet to the main flow (except during the dry season when they become shallow and isolated); after succession has taken take form a series of lakes; derive their water from main flows and from swamp sources – and have muddy sediment loaded water bodies.</i>	<i>These lakes are the characteristic and dominant lake formation of the Mamberamo and gave the name “Lakes-Plain”. There are several hundred ox-boxes at different stages of succession in the Lakes-plain. Usually located immediately adjacent to several kilometers from the main channel. More distant from the channel generally more advanced the successional stage.</i>	<i>Due to muddy nature of these lakes, vegetation on the edges is usually dominated by grasses (<i>Saccarina sp</i>) – adjacent habitat types are variable as the lake formation is produced by main river course cutting its new course.</i>	<i>These lakes are generally rich in fauna due to the regular input of sediments / nutrients from swamps and main flows. They are a very important source of livelihoods especially during the drier seasons, when the lakes become shallower and totally isolated from the main channel (fish are easier to catch and crocodiles harder to escape)</i>
Isolated Black water lakes (Karu Tee)	<i>These are located in deep depressions and only receive drainage water from adjacent swamps, rainwater or ground water. They have no outflow via outlets.</i>	<i>The lakes are found far from the main rivers courses. They are always in depressions within the lake-plains and never associated with the hydrological processes of the main Mamberamo river channel. These areas remain depressions as they do not receive mineral sediments from rivers and succession in these habitats is presumed to be very slow.</i>	<i>Often adjacent to Swamp scrub or Mixed Swamp forest. One particular formation of forest (consisting of homogenous stands of <i>Rubiaceae</i>) is also fairly common in the Mamberamo (however, the actual species is unknown as these lakes and adjacent swamp forest are exceedingly difficult to access. <i>Pandanus</i> is a common lake edge species.</i>	<i>Many isolated blackwater are not known of by all community members as the are hard to find. Also, due to the lack of an outflow and difficulty of access (plus the generally distant nature of this kind of lake formation), communities rarely use isolated black water lakes. They are an important refuge for wildlife (especially Giant softshell and crocodile) that migrate to these habitats at the highest flooding periods and therefore important is maintaining populations.</i>
Flowing Lakes (Karu Apapee)	<i>The Mamberamo also has many cases of series of lakes which are interconnected by a river network so that they form part of a larger drainage channel.</i>	<i>They are probably ancient remnants of Ox-bow lake formations form the Mamberamo river, but as they retain a substantial input of water from various sizes of river, we have termed them flowing lakes and their function is little different than that of rivers.</i>	<i>Adjacent vegetaion types tend to be swamp that are formed by extended inundation such sago forest and swamp grassland and scrub.</i>	<i>These lakes are generally rich in fauna due to the regular input of sediments / nutrients the river inputs. They are a important source of livelihoods especially during the drier seasons, when the lakes become shallow as lesser flow.)</i>

3.3. Hydrological processes and the impact on the temporal and spatial distribution of species

The distribution of certain species can be seen to some extent from the patterns of community livelihoods – where and when they hunt and use resources. As described above, livelihoods are highly linked to certain resources (sago, hunted wildlife for food and economic benefits). The community has adapted their strategies to optimize on seasons that are described above.

<i>Season</i>	<i>Strategy</i>	<i>Habitats Used</i>	<i>Species Sought</i>
Dry season (Tiguwaig)	<i>Hunting (terrestrial)</i>	<i>Mixed Swamp Forest; Riparian Forest; Sago swamp;</i>	<i>Casuarius unappendiculatus, Goura victoria, Dorcopsis hageni, Sus scrofa, Spliocuscus rufoniger dan S.maculatus</i>
	<i>Crocodile and turtle Hunting</i>	<i>Ox-bow Lakes; Flowing Lakes; Main Mamberamo river</i>	<i>Crocodylus novaeguinae and C. porosus; Pelochelys cantorii</i>
	<i>Fishing</i>	<i>Ox-bow Lakes; Flowing Lakes; Main Mamberamo river</i>	<i>Fork-tailed Catfish (Arius sp.) – mixed freshwater species</i>
	<i>Sago harvesting</i>	<i>Sago Swamp; Mixed Swamp Forest</i>	-
Rainy Season (Aridogkwariwai)	<i>Hunting</i>	<i>Accessible Riparian Forest (occasionally and when not affected by floods);</i>	<i>Casuarius unappendiculatus, Goura victoria, Dorcopsis hageni, Sus scrofa, Spliocuscus rufoniger dan S.maculatus</i>
	<i>Crocodile and turtle Hunting</i>	<i>Rarely in Ox-bows and Flowing Lakes to lesser extent</i>	<i>Crocodylus novaeguinae and C. porosus; Pelochelys cantorii</i>
	<i>Fishing</i>	<i>Ox-bowlakes; Smaller river</i>	<i>Fork-tailed Catfish (Arius sp.) – mixed freshwater species</i>
	<i>Sago harvesting</i>	<i>Accessible Sago Swamp</i>	-
High flood (Akhu koripira)	<i>Hunting (game)</i>	<i>Mixed swamp Forest (this swamp is usually completely flooded at these events but not to animal congregations specific areas (refugia) are targeted by communities as animals cannot escape; Similar in areas swamps – if accessible and congragations exist – targeted.</i>	<i>Casuarius unappendiculatus, Dorcopsis hageni, Sus scrofa.</i>
	<i>Crocodile and turtle Hunting</i>	<i>Not hunted</i>	<i>Crocodylus novaeguinae and C. porosus; Pelochelys cantorii</i>
	<i>Fishing</i>	<i>Ox-bowlakes; Smaller river</i>	<i>Fork-tailed Catfish (Arius sp.) – mixed freshwater species</i>
	<i>Sago harvesting</i>	<i>Swamp large inaccessible (turn to sweet sago – a Arangga palm of lowland forest or rely on stored sago</i>	-

Whilst terrestrial species such as cassowaries, pigs and wallabies live and thrive in swamp forest habitats, they will try to avoid high floods. The communities take advantage of this fact by targeting areas that do not flood as much as the surrounding swamps and species (that are usually solitary) congregate, particularly in mixed swamp forest. Even though access for communities is difficult during the floods, hunting for these species is much less productive during the dry season, as they disperse throughout the swamps as water levels recede, to search for food and breed. Many of the habitats are very difficult to enter on foot due to the heavy undergrowth and (still) swampy-ness of the habitats so these areas provide some refuge for endangered species that can be relatively easily hunted during the peak rainy season.

The opposite is true of aquatic species sought after by local communities. During the rainy season, these species disperse over a wide area, and whilst it may be easier to reach some habitats such as distant lakes and swamps by canoe, the area that these species inhabit, the increase in sources of food in recently inundated areas and the sheer volume of water present, makes hunting for these species futile. It is at these times that aquatic species find refuge in more remote parts of the basin that are difficult for communities to access. Both *Pelochelys cantorii* and *Crocodylus* breed in the dry season in the north of Papua (unlike southern freshwater *C. novaeguineae*). *C. novaeguineae* are thought to use the flooding season for dispersal to reach isolated swamp scrub and swamp grassland where they breed on floating mats of vegetation and overgrown tributaries. *Pelochelys* nests on riverbanks.

During the dry season turtles and crocodiles become easier to hunt as the water level decreases in lakes and swamps. These aquatic species are forced to find deeper stretches of water and congregate in lakes and permanent swamps. Those habitats with easy access are targeted by local communities. Fortunately for these species, there is still large expanses of habitat that is not accessible and therefore these species are thought to be safe (i.e. the community has not reported a drastic reduction in populations).

3.4. Impact of Hydrology on Habitats

The relationship between hydrology and habitats in the Mamberamo is complex (and still being studied) but there are some trends that have been identified. Areas that are inundated for longer (or permanently) are less forested than areas that tend to dry out. This is clearly related to drainage and elevation compared with surrounding areas. Swamp Grassland and scrub are associated with old river courses and larger natural depressions where water collects and remains even in the drier months.

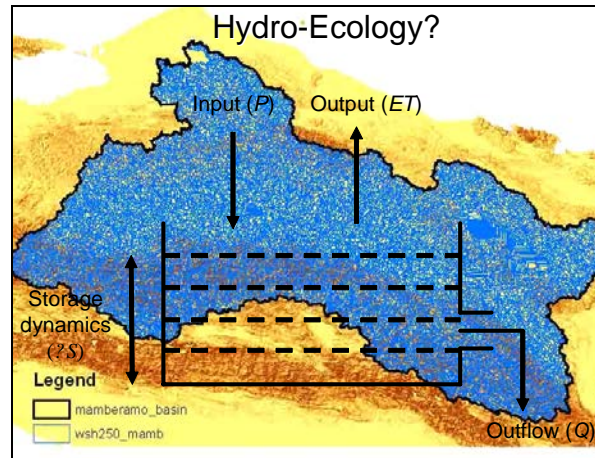
In general, the community confirmed that areas closest to tributaries undergo a levee building effect. When the river floods, water tops the banks and inundates the areas adjacent to the river. Sediment from the uplands is deposited immediately on these areas. Over many years high banks are produced, rich in mineral soils on which taller riparian forest (high diversity of species and important areas for hunting for local communities) is found. Further away from the banks, sago forest and mixed swamp forest dominate, with a lower land profile, and therefore liable to flood for longer periods. Also because of the levee system that naturally builds up around river systems, mixed swamp forest and sago swamps have poorer drainage, again maintaining these habitat types.

The patterns of flooding and habitat delineation are presently being mapped using Radar Technology. When results are available the patterns between hydrology and habitats will become clearer. This is particularly important to predict how potential changes in land-use (especially in the uplands) will affect the swamp lands and livelihoods. At present we can only make predictions about how future land changes will affect the swamp forests of the Mamberamo. How will fast delivery rate and higher sedimentation loads (that are predicted to occur from increased deforestation) affect these habitats and species that inhabit them (and in turn the communities that rely on them for their livelihoods)?

The present hypothesis is that flooding will happen more frequently and with higher intensity during the rainy season and lower river levels for longer periods occur during the dry season. More flooding and longer dry seasons will likely change the composition of swamp habitats in favour of forest, riparian forest and sago forest, in favour of swamp scrub and grassland. This may not negatively impact on threatened species such as cassowaries or turtles, but biodiversity on the whole will certainly be lower, if this is indeed the long-term result of land-use change with the watershed due to roads, plantation development, logging and agricultural encroachment.

4. Conclusions and Recommendations from the Assessment

The dynamics of water stored in the basin is determined by changes in the inputs and outputs of water in the system. Relatively small outflow in the outlet affects the extent and characteristics of the wetlands dominating the landscape of Mamberamo. This outflow is produced because of the narrow gorge between the Foja and Van-Rees Mountains. This unique topography essentially creates a vast tank fed by an extensive upland system. Flooding can happen relatively quickly as delivery rates from the highland / uplands are fast, but as the waters enters the flat Lakes-plain, delivery rates slow and flooding results. Flooding recedes slowly as most the are is covered in forest, there is a limited outflow from the basin and the topography is almost totally flat. Hence the formation of the extensive swamp along the Mamberamo.



4.1. Recommendations for Conservation

This information from community based assessment of hydro-ecological processes is important so that the location of these breeding areas for threatened and socio-economically important species can be identified more accurately (remembering that community rarely visit these areas). Through increased survey effort and mapping, additional KBAs can be designed and protected for the future conservation of these species. Additionally, areas that are targeted for hunting terrestrial species should be managed through community conservation agreements whereby populations and trends are monitored in the short term and control measure implemented if population experience decreases.

The Mamberamo project is still a long way from being able to confidently set targets for conservation in the uplands in order to protect the habitats and species within the Mamberamo lakes-plain. Until that time it is important to take a conservative approach to try and safeguard hydrological processes that, at present, support the sustainable livelihoods of the communities within the Lakes-plain. Communities have developed a strategy that whilst exploitative, is naturally balanced by the difficulties of access throughout different season. Changes in the hydrology cycle may encourage increased exploitation (by local communities and outsiders) by providing more opportunities for access to otherwise primary habitats. Alternatively, livelihoods of local communities maybe made increasing difficult by changes in hydrological cycles and their affects on habitats and species. It is essential to start measuring hydrological processes and their present impacts on habitats and target species, and continue to measure hydrological variables into the future and correlate these to land-use changes that are occurring with catchments or sub-catchments.



Mixed Swamp Forest – the typical swamp forest of the Mamberamo. Although this swamp forest is also variable from open formations with scrub vegetation (left); to closed canopy forest (right) as seen from approximately 1,500 feet altitude. Whilst not particularly heavily used by communities, certain areas are targeted for hunting cassowaries, pigs and other game during the higher floods as these species tend to congregate.



Sago Swamp are common throughout the Mamberamo and coverage an estimate 200,000 hectare. They are often found in pure formations or mixed trees species that can stand permanently wet and peaty soils (such as *Terminalia* sp.)



Swamp Grassland is usually associated with depressions and lakes. As early succession vegetation type, the grasslands are always inundated or otherwise experience a high fluctuation in water levels that other vegetation type cannot tolerate. Often the grass grows as floating mats at times of high flood.



Swamp Scrub is usually associated with old river courses and is a successional vegetation type from swamp grassland before mixed swamp forest. As Scrub lies in depressions it is wet / inundated all year round which prevent the growth of trees. These habitats are extremely difficult to penetrate by the community and are also safe refuges for crocodile and turtle breeding. Below shows a mosaic of swamp grasslands, swamp scrub and mixed swamp forest at high flood.



Riparian Swamp Forest attains a higher stature than other forest types as the soil is high in mineral sediments that accumulate on the banks. These banks are important features that restrict drainage from areas further from the river and therefore have a different vegetation type – sago, mixed swamp and brush. Riparian forests, although restricted in the lakes-plain, are very important habitat types for local livelihoods, supporting a wide variety of species.



Ox-bow Lakes are the characteristic lakes found along the Main river sources in the Mamberamo lakes-plain. Lakes formed in the recent past retain some connection with the main river course but become isolated in the dry season (above). Often several ox-bows merge together as the river continually shifts its course. Older ox-bows become shallower and vegetated with swamp, but as they become more isolated the sediments cannot flow into the lakes as often and the succession processes slows (the low lake in the above picture, and the smaller lake in the below picture). These more isolated (black water) lakes are important refuges from threatened and socio-economically important species.



Flowing lakes in the Mamberamo are found in depressions along river courses, rivers clearly flow in and out of these lake. Whilst similar in function to an ox-bow lake, the communities clearer differentiate as they do not become isolated in the dry season and are therefore not as important for hunting crocodiles and fishing.



Black water Lakes do not have obvious inflow and outflows, receiving water through seepage from the surrounding swamps. Usually associated with Swamp Grassland and Swamp Scrub in depressions within the Mamberamo Lakes-Plain. The water has little sediment load as not connected directly to silty rivers. These lakes are usually very isolated and very infrequently visited by communities.



The Northern Cassowary (*Casuarius unappendiculatus*) – left - and a globally threatened species due to hunting. This species is an important provider of protein to local communities. The maintenance of riparian forest and monitoring and regulation of hunting pressure in areas where they congregate in times of flood is needed. More knowledge about how they use other swamp habitats needs more attention.

The dry season provides a bounty of fish – right – as the ox-bow lakes dry out. These provide protein for local communities and an income based on the dried swim bladders of *Arius* spp. However, prolonged drought increases temperatures and turns these lakes stagnant, killing fish. Maintenance of the hydrological cycle that floods and ebbs several times during a (dry season) is therefore very important for biodiversity.



The globally threatened giant softshell (*Pelochelys cantorii*) (EN) is almost extinct from much of its natural range. However in the Mamberamo very large individuals are common and hunted by local communities for food. Due to the inaccessibility of much of the lakes-plain, breeding and many feeding grounds remain secure and free from hunting. The same is true of the crocodile *Crocodylus novaeguineae*, that whilst not threatened at present is an important economic species for crocodile skin.



With habitat degradation in the uplands caused by development and agricultural expansion, threats are posed to the Lakes-plains. Upland deforestation and degradation is expected to change delivery rates, increased sedimentation and flooding. This has the potential to shift river patterns inundate larger areas thus altering habitats and thus threaten terrestrial species that rely on these. The swamps are also expected to experience increases fluctuations (greater extremes) with longer dry period also. Even with greater flooding during the wet season, longer droughts will disadvantage aquatic species also. Target for conservation of the uplands is necessary to maintain downstream hydro-ecological processes. These target are difficult to assess and more work quantifying bio-physical attributes are necessary.