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ECOSYSTEM SERVICES WITHIN A KEY SUBTROPICAL REGION AFFECTED BY THE YACYRETA DAM IN PARAGUAY

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ABSTRACT

One of the most striking features of the ecosystem concept is that their components, through natural structures and processes, render ecological functions, which are valued by society. The objective of this research was to identify and describe ecosystem services provided by the Natural Reserve Yacyretá, in accordance with the goal of Paraguay's National Law Nº 3,001 of 2006 of conservation, protection, recovery and sustainable development of national natural resources and biological diversity through fair, timely and adequate valuation and payment for ecosystem services. The study was conducted during an environmental monitoring campaign in October 2016 in the reserve, using an ecosystem services checklist constructed based on the classification provided by *The Economics of Ecosystems and Biodiversity*. This reserve is part of the conservation, protection and compensation actions carried out by the Yacyretá Binational Entity in the area of influence of the dam constructed between Paraguay and Argentina for the Hydroelectric Power Station Yacyretá. Its purpose is the protection of ecosystems, communities of biological elements that, due to their rareness, fragility, importance or singularity deserve a special assessment. This reserve has a high representativeness of the resources of the Ñeembucú eco-region, and the presence of two ecosystems scarcely represented in Paraguay, such as forests of arary (*Callophyllum brasiliense*) and a small formation of vegetated dunes. The reserve provides all four categories of ecosystem services, directly and indirectly. These results will be practical for stablishing conservation strategies to update its management plan and assess access to the system of valuation and payment for ecosystem services.

Key words: *Conservation. Ecosystem services. Yacyretá dam.*

INTRODUCTION

An ecosystem is the basic unit of nature (Tansley, 1935) that includes both the biotic and abiotic components of a given area (Constanza et al, 1997) and their interrelationships (Beichler et al, 2017). One of the most striking features of the ecosystem concept is that their components, through natural structures and processes, render ecological functions. With an anthropocentric approach, they

produce benefits for people (de Groot et al, 2002; MEA, 2005). Therefore, ecosystem services, according to The Economics of Ecosystems and Biodiversity (2010), are referred to as the direct and indirect contributions of ecosystems to human well-being. The flow of ecosystem services to society is often studied in the environmental economics field, since it provides a quite comprehensive tool for decision-makers to value and even monetize ecosystem services. For example, since 2006, Paraguay has a valuation and payment system for ecosystem services established by National Law Nº 3,001. Its goal is to promote conservation, protection, recovery and sustainable development of national natural resources and biological diversity through fair, timely and adequate valuation and payment for ecosystem services. This law considers ecosystem services all human activities of management, conservation and recovery of ecosystem functions that benefit people directly and indirectly.

The Yacyretá Dam of Hydroelectric Power Plant Yacyretá, is one of the three projects that provide electricity to Paraguay. It is a binational project with Argentina, located on the Paraná river, between the cities of Ayolas (Paraguay) and Ituzaingó (Argentina), 300 Km Southwest of Asunción and 1,000 Km North of Buenos Aires. Because of its several environmental impacts and as compensation for the loss of natural environments caused by the flooding for the filling of the reservoir, the Yacyretá Binational Entity (EBY, for its initials in Spanish) has executed a series of actions tending to the protection of different representative habitats and species in their area of influence. According to what is stated by National Law Nº 3,001, these biodiversity reserves could access the system of valuation and payment for ecosystem services. The purpose of these reserves is the protection of ecosystems, communities or biological elements that, because of their rareness, fragility, importance or singularity deserve a special assessment, according to Paraguay's National System of Protected Wild Areas (SINASIP, for its initials in Spanish) and 1994 National Law Nº 352 of Protected Wild Areas. Particularly, EBY has settled in Paraguay a total of 19,256 hectares in biodiversity reserves,of which 6,300 correspond to the Natural Reserve Yacyretá. This reserve has a high representativeness of the resources of the Ñeembucú eco-region, and there can be found forests in flooded soil with dominance of arary (*Callophyllum* brasiliense and small formations of vegetated dunes. These have a special relevance because of their rareness since these ecosystems appear scarcely represented in Paraguay, respectively only found in the Yacyretá Island and in a very limited area in the Boquerón department, on the North border with Bolivia. Despite all conservation and management efforts, there are several critical points, especially of anthropic pressure caused by poaching, arson, transit of vehicles and people, nearby human settlements and solid waste. It should be noted that the nearby area is subject of study for rice production through the exploitation of the Aguapey stream basin, where the reserve is located. The management plan of the Natural Reserve Yacyretá (2005), has objectives related to conservation of biological diversity, environmental education and research, among others, but none directly related to the identification of ecosystem services. Therefore, this paper

intended to identify and describe ecosystem services provided by this reserve within this key subtropical region affected by the Yacyretá dam, in accordance with National Law Nº 3,001 of 2006.

MATERIALS AND METHODS

This research had a descriptive approach, according to Hurtado de Barrera (2000), as it intends to identify and describe ecosystem services provided by the Natural Reserve Yacyretá, in accordance with the Paraguay National Law Nº 3,001 of 2006. There are no previous similar studies in the reserve that consider ecosystem services, even if they are necessary for a better understanding and management of these natural resources and for considering access to the valuation and payment system. Paraguay's system includes forest protection and management, reforestation and other activities that mitigate greenhouse gases, protection services for water resources, springs, wetlands and watersheds, protection services of species and ecosystems, care of natural landscapes, and soil protection and recovery services, to name a few. Even though it provides a general concept and description of ecosystem services, it lacks the structure that the de Groot et al (2002), MEA (2005) or TEEB (2010) have. For this reason, this study was conducted considering their classification, as can be seen on the next table.

Table 1. Categories of ecosystem services

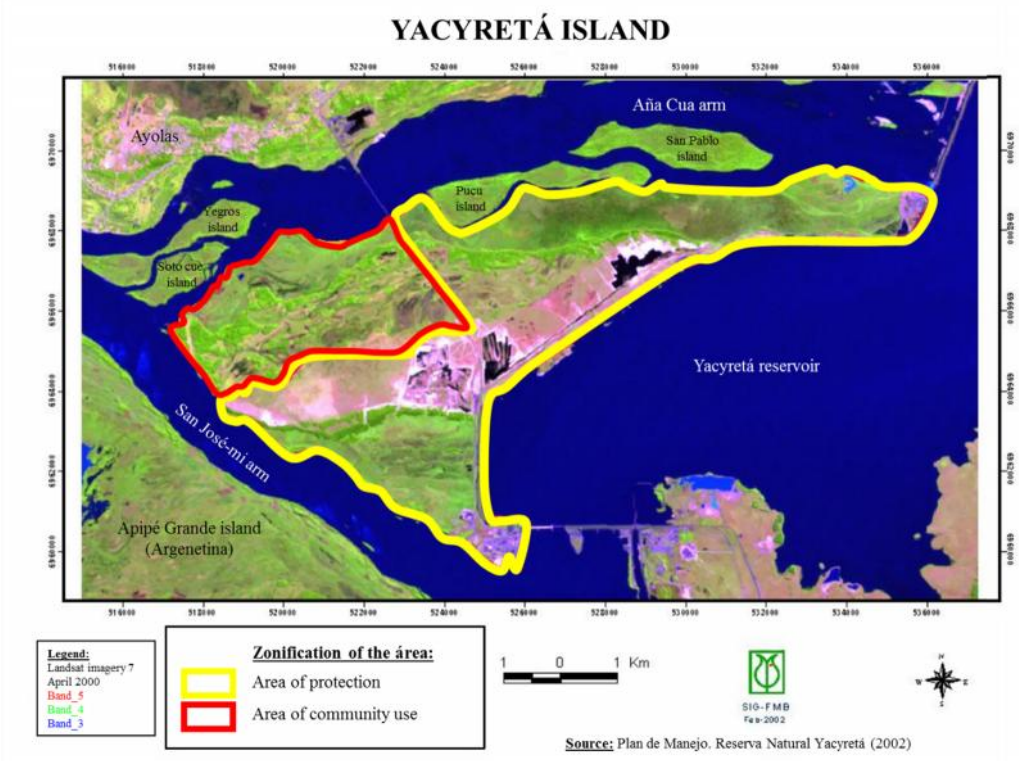
Provisioning services	**Regulating services**	**Cultural services**	**Habitat services**
They describe the material outputs from ecosystem.	Capacity to regulate essential ecological processes and life support systems through biospheric processes.	Include the non-material benefits people obtain from contact with ecosystems	Ecosystems provide living spaces for plants and animals. They also maintain a diversity of different breeds of plants and animals

Adapted from de Groot (2002), MEA (2005) and TEEB (2010)

Provisioning services include food, raw materials, fresh water and medicinal resources. Regulating services incorporate local climate and air quality regulation, carbon sequestration and storage, moderation of extreme events, wastewater treatment, erosion prevention and maintenance of soil fertility, pollination, and biological control. Cultural services involve spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience. Supporting of habitat services cover soil formation, photosynthesis, primary production, nutrient cycling, and water cycling. All four categories were considered for the arrangement of a checklist of ecosystem services, which was applied in a monitoring campaign in October 2016. The observations were later organized, analysed, integrated and consolidated in a report of results, which are presented in the next section of this paper.

The study was conducted in the Natural Reserve Yacyretá, created in 2009 by EBY Resolution Nº 11,716, located in the Yacyretá island, in the Ayolas district

(Misiones department), West of the trace of the Yacyretá dam. It is delimited North by the Aña Cuá arm and South by the San José-mi arm. These details can be found in the next map:



Map 1: Location and distribution of the Yacyretá Island – Translated from EBY (2002)

RESULTS AND DISCUSSION

Provisioning ecosystem services

Even though hunting and fishing are prohibited in the reserve, the ecosystem presents a high production of edible plants and animals such as wild mammals, fishes, birds, fruits, and exotic items like bird's nests. According to the Management Plan (2005), there were registered specimens of kui'î or porcupine (*Sphiggurus spinosus)*, lobope (*Lontra longicaudis*), apere´a (*Cavia aperea*), tatu poju (*Euphractus sexcinctus*), tatu hû (*Dasypus novemcinctus*), akuti (*Dasyprocta azarae*), teju guasu (*Tupinambis rufescens*); birds like the white heron (*Ardea alba*), mytû (*Penélope obscura*) and *taguato´i* (*Buteo magnirostris*). Different species of primates can also be found in this ecosystem, standing out the karaja (*Alouatta caraya*) and the ka'i paraguái, also known as Capuchine monkey (*Cebus apella*), aside from several species of reptiles and amphibians. In addition to the mentioned species, several forests and shrub species can be used as raw

materials for food, firewood and charcoal, pasture and forage, nectar and honey, medicines, crafts, industrial and ornamental uses, among others.

Table 2: Species of flora of ecological and economic importance in the Yacyreta Natural Reserve

Scientific name	Common name	Scientific name	Common name
Acrocomia aculeata	Coco	*Myrciaria baporeti*	Yvaporoity
Calophyllum brasiliense	Arary	*Pterogyne nitens*	Yvyra ro
Rheedia brasiliensis	Pakuri	*Helietta apiculata*	Yvyra ovi
Xylopia brasiliensis	Yvyra katu	*Enterolobium contortisiliquum*	Timbó
Tabebuia pulcherrima	Tajy saʻy ju	*Gleditsia amorphoides*	Yvope
Tabebuia impetiginosa	Tajy	*Jacaratia spinosa*	Jacaratia
Tabebuia heptaphylla	Tajy	*Bumelia obtusifolia*	Yvyra hu
Butia jatai	Jataʻi	*Chrysophyllum gonocarpum*	Aguai
Syagrus romanzoffiana	Pindó	*Guadua angustifolia*	Takuarusu
Bahuinia forficata	Pata de buey	*Ocotea spp*	Laurel
Brachiaria sp.	Pasto	*Nectandra spp*	Laurel
Sebastiania brasiliensis	Yvyra kamby	*Inga uruguensis*	Inga guasu
Senecio brasiliensis	Agosto poty	*Holocalyx balansae*	Yvyra pepe
Trichilia catigua	Katigua pyta	*Elionurus muticus*	Espartillo
Trichilia clausenii	Guatambi mi	*Pseudananas ananoides*	Ananá de monte
Trichilia pallens	Katigua moroti	*Bromelia balansae*	Karaguatá
Trichilia pallida	Cedrillo	*Tillandsia sp*	Clavel del aire
Sapindus saponaria	Palo jabón o casita	*Rhipsalis sp*	Cactus
Sorocea bonplandii	Ñandypa mi	*Oncidium sp*	Orquidea
Maclura tinctoria	Tatajyva	*Myrciaria baporeti*	Yvaporoity
Eugenia uniflora	Ñangapiry	*Pterogyne nitens*	Yvyra ro
Hexachalamys edulis	Yva hai	*Helietta apiculata*	Yvyra ovi

Source: EBY (2005)

The extraction of these floral species is also prohibited in the reserve. Amid these floral species, there are several medicinal plants, such as tajy (*Tabebuia heptaphylla*), pata de buey (*Bahuinia forficata*), palo jabón or casita (*Sapindus saponaria*), ñangapiry (*Eugenia uniflora*), ybaporoity (*Myrciaria baporeti*) and aguai *(Chrysophyllum gonocarpum*). About freshwater production services, several artificial lagoons can be found in the reserve stocking rainfall water. These lagoons formed as result of sand exploitation for the construction of the dam.

Habitat or supporting services

Alongside the Yacyreta reservoir, there are large extensions of land with conserved areas for protection of different species. Natural ecosystems have an essential role in regulating and maintaining ecological processes as well as maintenance of genetic resources, so areas like the vegetated dunes provide habitats for plants and animals. While the collection of species for commercial use is prohibited, during this study, wild species like lobo pe (*Londra longicaudis*) and kui'i or porcupine (*Sphiggurus spinosus*) were observed. This species can be used for meat and several other flora species have uses in medicine and industry, like it was mentioned before.

Regulating ecosystem services

Although the reserve represents a 4.5 % of forest cover of the Ayolas district, according to the National Forestal Institute (2016), this could be considered relatively low. Despite this, the reserve sequestrates and stores carbon from the atmosphere, which can provide regulation of local climate and air quality. The atmosphere of the vegetated dunes ecosystem appears to have no signs of pollution in its natural state, since there are no industries or densely populated urban areas in the proximities. Regarding UV radiation, it was observed an increase due to the reflection of the artificial lagoons.

In respect to moderation of extreme events, the presence of forests in around 50 % of the total area of the reserve helps to absorb rainfall, flooding, and balances local climate because of the carbon sequestration and storage. Around the reserve, there are wetlands of approximately 1 Km wide and 15 Km long that work as firewalls against natural fires and arson.

About pollination service, butterflies, bees and hummingbirds were observed acting as pollinators. This is an essential service for the ecological balance of the reserve. It ensures the life cycle of plants and genetic variability needed to adapt to changes in the environment.

Natural ecosystems control a high percentage of all potential crop pests and disease vectors. These can be easily controlled in a pristine environment, but the Yacyreta Natural Reserve has a continuous flow of visitors that can cause risks for the ecosystem, due to the hauling of pests and diseases, plant manipulation, and constant trampling.

The reserve's soil is of basaltic origin, with very little organic material, and degradation of rocks due to human intervention. Since the area is covered with native and exotic shrub and herbaceous vegetation, the soil is protected from the erosive action of wind and water. Grass species, through the action of their roots, act as structures for soil particles and help avoid direct impact from raindrops.

Vegetation and biota have a role in removing and decomposing nutrients and foreign components. The vegetated dunes are subject to constant visits from tourists and students, visits that transport foreign components such as dust, yerba mate, hot and cold water, and buses can bring seeds, dirt and mud from other places. Despite these characteristics, there could not be found visible solid waste like plastic bottles and paper cups, or even smaller particles like yerba mate.

Cultural ecosystem services

The vegetated dunes offer opportunities for different forms of nature tourism, for instance, trekking, controlled or sectored eco-tourism, and sightseeing that can also provide environmental education to visitors. The presence of many important species of birds offer opportunities for bird watching. Other species of mammals, like capybaras and karajas, can be exploited for guided visits and photographic safaris. The reserve can also be visited for educational and scientific observation purposes.

It should be noted that the vegetated dunes in Yacyretá Natural Reserve represent a unique ecosystem in Paraguay. Pieces of driftwood can be found and extracted

from the river and artificial lagoons, which then can be used by artisans to create wooden sculptures. Other ornamental resources like seeds, feathers, claws, teeth could be exploited. Other plants and animal products could be sold as souvenir or as collection items, such as orchids and butterflies, which could attract tourists and collectors. The reserve's objectives are clear about conservation, though. Despite this, its uniqueness could inspire books, documentaries, paintings or even advertising, activities that don't have extractive purposes.

According to the reserve's guides, the vegetated dunes do not receive visits for spiritual, religious or historic experiences, only for recreation and tourism. However, this ecosystem provides a proper environment to value natural and even religious heritage. Regarding the latter, the reserve's natural characteristics and distance from populated areas can make it an ideal place for meditation.

CONCLUSIONS

The environmental monitoring campaign identified potential uses of available resources and helped comprehend ecosystem's intrinsic value as generator of ecosystem services. These aspects could be included or considered to update the current management plan, especially bearing in mind the conservation objectives of the reserve. The vegetated dunes in the Yacyretá Natural Reserve provide regulating, provisioning, cultural, and support ecosystem services. All four categories could be observed, some directly, like food and raw materials, and others indirectly, such as medicinal resources. This shows that this ecosystem needs more research in this field, maybe considering each ecosystem service separately. A carrying capacity study is urgent since this ecosystem is part of an eco-tourism circuit in the Yacyreta Natural Reserve. If these visits surpass its carrying capacity, the provisioning of ecosystem services could be endangered.

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