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# COASTAL LAGOON GOODS AND SERVICES AND HUMAN DEVELOPMENT

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# Resumo

Os ecossistemas lagunares para além do grande valor ecológico que possuem também providenciam muitos benefícios de valor económico. Estes por sua vez, incluem uma grande variedade de benefícios, derivados dos bens e serviços obtidos nestes sistemas lagunares. O desenvolvimento humano pode criar pressões que por sua vez pode causar impactes nestes bens e serviços. Portanto, de maneira a avaliar as alterações sofridas nesses bens e serviços, 3 lagunas costeiras foram estudadas e comparadas: a laguna Oropuche (Trinidad & Tobago), a Ria Formosa (Portugal) e a laguna de Veneza (Itália). A laguna Oropuche lagoon encontra-se num país em desenvolvimento, onde o ecossistema lagunar está ameaçado por alterações no ordenamento do território, exploração insustentável, e onde existem poucas medidas de gestão. Nos países em desenvolvimento, os valores ecológicos estão frequentemente sacrificados a fim de permitir o desenvolvimento económico. Este estudo pretende assim demonstrar aos políticos e governantes o valor real da laguna Oropuche se fôr gerida de uma maneita sustentável. Este estudo demonstra que apesar do nível de desenvolvimento humano: baixo, médio ou elevado, os impactes nos ecossistemas lagunares podem variar, mas apesar disso as lagunas continuam a providenciar bens e serviços. O estudo demonstra que o potencial da laguna Oropuche pode aumentar de maneira significativa se houver uma gestão sustentável, mantendo o seu nivel de produção para gerações futuras.

Palavras chave: laguna costeira, bens, serviços, desenvolvimento, sustentabilidade, gestão.

# Abstract

Coastal lagoons are valuable ecosystems, which provide humans with many benefits. These benefits may take several forms but the economic benefits are highly valued, and are obtained from the lagoon's goods and services. These goods and services are subjected to pressures and impacts from human development. Therefore in order to assess what changes may occur in these goods and services, three coastal lagoons are studied: the Oropuche (Trinidad & Tobago), Ria Formosa (Portugal), and Venice (Italy) lagoons. The Oropuche lagoon exists in a developing country, where the lagoon ecosystem is threatened by land use changes, a decrease in sustainable use and where management interventions are minimal. In developing countries, too often are ecosystem values suffered for the sake of economic development, therefore the study also aims to demonstrate to policy and decision makers about the need for improved management in the Oropuche lagoon. The study has showed that despite the level of human development: low, medium or high, impacts to the lagoon ecosystem may vary, but the lagoons essentially continue to provide key goods and services. It has also shown that there is a large potential for the Oropuche Lagoon to be sustainably managed so that its value can at least be maintained for future generations.

Keywords: coastal lagoons, goods, services, human development, management.

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# Introduction

Coastal Lagoons are both valuable and vulnerable ecosystems that are attractive to human activities but which can be impacted by them. Lagoons have been providing humans with fisheries, recreation and transport, amongst the many uses and functions which they serve. More specifically, these uses and functions can be classed according to the goods and services obtained. Humans have been utilising coastal lagoons for centuries, and so too the benefits derived from them, thereby making them very valuable ecosystems, in economic as well as ecological terms.

Despite its importance, this value is not always obvious, frequently misunderstood, and taken for granted. Therefore, many coastal lagoon ecosystems are being used in unsustainable ways and are being severely threatened. Many human activities and developments have impacted on these lagoon ecosystems in some way. Some Southern European lagoons for example, have the particularity of being subject to strong anthropogenic pressures due to tourism and/or heavy shellfish/fish farming (DITTY Project, 2002).

In order to ensure that the appropriate value to society is understood, and to allow better management of these ecosystems, lagoons must be placed in an economic context. The economy is a key driver of the policy makers, in order to act and make informed decisions about managing natural systems. When we understand the value of these systems, only then can we truly appreciate the benefits derived, and can manage in a sustainable way.

## *Objectives of the Study*

In order to understand the effects of human impacts and continued development on ecosystems, it is useful to compare systems that have already undergone changes or development, so that the lessons learnt and experiences can be applied to those that have not yet undergone changes. Therefore, this study aims *to assess the ecosystem goods and services derived from coastal lagoons based on the level of human development and to demonstrate the importance of lagoon management in a developing country*. Three coastal lagoons have been studied, on the basis of their human development and impacts: Oropuche Lagoon, Trinidad; Ria Formosa, Portugal; and Venice Lagoon, Italy. The Oropuche Lagoon exists in a developing country, where there is minimal management of the lagoon, but is under increasing and varied development pressures. The study will determine the present economic value and uses of the lagoon. Determining this value, and showing this in the national context, will demonstrate the importance of management interventions, so that the ecosystem goods and services of the lagoon will be sustained for future generations.

The two other case studies of ecosystem goods and services of lagoons are useful for comparison, and changes with respect to the level of human development can be assessed. This context is useful for the case of developing countries, which can strongly benefit from the experiences and lessons learnt from developed countries. Economic values for the Ria Formosa and Venice lagoons are not determined in this study. A value for Oropuche is estimated to provide background information for local policy and decision makers.

To summarise, the objectives of the present study are to:

- conduct an economic valuation of the Oropuche Lagoon, Trinidad, and to determine its present uses; goods and services derived, so that its overall value can be presented to policy and decision makers
- use the Ria Formosa and Venice lagoons as comparative case studies to outline the goods and services derived from them, and the impacts of human development .
- outline the changes in goods and services derived from coastal lagoons according to the level of human development
- discuss management for the sustainable use of the Oropuche lagoon based on the results.

## *Approach to the topic*

Although the lagoon environments being studied are different in many respects, in essence they are all still coastal lagoons, all serving similar functions, and providing similar resources. These natural ecosystem goods and services include: sediment retention; water quality maintenance; wildlife habitat; and maintaining the hydrological balance. Although the lagoon environments being compared vary in latitude, biodiversity, chemical features among other characteristics; they also present many similarities as coastal lagoons.

The economic valuation of the Oropuche is not a comprehensive one, but it is a preliminary and rough estimate of the value of the lagoon, so that its economic importance can become more relevant to the policy and decision makers. According

to Howarth & Farber (2002), economic valuation can contribute positively to the formulation and evaluation of environmental policies. However, only the marketed goods and services will be valued, since they already have a pre-defined market price assigned to them, and they will be valued at 2007 prices. It is recognised that this market price will reflect the valuation of the goods and services, but will only on the margin (Farber *et al.*, 2002). Non-marketed values such as aesthetic value will be considered, but will not be measured in the context of the present study. More expertise and experience is needed to reasonably quantify the non-marketed values of the lagoon, and this was limited with the time and budget in the present research.

# Chapter 1 : Valuing Coastal Lagoons

## 1. Valuing the Ecosystem: Ecosystem Goods and Services

Ecosystem valuation has been a long topic of research (e.g. King, 1966; Helliwell, 1969; Odum and Odum, 1966) but more recently it has become an increasingly important area of study, and, to date there are many studies published, (Daily, 1997; Costanza, 1997; Bockstael et al., 1995; de Groot, 1994; de Groot et al., 2002; National Research Council, 2005; Barbier *et al.,* 1997; Pimm, 1997). These discuss the value of ecosystems and how this value is measured. However, it is challenging to give to clear cut definition or description of exactly what valuing the ecosystem is, and consequently, what are the ecosystem goods and services provided.

Despite this challenge, a comprehensive definition of ecosystem services can be defined according to Daily (1997) as 'the conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfil human life. They maintain biodiversity and the production of ecosystem goods'.

The earth's ecosystem is an inextricably linked complex. On a broad context, it has been recognised[1] (IGBP, 2008) that it involves interactions between biological, chemical and physical processes and human systems. It contains the millions of species and their interaction with one another and the physical environment. Together, they provide the ecosystem goods such as fuel, water, fish, timber etc. Some ecosystem services are not often thought about, but include the maintenance of global

[1] www.igbp.net

climate, recycling of wastes and contributing to biogeochemical cycles. Defra (2005) makes a distinction between the value of goods and services. According to their definition, goods are those which are used directly by humans (such as fish), and services are those which indirectly support human welfare (such as the provision of nursery for juvenile fish).

Returning to Daily's definition, we need to consider the benefits from this holistic interaction for the human profit. The Millennium Ecosystem Assessment (2003) identifies four categories of ecosystem services: provisioning, regulating, supporting and cultural. This grouping enables the services to become clearer, and shows how important they are in a role for human welfare.

It therefore becomes controversial when trying to place a value on these ecosystem goods and services. There are several types of valuation of ecosystem goods and services: spiritual/ cultural, economic, existence, option, use, and non-use value. Each value varies with individuals for numerous reasons (Costanza *et al*., 1989). For example, the Ganges River in India is valuable for the Hindus spiritual beliefs, and their value of it may be different from someone else's.

Existence value is the satisfaction one enjoys from knowing the existence of some entity. People living in the deserts of Africa may never experience the cold temperatures of the Artic, but they may value it just because they know it exists. Option value is that value one gets by not using a service or good from something, but knowing it is there if it proves to be useful in the future. Another type of value is use value. An example of this is the satisfaction one gets by swimming in the sea. In

contrast, non- use or indirect use value can be the value attached to the sea because it regulates climate, which in turn allows humans to live in a variety of environments. The main objective of valuation in decision making is generally to indicate the overall economic efficiency of the various competing uses of ecosystem goods and services.

The economic value of any good or service is usually measured in terms of what humans are willing to pay for the commodity, less what it costs to supply it (Barbier *et al.,* 1997), and based on direct or indirect benefits. Economic value is vital, because their value is often overlooked in decisions about resource use; not because they are unimportant, but because they are often regarded as 'free' goods. Since decision makers usually operate in economic terms, the value of these ecosystem goods and services must be estimated. This is not always an easy task, but as Bingham *et al.* (1995) puts it: 'Ecosystem services can be valued in dollars only after those services are well understood, yet predicting how ecosystem service flows will change as a result of human intervention is often difficult or impossible.' Economic valuation may therefore help inform management decisions, but only if decision-makers are aware of the overall objectives and limitations of valuation.

It is important to recognise that the problem of double counting should be acknowledged in any economic valuation study (Fisher *et al*., in press). This can be done by defining intermediate and final services provided by ecosystems, and by clearly stating which is used in the valuation study.

All economic valuation methods focus on the exchange value of ecosystem goods and services, which is their trading ratio; both of market and non-market exchange

processes. When traded on the markets, their value is reflected in the market price (Winkler, 2006). Economic valuation usually attempts to measure all goods and services in monetary terms, in order to provide a common metric in which to express the benefits provided by the ecosystem goods and services (Millennium Ecosystem Assessment, 2003).

However, other valuation methods for ecosystem goods and services exist, such as: contingent valuation, hedonic pricing, travel cost, cost-benefit analysis; and have been established to derive exchange values when market valuation does not capture the social value. It is true that in most instances, many goods and services are not reflected by market prices at all, and economic valuation alone cannot be used to value the ecosystem services and goods provided. Following this, a Total Economic Value (TEV) captures the non-marketed aspect of the benefits derived from ecosystems. This TEV captures direct and indirect use and non-use values to create the overall or total value of the ecosystem goods and services (Pearce and Warford, 1993).

With respect to the above, ecosystem valuation is with no doubt an important managing tool. Efforts to assess the monetary value of these ecosystem goods and services play multiple roles in managing the links between human and natural systems (Howarth & Farber, 2002).Used in the right context, and when the true value of the ecosystem, its goods and its services are understood and appreciated, economics can support improved management practices and sustainable development.

## 2. Coastal Lagoons: their importance and vulnerability

Coastal Lagoons are diverse ecosystems, and very different from estuaries. They are also the most valuable elements of coastal areas, both in terms of the natural ecosystem and biodiversity, and the goods and services that are derived from them. Coastal Lagoons are 'shallow coastal water bodies separated from the ocean by a barrier, connected at least intermittently to the ocean by one or more restricted inlets, and usually oriented shore-parallel' (Kjerfve, 1994). Lagoons grade into other coastal habitat types: semi-enclosed marine bays, freshwater lakes, and estuaries; and some of these intergradations may represent stages in an evolutionary sequence (Barnes, 1980). They are classed as wetlands according to the Ramsar Convention[2].

Lagoons are highly dynamic and rapidly changing ecosystems (Barnes, 1980; Mee, 1978; Sikora & Kjerfve, 1985). Their biology has not been thoroughly understood and their study has been neglected in comparison to estuaries. Sizes of coastal lagoons vary in size from small bodies of water, to large bodies, as in the Lagoa dos Patos in Brazil, with a surface area of 10,200 $km^2$ (Kjerfve, 1994). They occupy 13% of coastal areas worldwide. Its global distribution is estimated at 17.9% for Africa, 17.6% for North America, 13.8% for Asia, 12.2% for South America, 11.4% for Australia, and 5.3% for Europe (Barnes, 1980).

Coastal Lagoons serve many important ecosystem functions. In general, they trap inorganic sediments and organic matter, and thus serve as material sinks and filters (Kjerfve, 1994). They also exhibit high productivity and secondary production rates, because of their physical characteristics, and are extremely valuable for fisheries and

[2] www.ramsar.org

aquaculture. Regardless of location or latitude, coastal lagoons play a key role in maintaining hydrological balance, and providing habitat for birds, fish, mollusks, crustaceans, and other kinds of ecologically and commercially important organisms (Beck *et al*., 2001; Levin *et al.,* 2001).

The recognized importance of lagoons and their uses has partly resulted in their vulnerability. Increasing human development and use of coastal regions and coastal lagoons has resulted in the decrease of productivity and has contributed to making these areas highly sensitive and vulnerable (Gönenç & Wolflin, 2005). Human activities such as hydraulic works, land reclamation schemes, and changes in the inland watershed, impact upon the biology and features of lagoons. Increased use of fertilizers and pesticides in the ever growing agricultural and aquaculture industry has led to eutrophication of coastal lagoons, which in turn, reduces their productivity potential.

Lagoons are regions of restricted exchange (Tett *et al*., 2003), and are relatively small and shallow water bodies. Due to their variable admixture of fresh and salt waters, the physical environment is often severe and subject to considerable short and long term fluctuations (Colombo, 1977). Moreover, coastal lagoons are also liable to occasional catastrophic events and forcing from; invasion from the sea during storms, sea surges and hurricanes, landward from riverine floods, wind stress, tides, precipitation and evaporation balance, and surface heat balance (Kjerfve, 1994; Colombo, 1977). Some of these events do play a role in their evolutionary development, but because of their sensitivity to such features, it makes them particularly vulnerable to climate change and sea level rise.

Therefore, because coastal lagoons are valuable, productive ecosystems threatened by direct and indirect impacts, their ability to meet the increasing human demand for use and development has been reduced. All these factors make coastal lagoons valuable and vulnerable areas.

## *3. Coastal Lagoon Ecosystems: Goods and Services*

As previously mentioned, coastal lagoons are valuable, highly productive coastal areas. Their size and abundance and their fisheries interest make coastal lagoons a very important habitat to man (Barnes, 1980). Apart from fisheries, they offer numerous other valuable goods and services (Table 1).

The range of ecosystem goods and services provided by coastal lagoons is extensive, and varies from system to system. However, there are some key goods and services which are recognized and vitally important.

Due to their sheltered location on the coastline, their high nutrients and high primary and secondary productivity, coastal lagoons provide excellent sites for fishery and aquaculture development. Lagoons provide not only fish, but shrimp and prawns, clams, mollusks, oysters, and other kinds of food resources. The average natural fish production is about 100 kg/ ha/yr (Kapetsky, 1984), making them twice as productive per unit area than coastal seas and most fresh water systems (Macintosh, 1994). In some countries such as the Philippines, Thailand, and Sri Lanka, aquaculture from lagoon fisheries support a valuable amount of the country's economy (Brown, 1977).

**Table 1: Ecosystem goods and services provided by coastal lagoons. (Non-exhaustive).**
Adapted from Ewel, 2002; Postel & Carpenter, 1997; MEA, 2003; Barbier et al. 1997; Beck et al., 2001; Levin et al., 2001.; Schuyt & Brander, 2004.

| Ecosystem Goods and Services | Description |
|---|---|
| **GOODS** | |
| Food Resources | Fish, shellfish, waterfowl etc. |
| Timber, fuel wood and tree products | Materials for construction, cooking and heating, and tree products for tannins, glues, and handicraft resources etc. |
| Wildlife | Reptiles, fur bearing mammals etc. Can be used to attract tourism |
| Mineral Resources | Salt extractions, oil and gas, sand mining, peat etc. |
| Medicinal Resources | Flora and fauna can be used for the manufacturing of drugs, pharmaceuticals and for other medicinal purposes |
| Tourism | Lagoons itself can be a tourist attraction |
| Water transport | Usage of channels and waterways for water transport |
| Water supply | Source of water for domestic, agricultural or industrial use |
| Provision of land for agriculture | Promotes deposition of fertile soils and maintains the fertility of riparian land for a wide range of agricultural uses |
| **SERVICES** | |
| Hydrological | Help maintain the hydrological balance |
| Cleansing | Filtering of pollutants from water |
| Habitat provision | Provides a habitat for birds, fish, crustaceans and other kinds of commercially and ecologically important organisms. |
| Maintains biodiversity | By providing habitat for a variety of organisms, it allows them to interact and create an environment that is rich in biodiversity |
| Nutrient mixing | Mixing of nutrients from freshwater and tidal sources, making them very fertile environments |
| Biological productivity | Important nursery area for fisheries and other species. High primary productivity |
| Disturbance regulation | Capacity to mitigate floods and offer storm protection |
| Historical, traditional and cultural services | Have spiritual values attached to them e.g. ancestral associations or religious beliefs |
| Biogeochemical | Carbon sequestration, fuel production, maintains biogeochemistry: denitrification, sulphur reduction |
| Education and research | Provides opportunities for education, scientific and other research information. |
| Recreation | Provides natural beauty, relaxation and inspiration. E.g. social outings, bird watching etc. |

Their ability to effectively control nutrients and other chemicals and mineral particles from agricultural and urban areas is an important service offered by coastal lagoons. This is particularly important where intensive farming or urban developments occur. Surrounding areas of lagoons also provide excellent opportunities for agriculture and tourism sectors on the one hand and fishery and aquatic products on the other hand, (Gönenç & Wolflin, 2005) play important roles among coastal zone ecosystems because of their location, and provide a suitable breeding ground and habitat for many species.

Recreational uses of lagoons are frequent, especially in areas of high population density in developed countries (Colombo, 1977). In coastal resort towns, for instance, small lagoons are used as boating lakes and natural swimming pools, because of their shelter and consequent lack of strong wave action. This feature has also made them utilized for harbours, industry and commerce.

Their use for fisheries and aquaculture, tourism, urban, industrial and agricultural developments uses are not only uncontrolled, but often competing. With improving managing practices, and policies, it is hoped that these coastal lagoons will be sustained to continuing providing their vital goods and services to humanity.

## *4. Defining Human Development*

Human development, like any other term, can be defined in many ways, depending on the aims of what its definition is being used for. For example, human development is defined by United Nations by calculated human development indices (HDI) based on a number of variables (Human Development Report, 2001). Based on the index value, ranks of development are assigned for each country. However, whereas the HDI is a very valuable and important tool, in this study of coastal lagoons, such a definition of human development will be somewhat irrelevant, as the HDI tells nothing about the development of specific environmental areas, such as in coastal lagoons. It therefore becomes necessary to then assign a definition for use.

In this study, human development is defined according to the human impact on the lagoon in terms of years, i.e. in terms of the length of human use. Therefore, a lagoon that has been used by humans for centuries will be classed as having high human development, as compared to a lagoon which has only been used for only 50 years.

It is recognised that the length of use alone cannot justify the impacts upon the lagoon. However, that in essence is what this thesis will access; to see the changes and effects with 'human development', a combination of the length and the degree of use. The activities around the lagoon will help assess the impact of the human development, by also considering the use age. This is necessary because a lagoon may only be recently used, but have large pollution activities occurring around it, and may be heavily impacted, whereas another lagoon could have been used for a longer time, but with less negative impacts. It is becoming increasingly possible and important to identify

such possible negative impacts by the use of Coastal Lagoon Management, so that especially developing[3] countries can learn from other developed[4] nations.

[3] & [2] these terms are referred to the standard definitions of developed and developing nations.

# Chapter 2 : The Oropuche Lagoon, Trinidad

## *1. Site Description*

The location of Oropuche Lagoon lies on the South West coast of Trinidad (Figure 1) between 10° 14' N latitude and 61° 31' W longitude. It has more recently also been referred to as the Godineau Swamp, as reported by James *et al.*(1986), 'to include a coastal lagoon behind a sandbar with mangroves and a tidal mudflat, and fresh to brackish marshes on the landward side with rice paddies'. The lagoon is the third largest wetland in Trinidad.

This area of transitional water (EU, 2000) extends over a size of approximately 56 $km^2$ and is a choked lagoon (Barnes, 1980), aligned perpendicular to the coastline. The lagoon is predominantly estuarine, and salt water influences are mostly observed until the middle reaches of the lagoon (Juman & Sookbir, 2006). Moving inland from the west coast of the lagoon, there are pronounced changes in the ecosystem; from being marine and brackish to more freshwater inland (Ramnath *et al*., 1997). However, salt water influences as far inland as the road running parallel through the lagoon (seen in Figure 1**,** as the sample points traversing the map). In the dry season (Jan-May), there is significantly less freshwater runoff so saltwater intrudes further inland. The lagoon barrier is broken by two channels, which connects it to the sea, the Godineau River and Mosquito Creek. A mixed semi-diurnal tide exists. Tides are micro-tidal with a spring tide range of 97 cm, neap tide range of 44 cm and a mean semi-diurnal range of 77 cm (Juman & Sookbir, 2006). The average temperature is 27°C, and salinity ranges between 34.30 and 0.10 ppt (Norville & Banjoo, 2006).

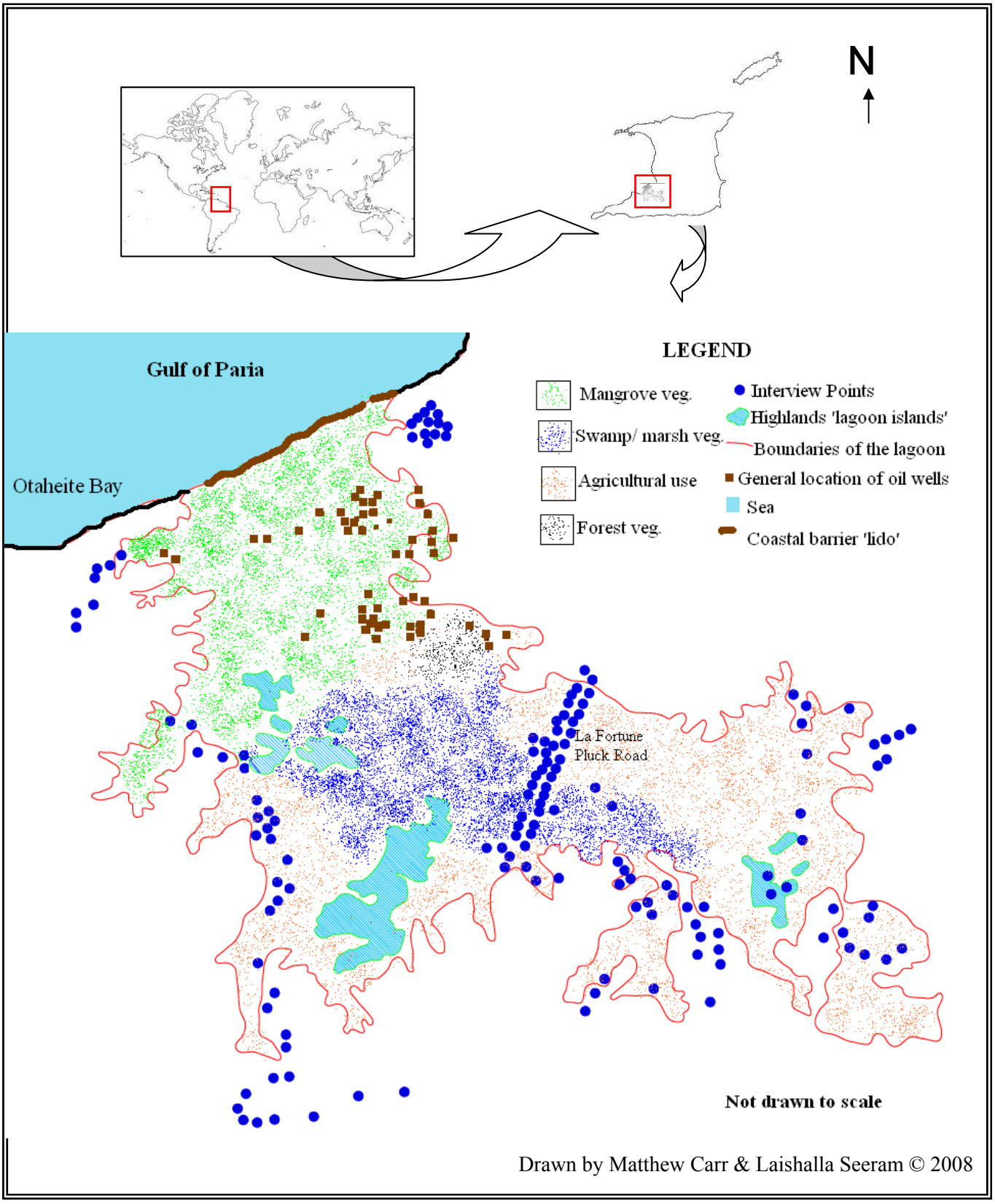


**Figure 1: Geographic location (Insets) and general map of the Oropuche Lagoon.**

The lagoon has traditionally been used for agriculture, mainly rice, and later for oil exploration activities, but, in order to get a better understanding of the usage and modifications of the lagoon, a brief **historical account** is given. The lagoon has undergone hydrological modification since 1852 (de Verteuil, 2000), and as such, is responsible for the previous and present activities and characteristics of the lagoon. In 1852, the natural sand barrier was developed into a higher permanent concrete barrier, and a main roadway was constructed across it.

After the emancipation of African slaves in 1838 in Trinidad and Tobago, indentured labourers were brought from India to work on the sugar cane plantations. At the end of indentureship, the Indians were offered either a free passage to return to their homeland, or, in lieu, a parcel of land to settle if they decided to stay in Trinidad. Many, who chose to stay, settled from 1878, in areas like Oropuche (Boston, 1967). Presumably, the possibility of rice **agriculture** in this low lying area was a major attraction, as it was similar in many respects to the rice growing areas in India.

As such, hundreds of hectares of mangrove were cleared to facilitate rice farming. Therefore, most of the lagoon (1,429 ha) was previously under rice cultivation, and rice farming was traditionally the major economic activity in the area (Juman, 2003). It has been told (personal communication, Anonymous) that rice was grown in the wet season, and during the dry season, short term crops such as watermelon, tomatoes, peas etc. were grown. The Oropuche Lagoon was once the nation's bread basket (Sharma, 1972).

In the 1920's oil was discovered in areas surrounding the lagoon, and so to facilitate operations, and explorations, the lagoon was drained at a cost of £80,000 (Higgins, 1996) and many roads and channels were cut into the lagoon. It was considered that even if the ensuring oil explorations were unsuccessful, the value of the reclaimed land would be over twice the capital value of the company (Higgins, 1996). The first oil well was drilled in 1923, on the southern boundary of the lagoon. Over 200 wells were drilled in the Oropuche Lagoon, (Higgins, 1996) but today, there are roughly only 25 producing wells left (the general location of the wells can be seen in Figure 1). Oil and gas drives the economy of Trinidad and Tobago, and this factor alone can help give an idea of the economic importance of the lagoon. Oil spills and leaks are certainly not uncommon in the area, but these impact negatively on the natural environment and on the other economic uses of the lagoon.

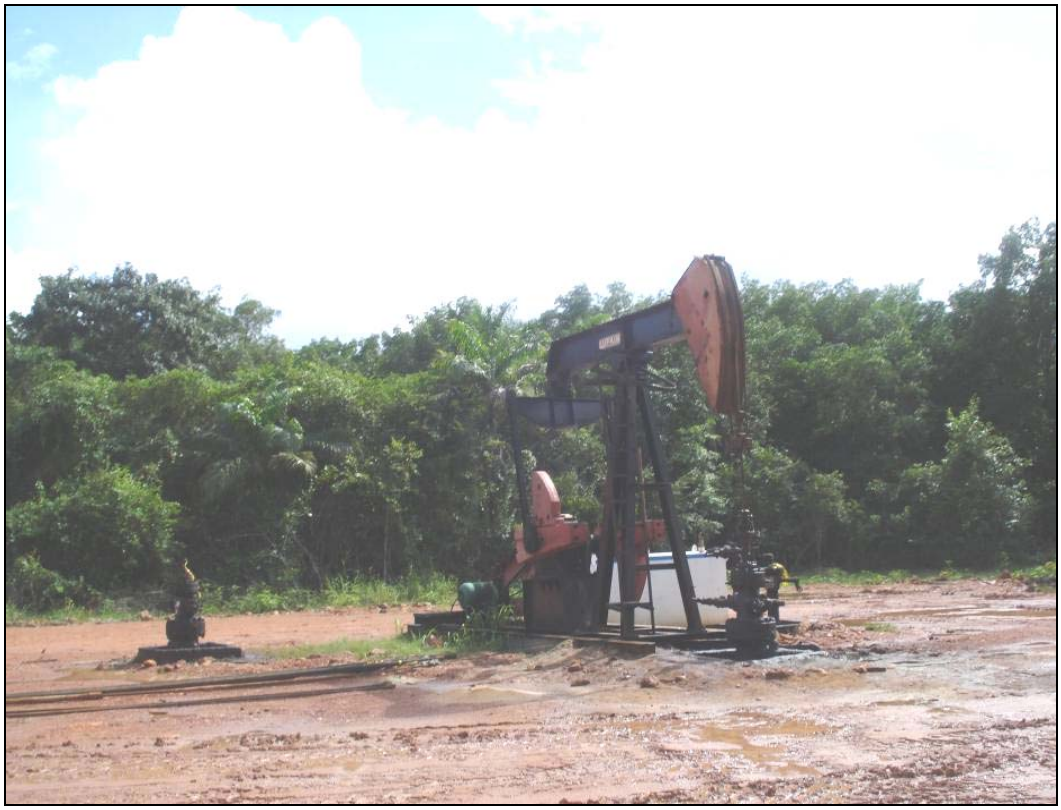

**Figure 2: One of the many oil wells within the lagoon.**

In the 1950's it was thought that improved **water management** in the lagoon would release more lands for agricultural production (Dwars & en Verhey, 1957) and so more drains and channels were constructed to alleviate flooding. This led to rapid drainage in some areas and the lowering of the water table. Also, the encroachment of sea water, especially during high tides, adversely affected the growing of crops, reducing the rice production feasibility. Several water control gates were installed in the main river channels to control and regulate the water flow in order to address the sea water intrusion (Landell Mills, 1991). However, a lack of proper maintenance and management of these gates over the years have resulted in the failure of the flood and salt control system. All these activities and changes have severely altered the natural lagoon environment.

**Figure 3: Water control gates installed in the lagoon to regulate the salt water intrusion and flooding.**

At present, the major types of **vegetation** in the lagoon are mangrove forest, tidal marsh, swamp forest, and grasses (*Eleocharis mutata* and *Cyperus articulatus*). Presently, there is no more rice cultivation due to the intrusion of salt water and

changes in government policies (Juman, 2003). Rice fields were left to lie fallow and are now occupied mostly by grasses and sedges. Some abandoned fields are used for grazing of cattle, goats and sheep, and are referred to as wet pastures. There are however, small areas of vegetable farming still present, mainly for the production of the traditional short term crops.

**Figure 4: Left: Sedges and grasses now occupying most of the lagoon. Right: Vegetable farming occupies the more westerly reaches of the lagoon, beyond the limit of salt water intrusion.**

There are over 30 species of important birds, including the national bird of Trinidad and Tobago, the Scarlet Ibis (*Eudocimus ruber*) (James, 1990), and important commercial **wildlife** such as the caiman (*Caiman sclerops*), blue crab (*Cardisoma guanhumi*) and cascadura (*Hoplosternum littorale*). The lagoon is used extensively as a nursery and feeding ground for many species of commercially important fishes, and it supports an extensive bank (Oropuche Bank) offshore, which is the focus of a thriving fishing industry (Chan A Shing, 2002).

**Figure 5: Support for a thriving fishing industry on the coast.**

The **catchment areas** of the lagoon mainly encompass small and scattered rural houses, and agriculture. Some areas bordering the lagoon are being developed for industry and housing. Several individual plots of lands within the lagoon are being reclaimed for building, and some large expanses of the lagoon are being cleared for development. There are plans for the development of a highway on the southern boundary of the lagoon and a reclaimed island at the front of it in the Gulf of Paria. These activities and land use changes are either already threatening or will potentially threaten the lagoon, either by direct encroachment or indirectly by pollution etc.

At present, the **governance** and **management** of the lagoon is poor. There are polices and legislations governing the use and protection of the lagoon (Goodridge, 2003), but evidence of poaching, pollution and cutting of the mangrove suggest that proper enforcement is lacking. Part of the lagoon, the mangrove swamp area is managed and protected under the Forestry Act, prohibiting hunting and fishing in closed seasons, and cutting of the mangrove. The Environmental Management Authority presently has the empowerment to govern this lagoon, for example pollution inputs, but there is no monitoring of the system.

**Figure 6: Pollution of the lagoon by indiscriminate garbage disposal.**

## *2. Methodology*

The economic valuation of the Oropuche Lagoon was conducted using the Step by Step guide as outlined by Barbier, *et al*. (1997).

**Step 1**: Choosing the appropriate assessment approach.

A total valuation assessment approach was chosen, as the study aims to demonstrate the net benefits derived from the lagoon, in order to make suggestions for improved management. However, only the marketed goods and services will be valued. Non-marketed values such as aesthetic value are not measured in the context of the present study.

**Step 2**: Defining the wetland area and specifying the system boundary between this area and the surrounding region.

The definition of the lagoon area and the boundaries was adopted from earlier studies by Juman & Sookbir (2006). In defining the system and recognising its difference from the surrounding region, a topographic map was used. From it, vegetation such as mangrove, marsh, wet pasture and swamp were included; all under the 25 feet (7.62 metres) above contour boundary. The resulting definition is shown in Figure 1.

**Step 3**: Identify the goods and services of the wetland ecosystem and rank them in terms of importance (e.g. high, medium, low).

This step was accomplished using various data sources and from field observations. Visits were made to government ministries and agencies, where scientific studies and consultancy reports were obtained. From them, a list of the components, functions, and attributes were derived, but more briefly stated as goods and services. They were ranked by order of importance from a combination of both an ecological and economic standpoint.

**Step 4 and 5**: Relating the goods and services to the type of use value (e.g. direct use, indirect use and non-use) & Identifying the information required to assess each form of use (or non-use) which is to be valued and how to obtain the data.

To achieve these steps, a field survey was conducted in the lagoon (Box 1).

**Box 1: Developing and implementing the Survey**

A survey questionnaire was developed which focused on finding out about the uses and the economic gain from the Oropuche Lagoon (Appendix 1). It was developed using guidelines from Fink (1995a, 1995b, 1995c, and 1995d), Frey & Oishi (1995), Litwin (1995) and Babbie (1998).

The questionnaire was peer reviewed at the 3rd European Conference on Lagoon Research (19-23 November 2007, Naples, Italy) and pilot tested in the lagoon. Appropriate changes were made and a final version of the questionnaire developed.

In Trinidad, visits were made to several relevant agencies and government ministries, who were believed to have some affiliation to the lagoon. This was done to get

background information and reference to any previous studies that were conducted concerning the lagoon.

The defined boundary was outlined on a topographical map, used as the field map. Field visits were conducted between December 2007 and January 2008.

Enumeration data from the governmental Central Statistical Office (Ministry of Planning and Development) was used to determine the sample size in the lagoon. Based on the Community Register of 2000, Population and Housing Census for Trinidad and Tobago, the topographical area of the lagoon was overlaid on top of an enumeration map. It fell within two regional corporations, Siparia, and Penal/ Debe. Population data was then extracted from the enumeration districts. This encompassed a total of 10 districts, with a total of approximately 1439 households. Using a 10% value of this population, a target of achieving a minimum of 144 surveys was made.

Households were chosen at random, but the lagoon was subdivided into the enumeration districts it fell within, and a 10% target of each district was used to encompass the total sample size. Sample locations were taken around the perimeter of the lagoon (<1 mile) and in populated areas within the lagoon (Figure 1).

When a prospective household was approached, the purpose and scope of the project was explained and a self introduction was made. Face to face interviews were conducted and lasted between 10-30 minutes based on the respondents' use of the lagoon. One person per household was interviewed. A final sample of 153 interviews, and 6 pilot tests were conducted within the Oropuche Lagoon.

Questionnaires were numbered, dated and coded according to the locality of where the interview was conducted. At the same time, the numbers were plotted on the field map, to record points of sampling.

Responses were inputted into a data base as 'word for word' of the responses and then grouped and coded. Simple data analyses were made. A list of the uses was derived, and indirectly, the functions/ services to the locals were also obtained. Where it was possible, monetary benefit data was obtained from the respondents. Not all respondents felt comfortable giving such information, but other data such as quantity of goods was obtained in order to later assign a price value.

Photographs were taken to show the various uses encountered in the lagoon, and where the use varied with the location within the lagoon, this was also indicated on the field map.

Other information gathered from previous reports and studies, and through local authorities and private institutions, was obtained. This included economic information on the major uses: oil and gas production, agriculture and fisheries production in the bay which the lagoon supports.

**Step 6 & 7**: Quantifying economic values & implementing the appropriate appraisal method

The market prices were used as an indicator of the willingness to pay for the goods obtained from the lagoon. The economic valuation was done using the direct use goods, as identified as the major uses. These were as a result of the final services offered by the lagoon ecosystem. The market price values of these goods were used to put a value to the lagoon. Values were calculated using raw data obtained from private and government agencies, and from field results, and the values for 2007 were used.

## *3. Results: The Use and Value of the Oropuche Lagoon*

### 1. The Use of the Oropuche Lagoon

From the survey, only 62% of respondents said that they used the lagoon. The main types of these uses are summarised below:

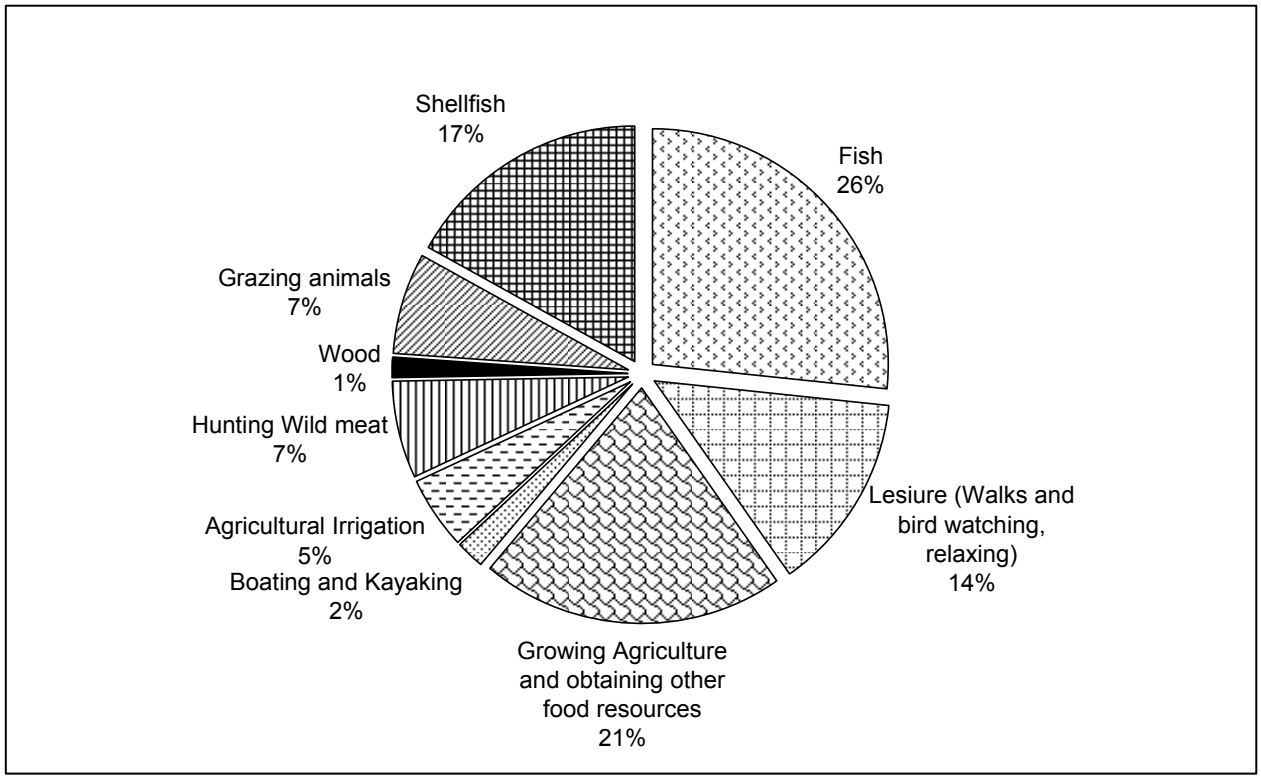


**Figure 7**: **Percentage of various uses of respondents in the Oropuche Lagoon.**

The majority of the lagoon's goods and services are used by the local people, as part of their routine life. For example, because the lagoon has been historically associated to their ancestors etc, most people do not use the lagoon for commercial uses, but as a subsistence or support to their normal life. There is a large cultural and traditional attachment and value to the lagoon. Although this would increase the overall value of the lagoon, among other values such as opportunity value, it was not the aim of the

report. It is however recognised that these values are of great importance, and hence recommendations are being made for such valuation studies to be done on the lagoon. The three main uses of the lagoon can therefore be classed as those which give the lagoon the most value. These uses are oil production, fisheries, and agriculture.

As a first visitor to the lagoon, the oil producing capacity of the lagoon is not obvious, because the oil wells are located in restricted areas of the lagoon. However, on further analysis and enquiry, it becomes evident as to how much value the lagoon has because of this oil production.

The lagoon acts as a very important nursery for fisheries just at the coast bordering the lagoon (Juman & Sookbir 2006; Ramsundar 2005). This subsequently supports a very productive fishing area, called the Otaheite Bay, which is represents an important fishery landing site for the country.

The third major use, agricultural production is an important good provided by the lagoon. This good not only allows the local population to sustain themselves, but also contributes to the food security of the country. Although agriculture in the lagoon was once more important than today, it still continues to play a vital role. Apart from obtaining food subsistence, many people have an attachment to the lagoon, and its ability to provide food resources. In some of the words of the locals *'… the lagoon was our happiness…we didn't go to school, but we know how to work hard, so we still earned a living from the planting in the lagoon.. I wish I was young again, for the lagoon to be how it was…'* The goods and services of the lagoon were identified (Box 2) and Table 2.

**Box 2: Goods and Services of the Oropuche Lagoon**

*GOODS*

**Oil:** this good forms the basis of the country's economy. The lagoon currently produces 400 barrels of crude oil per day, but is at the end of the production. A value of €8,287,706.21 was obtained from this activity in 2007 (gross).

**Agriculture:** The fertile lands of the lagoon are used for this important activity. The lagoon has been called the 'food basket' of the country in earlier years because of the high agricultural produce. Rice production was the main crop, but today vegetables are mainly planted. Agriculture in the lagoon is however declining.

**Fisheries:** The lagoon supports over 29 fish species (Ramsundar, 2005) distributed over the different salinity zones. Most of the fish caught in the lagoon are done by recreational and part-time users (Ramsundar, 2005). The most common fish catch including shell fish are the catfish (*H. bonillai*), common snook (*C. undecimalis*), oysters (Crassostrea rhizophorea) and crabs (*Callinectes* sp.).

**Wildlife:** Apart from fisheries, other wildlife species are hunted. This is done so as recreational hunting, and for subsistence income. Animals that were reported to be caught in the lagoon include the lappe (*Agouti paca*), and the manicou (*Didelphis marsupialis*).

**Water:** Some water extractions are made from the lagoon to irrigate agricultural produce. However, there are high incidences of salt intrusion and care is made with the use since with the presence of salt water in the irrigation water, crops are damaged.

*SERVICES*

**Supports a range of biological diversity**: the lagoon consists of many environments, including mangroves, tidal mudflats, lagoon islands and fresh water and brackish water marshes. Among its range of biological diversity is the national bird, the Scarlet Ibis (*Eudocimus ruber*).

**Water Transport:** Although the lagoon is not used for transport on a large scale, local users still use the lagoon's water channels to access the sea on the coast, or for recreation.

**Recreation**: The lagoon provides several recreational opportunities including fishing, hunting, and picnicking. The majority of the users are those who live within and around the lagoon, and they have indicated by survey that it brings joy to them.

**Cultural, historical and traditional**: There is a strong cultural link to the lagoon as evidenced by the many Hindu ceremonies and traditions within it.

**Flood and flow control:** The lagoon has the capacity to control flooding to the lands surrounding it. However, because the channels are not maintained, and cleaned, this service is not effectively allowed to be carried out.

**Supports a productive fishing environment:** The main fisheries caught on a commercial basis occur on the sea in front of the lagoon, in the Gulf of Paria. The lagoon supports this productive fishing area by acting as a nursery and shelter for juveniles. This fishing area is one of the major fishery landing sites in the country.

**Table 2*:* Use of Oropuche Lagoon (Adapted from Barbier *et al*., 1997)**

| Economic Values | direct | indirect | Non-use |
|---|---|---|---|
| *Goods* | | | |
| 1. Oil and Gas | ♦♦♦ | | |
| 2. Fish and Shell fish | ♦♦♦ | | |
| 3. Agriculture | ♦♦♦ | | |
| 4. wildlife | ♦♦ | | |
| 5. agricultural water | ♦ | | |
| 6. wood | ♦ | | |
| 7. grazing area (grass) | ♦♦ | | |
| *Services* | | | |
| 1. Recreation | ♦♦♦ | ♦♦♦ | |
| 2. cultural areas | ♦♦♦ | ♦♦♦ | ♦♦♦ |
| 3. flood and flow control | | ♦♦ | |
| 4. water transport | ♦ | ♦ | |
| 5. biological diversity | ♦♦ | ♦♦♦ | ♦♦♦ |
| 6. nursery for fisheries | | ♦♦♦ | |
| 7. nutrient retention | | ♦♦ | |
| 8. sediment retention | | ♦♦ | |
| 9. shoreline stabilisation | | ♦♦ | |
| 10. water quality maintenance | | ♦♦ | |
| 11. groundwater recharge | | ♦♦ | |
| **Key:** | High ♦♦♦ | Medium ♦♦ | Low ♦ |

Table 2 shows the results of Step 3 which aims to illustrate the importance of determining and ranking the relevant direct and indirect use and non-use values of wetlands such as the Oropuche Lagoon. The lagoon's most important direct uses are: oil and gas production, fish resources, and use for agriculture. The most important ecological functions (services) provided and used indirectly from the lagoon's existence are recreation, and nursery for fisheries. Biological diversity and cultural areas are used both directly and indirectly and are important services offered. These services also have a high value for the lagoon's non-use; for example, the importance it may serve in its own existence, without human interference. Other services such as flood and flow control, water quality maintenance etc, are not particularly significant, though they still play a part in the lagoon's functioning.

## 2. Measuring the Economic Value of Oropuche Lagoon

The economic valuation was done using the direct use goods, as identified as the three major uses: oil production, fisheries, and agriculture. The market price values of these three goods were used to put a monetary value to the lagoon. It is recognised that the value is not a true representation of the total economic value for the lagoon, but it represents the monetary benefits directly obtained from the lagoon, and to give an idea of how roughly how much monetary benefits is directly obtained from the lagoon.

### a. Oil Production

In 2007, approximately 400 barrels of oil per day were obtained from the all the 25 producing wells left in the lagoon.

⇨ (400 x 365)= 146000 barrels produced in 2007.

The average price of oil in 2007 was determined (Jan-Dec). This value in US $ is $77.66 for West Texas Intermediate (WTI), as reported by the South Trinidad Chamber of Industry and Commerce (STCIC) 2008.

Income from oil therefore:

Price of oil per barrel x number of barrels produced

⇨ (146000 x 77.66) = **US $11,338,360.00** in 2007 from oil explorations.

In 2007 (US$31,064. per day)

To convert the US currency to Euros, the average daily exchange rates between Jan-Dec 2007 was used to determine an overall annual average value. The daily rates were available from Bank of Canada (2008) who had an online calculator available for converting currencies, and they had the data for the entire period available. From it, the average annual exchange rate was determined.

The resulting average exchange rates in 2007 had a value of 0.730944; i.e.

1 US $ = €0.730944

Value of oil contribution in euros:

Oil contribution in US $ x average exchange rate (US→Euro)

⇨ 11,338,360 x 0.730944 = **€8,287,706.21** in 2007.

b. Agriculture

Agricultural values were determined from the field research. Each interviewee was asked about the quantity and type of crops harvested from the lagoon, even if they were used for personal use. This was necessary because it was found that many people used the lagoon to plant crops as a subsidy for their food budget, increasing the benefits from the lagoon and its value, but were not traded on the formal market. In order to put standardised values to the agricultural goods, an average annual price (for 2007) was obtained for each crop. The average annual price was averaged from the monthly reports Jan-Dec 2007, (but excluding the months August and November) of the wholesale prices and volumes of agricultural commodities. The data from the months of August and November were not available at the time of the writing of the

report. These reports were produced by the National Agricultural Marketing and Development Corporation (NAMDEVCO) [5], for the Southern Wholesale Market, Debe. Some people, who sold the produce formally on the trading market, were unable to or preferred not to state the quantity of the goods they obtained from the lagoon. However, they were able to give the approximate income value obtained from the goods in 2007, and so this value was used in calculating the total value from agriculture.

**Table 3: Quantity and value of the agricultural produce from the Oropuche lagoon in 2007.**

| Commodity | Unit | 2007 Average Price TT$ | Quantity Produced | Value TT$ |
|---|---|---|---|---|
| **ROOT CROPS** | | | | |
| Cassava | Kg | $3.40 | 4536.00 | $15,408.79 |
| **CONDIMENTS AND SPICES** | | | | |
| Hot Peppers | (40 lb)Bag | $151.94 | 357.80 | $54,363.06 |
| **VEGETABLES** | | | | |
| Bodi beans | 5lb Bndl. | $17.66 | 6650.00 | $117,424.22 |
| Seim beans | Kg | $9.62 | 50.00 | $480.85 |
| Pigeon Peas | Kg | $11.48 | 1995.84 | $22,912.24 |
| Cucumber | Kg | $5.30 | 12700.80 | $67,365.04 |
| Melongene (M) | Kg | $3.48 | 722.13 | $2,513.82 |
| Ochro | 100's | $15.58 | 4600.00 | $71,663.40 |
| Pumpkin | Kg | $2.45 | 4989.60 | $12,209.55 |
| Tomato (M) | Kg | $10.19 | 1088.64 | $11,089.98 |
| Caraillie (M) | Kg | $5.24 | 4536.00 | $23,750.50 |
| **FRUITS** | | | | |
| Watermelon | Kg | $4.54 | 907.2 | $4,119.98 |
| | | | **TOTAL** | $403,301.44 |

| | |
|---|---|
| Cumulative income from those who did not give produce quantity, but stated income earned from agricultural produce in the lagoon | $164,560.00 |
| **TOTAL VALUE OF AGRICULTURE** | **$567,861.44** |

[5] Personal Communication: Mr. Avenesh Ali

From the results of the survey, the calculated value of the agricultural produce is **TT$567,861.44**. However, this value represents only the 28% of respondents who indicated that they used the lagoon for agriculture. Also, since the survey can be said to represent roughly only 10% of the households within the lagoon area, a value which represents the use of the entire lagoon should be calculated.

100% of the lagoon residents = 1439 (Central Statistical Office, 2002)

43 households contribute to the lagoon value of TT $ 567,861.44 which represents 28.3% of survey respondents.

Therefore: 28.3% of 1439 ≈ 407 residents (who may also use the lagoon for agriculture).

⇨ Total value of residents' use of the lagoon for agriculture therefore:

(567,861.44 / 43) x 407 = **TT $$5,374,874.51**

Using the annual average exchange rate in 2007 (Bank of Canada):

TT$ = € 0.116191

Value of agriculture in the lagoon in 2007:

⇨ $ 5,374,874.51 x 0.116191 = **€ 624,512.04**

## c. Fisheries

The fisheries landings and value for 2007 was not available within the timeframe of the project. Local data are gathered by field researchers and then the data is complied and published by the Fisheries Division. However, this publication does not become available until the middle of the following year (Barran, -personal communication).Therefore; an average value was estimated for 2007 using the previous landings and value of the last five years: 2002-2006 (inclusive). This is shown in Figure 8.

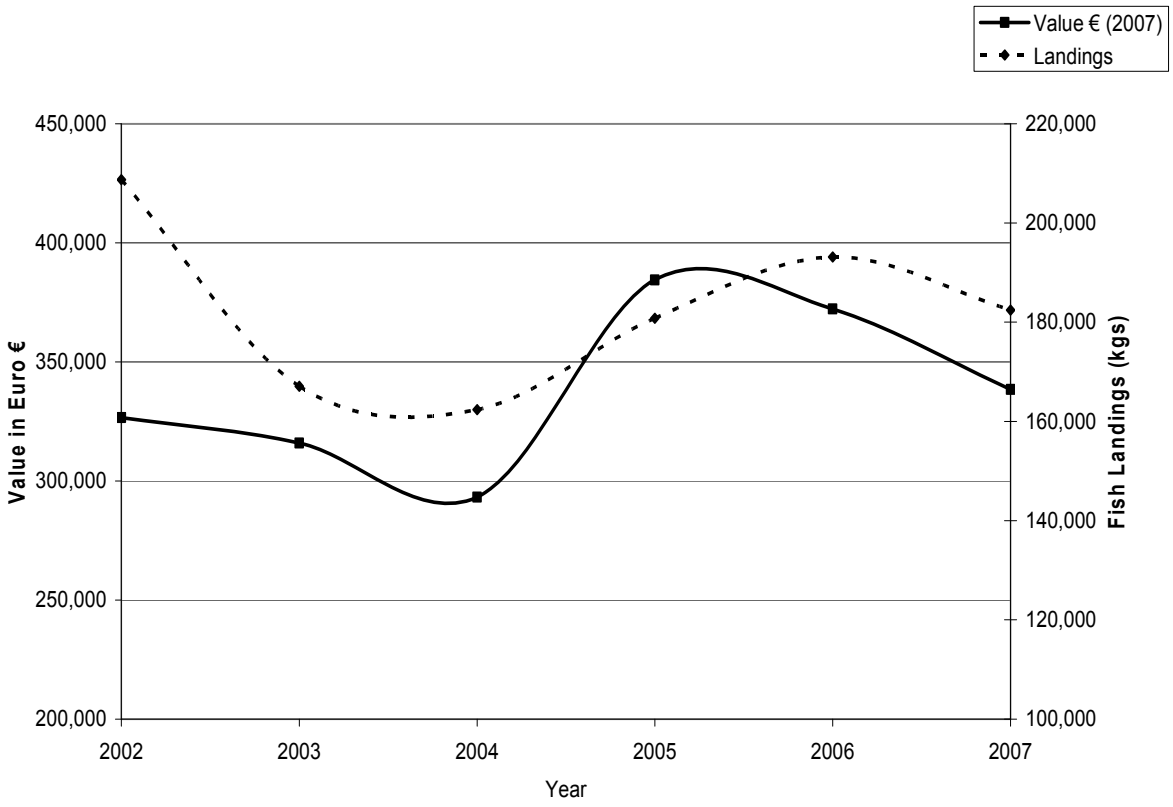


**Figure 8: Graph of Fish Landings and estimated Value in € (2007) in the Otaheite Bay, Trinidad. (Source of raw data: Fisheries Division).**

The value for 2007 was estimated to be worth **TT $2,913,035.00** Again, using the annual average exchange rate in 2007 (Bank of Canada):

1 TT$ = € 0.116191

Therefore: 2,913,035 x 0.116191 = **€338,468.00**

Combining the values obtained from the three main uses: oil production, agriculture and fisheries: (€8,287,706.21 + € 624,512.04 + €338,468.00), the estimated value for the lagoon in 2007 was €9,250,686.25.

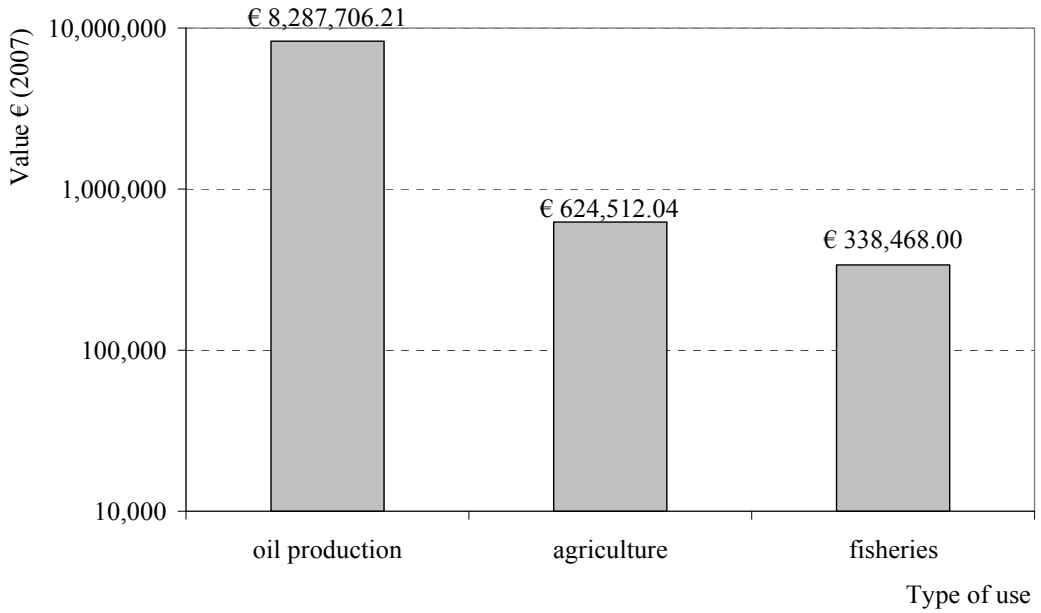


**Figure 9: Value of the three main economic uses of the Oropuche Lagoon.**

On an area basis value of the lagoon:

56 $km^2$= €9,250,686.25

1 $km^2$ = € 165,190.83 (in 2007)

## *4. The impact of human development*

The lagoon has been described by several authors (James *et al*., 1986; Ramcharan *et al*,. 1982; Ramsundar, 2005) as heavily impacted by anthropogenic activities. Although human development around and within the lagoon is not high, it has been heavily impacted. Overall, the level of human development as defined for the use of this study can be said to be low. However, the impacts from the use of the lagoon are very high. The major impact comes from the oil and gas industry and agriculture. These have greatly modified the hydrological regime of the lagoon.

The main impacts of the human development and activities in the lagoon are summarised in Box 3.

## Box 3: Impacts of human development in the Oropuche Lagoon

**Fishing:** there is a widely reported occurrence of over fishing occurring within the lagoon (Ramsundar, 2005). As a result, there has been a decrease in the fish catch and production.

**Oil Exploration:** This activity has the largest impact upon the lagoon. The lagoon has been drained, and several channels cut to facilitate oil explorations, and many alterations as been made to the hydrological regime of the lagoon (Juman & Sookbir, 2006). Some of the natural mangrove vegetation has also been cleared, and has led to the reduction of habitat areas and the true productive capacity of the lagoon from them. Roads were also constructed through the lagoon which has also led to habitat fragmentation, and increased accessibility for exploitation of the other lagoon resources. Oil spills frequently occur in the lagoon from the wells and pipelines that run through the lagoon. Some of it is due to the corrosion of old inactive pipelines that still carry residual flow and pollution from past oil related industrial processes (Ramsundar, 2005). Oil spills not only impact on the sediments and water quality properties, but also on the natural habitats, and vegetation. It has also contributed to the salt water intrusion within the lagoon, which can change the species distribution.

**Agriculture:** Approximately 233 ha of mangrove vegetation in the lagoon have been cleared to facilitate rice farming (Juman, 2003). However, this production has ceased, and now the areas are abandoned and colonised by grasses. Today, this area is being used by numerous bird species as a feeding ground. However, many other areas are presently used for growing agriculture, and although fertilizers are not widely used, this activity has also contributed to the alteration of the hydrological regime of the lagoon. This activity has also changed the ecological status of the lagoon's vegetative communities, and may have some impact on its biological diversity.

**Urbanisation:** Many areas of the lagoon are under threat or already lost from pressures of urbanisation and changing land use. Some people regard the lands of the lagoon as waste land and see other potential for housing in it. This was stated during some of the interviews conducted. As a result of this opinion there are pressures on the lagoon for land conversion. Urbanisation has also led to increase of pollution within the lagoon. New urbanisation proposals will alter the fishery and sediment dynamics occurring in the Otaheite bank, and in turn affect the economy for the local fishermen and the contribution to the national earnings.

**Drainage manipulation:** The construction of many canals and channels in the lagoon has led to salt water intrusion and subsidence in the lagoon. Penetration of saline water further inland, well beyond the earlier limits became problematic after the construction of one of the main channels, the Central Drain (Landell Mills, 1991). This has consequently led to the loss of agricultural lands, and its production. Changes in species diversity and structure will occur as a result.

**Pollution**: Pollution arises from the oil exploration activities, as solid wastes by indiscriminate dumping by the locals or people who come to the lagoon specifically to dispose of their garbage. This not only affects the natural landscape and aesthetics of the lagoon, but also poses as threat to the fauna.

## *5. Discussion*

The economic value for the Oropuche lagoon was calculated to be worth **€9,250,686.25** in 2007. This value is based on the market value of the major uses of the lagoon, and it is by no means an accurate value, but a rough estimate, to put the lagoon on a greater national context as to the benefit, and potential benefit of this important coastal lagoon. It is recommended that a greater and more comprehensive economic valuation of the lagoon be undertaken.

This value calculated is the gross value. It should be kept in mind that in order to obtain the net true benefits from the lagoon, other input factors needed to be considered. For example, in determining the net value from fisheries, fishermen's time, contribution to fuel, boat maintenance etc. need to be considered. For the net value from the oil production, information on the installation costs of the wells, well maintenance, engineer salary etc. all need to taken into account. However, because of the limits of the project, the gross value was given, because it would take more time, more questioning and general resources to determine the net value. As stated, the valuation aims only to give a rough estimate of how much the lagoon is worth, so that it can be seen as more important for management interventions to occur. Nonetheless, to agree with Howarth & Farber (2002), attempts to calculate the value of environmental goods and services can provide insights into the tradeoffs between market activity and environmental quality that are implicit in the process of economic growth. These efforts can promote informed debate concerning the achievement of sustainable development. This is needed in the Oropuche Lagoon.

The uses of the Oropuche Lagoon are not widely varied. The major uses by the local residents are for agriculture and recreation, mainly in the form of fishing and shell fishing. However, on a more national use, the oil producing capability of the lagoon is contributing highly to its present value. Without this good being derived, the lagoon may not have such a great economic value, but on the other hand, if oil was not present in the lagoon, then it may not have been drained, so the human impact would have been lower.

It has been reported (Anonymous) that the oil produced in the lagoon is locally converted to other by products and then these products are sold. However, the market value for oil was used since it represents what the oil is worth using a standard market value (in this case the price per barrel of the oil produced). As previously mentioned, there are 25 producing wells left in the lagoon, but it once accommodated about 200 wells. It should be noted that these 25 wells are at the end of their production phase, so the present value can be said to be lower, than what its total value from oil has produced over its time. As such, so too the future value of the lagoon from oil production will change. As oil production is no doubt important to the economy of the country, but it should be recognised that its production will not be sustained forever, and that greater efforts should be made to increase the long term sustainability options for the lagoon and those that depend on it.

The fisheries value obtained from Fisheries Division gives an estimate of the value of fishing activities linked to the lagoon. The lagoon acts as a nursery and nutrient source for the fishes caught in the Otaheite Bay (Ramsundar, 2005). However, it must be

noted that the reported landings for the site also includes fishes caught further out in the Gulf of Paria, with no obvious connection to the lagoon.

This value for fisheries also does not include the value of fishes caught within the lagoon for personal and recreational use. Many respondents were unable to identify or name the fishes caught, and there was no formal market for the shell fish sold. When the fishery resources caught from the lagoon were sold, they were mostly done on the sides of road ways (Figure 10) (personal observation). Therefore, the market prices were difficult to determine, and so only the formal fishery market prices were used from the Otaheite Bay. Although it was not possible to value the fish and shell fish caught within the lagoon itself, the value from the Otaheite Bay can give just an idea of the value of fisheries from the lagoon and functional value.

The two main species of fisheries landed (tonnes) in the Otaheite Bay are shrimp (Penaeids *sp*.) and Barracudas (*Sphyraena barracuda)*, (Barran, personal communication) with the shrimp having the highest landing contribution. Shrimp represents a valuable fishery resource for Trinidad, not only in terms of landings, but also for dollar value and foreign exchange earnings (Fisheries Division, 1997). Though the value of the fishery contribution is relatively small (2% of national GDP), it is making a significant contribution to the economy in terms of employment, nutrition, and the stability it gives to the rural communities (Fisheries Division, 1997).


**Figure 10: A food resource: shell fish (*Melongena melongena*) obtained from the lagoon is mostly sold at the side of roadways.**

Agriculture in the lagoon represents an important use for the locals. Many respondents depend on their harvest as a supplement to their household food budget. For some others, the activity of planting in the gardens helps them to obtain physical exercise, and is a source of comfort, to pass the day. Though the value for agriculture had to be adjusted into incorporating the entire possible use for residents of the lagoon, it was possible to do this from the percentage of respondents who used it for this purpose and then to interpolate to incorporate all the possible users.

There is a strong cultural heritage linked to the lagoon, which can be said to be reflected in the present use of agriculture. As seen from the average age of the respondents, the population of lagoon residents are ageing, and many have used the lagoon throughout their lifetime, as too did their parents. Although the traditional

usage for rice production no longer occurs, other short term crops are becoming more important. There are many evidences of this cultural link, but the value of which is difficult to determine. However, if it was known, it would no doubt increase the overall value of the lagoon. It was also found that the average age of the residents in the lagoon were due to the fact that most of the younger generation had moved out of the area. Respondents admitted that the older generation had ensured that the younger generation was well educated, and as a result they did not depend on the lagoon, or use the lagoon as once did by their parents, leading to migration out of the area.

The lagoon can be said to be one that is decreasing in general use, because of the lack of proper interest and management in the area. This is already evident by the generation gap. This is the challenge for management, but one that needs urgent attention. With declining fisheries in the Otaheite Bay, and in the lagoon (based on people's response), oil wells which are nearly expired, and a decrease in agricultural interest, it means that the value of the lagoon from these uses is also presently declining. This is where integrated management of the lagoon should come in.

The lagoon has a rich biodiversity, including a roosting site for the Scarlet Ibis, the country's national bird. The mangrove swamp still plays a vital role in storm protection, shoreline stabilisation, and nutrient retention. Also, the lagoon is located in the Southern region of the country, within reasonable distance of the second city, and a large shopping centre. Therefore, there is potential for the area to be kept as an ecotourism site for tourists, and even for locals. Ecotourism has been practised in similar wetland areas in Trinidad (e.g. Caroni Swamp), and so it is anticipated that the lagoon will be able to increase the potential revenue from tourism, and indirectly,

foreign exchange earnings. Once used in this way, local community groups can be put to manage the lagoon, since they will be getting the most benefit from the revenue. This can encourage more sustainable use on their basis, and in turn they themselves will learn to appreciate and encourage the younger generation to sustain the goods and services of the lagoon.

Apart from this potential, management of the lagoon needs to consider all other activities occurring around the lagoon's catchment area. Many respondents reported that pollution was a major cause of damage of threat to the lagoon. This pollution included chemical pollution from agricultural runoff, oil spills, and solid waste. Although there are pollution rules for the country, they are not enforced, and monitoring does not occur. Before the lagoon can be managed, an objective, or perhaps several objectives for the lagoon should be given, so that management for the lagoon can be to sustain agriculture, tourism, fisheries, or for many uses, to be integrated with specific goals.

**Figure 11: Oil pollution in the lagoon, one of the effects of human development.**

# Chapter 3 : The Ria Formosa, Portugal

## *1. Site Description*

The **location** of Ria Formosa lies in the South coast of Portugal, in the Algarve region, between 37° 02' N latitude and 07° 47' W longitude. The lagoon encompasses a true barrier island system (Figure 12) consisting of a coastal dune barrier, running parallel with the coast, and defending a shallow, warm water lagoon with, channels, tidal flats and islets (Figure 13). The intertidal area is mostly constituted by sand, muddy-sand flats and salt marshes (Michler, 2003). It is one of the most important lagoons in southern Europe, and is also cited in the Ramsar Convention as a wetland of international importance[6].

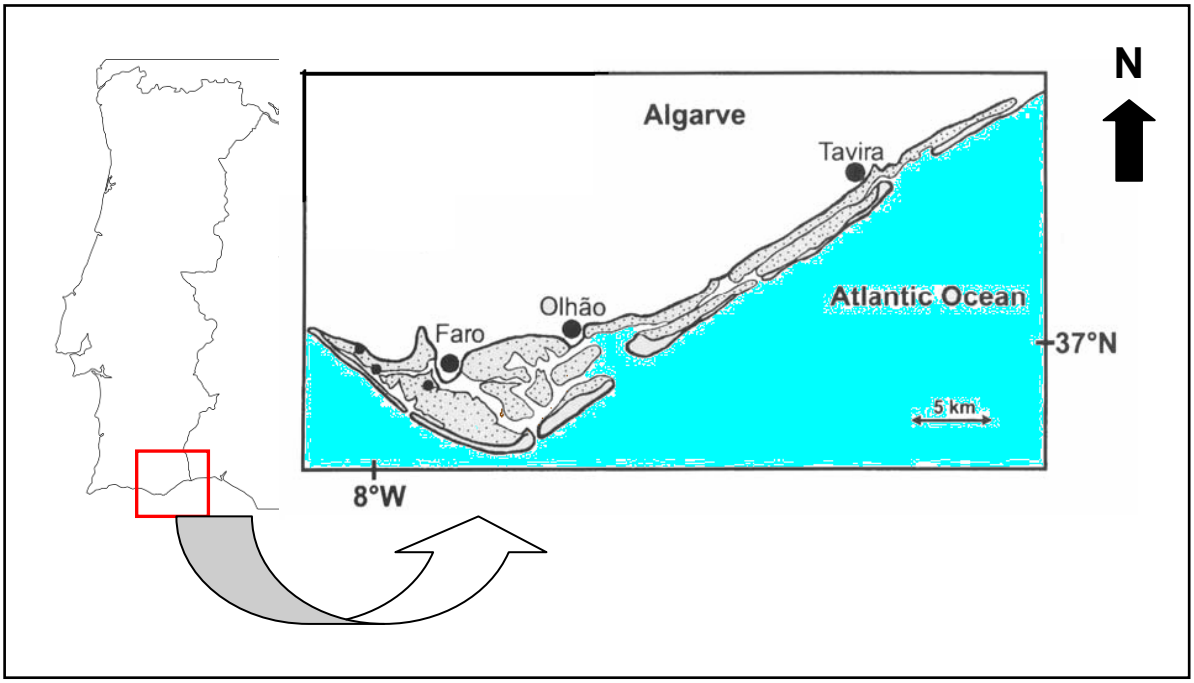


**Figure 12 : Geographic location of Ria Formosa, Portugal. (Modified from Michler, 2003).**

[6] www.ramsar.org

This lagoon extends over an area of approximately 160 $km^2$ and is classed as mesotidal. Water exchanges with the Atlantic Ocean occur through six inlets, but the lagoon is predominantly coastal. It has been reported ((Falcão *et al*., 1985 and Serpa *et al*., 2005) that except during heavy rainfall, particularly during winter time, and apart from small rivers and some seasonal streams, there is no significant freshwater input into the lagoon and salinity ranges from 35.5 to 36.9 PSU year round. The tidal range varies from 2.8 m to 1.3 m at spring and neap tides, respectively, (Sprung *et al*., 2001; Sprung & Machado, 2000),and the temperature ranges between 12 to 27ºC. (Loureiro, *et al*, 2006; Newton & Mudge, 2005)

This lagoon **ecosystem** is considered a nursery for a large number of important coastal species (Michler, 2003) and has a very high primary production. Around 66 species of fishes are reported to be found (Serpa *et al*., 2005), with 60% of that having a high/ medium commercial value. Aside from this obvious importance, the lagoon is highly diverse in flora and other fauna. It is a major feeding and breeding ground for migratory birds from Northern Europe, and contains several endemic plant species.

**Figure 13: The lagoon system: showing tidal flats, salt marshes, sand and channels.** (Left: Ariel photo of lagoon in vicinity of the Faro Airport; Right: near the bridge, Praia de Faro) (Original Photos).

The Ria Formosa has been reportedly used for many centuries, but no main literature was found which recorded exactly when. However, it was mainly used for fishing activities, especially sardine fishing (Falcão *et al*., 2003; Bernardo *et al*., 2002). Today, the main **economic activities** are tourism, fisheries and aquaculture (mainly clams and oysters). It has been reported (Serpa *et al*., 2005) that during the last decades tourism became the base of Algarve's economy. Undoubtedly, the Ria Formosa contributes to this increase, both indirectly and directly. However, the major economic support comes from the fishing and shell fishing industry (Figure 14). The extensive intertidal areas are used for the clam farming and aquaculture ponds. To give a better idea of its importance, the culturing of bivalves (including *R. decussates*, *Ruditapes romboides, Spisula solida)* in the area represent 80-95% of the total bivalve production in Portugal (Procesl *et al*., 1999; Pita *et al*., 2002; Serpa *et al*., 2005). The economical annual revenue from the lagoon represents a main source of income for a significant number of families in the region (CEMAS, 2003). Apart from these activities, salt sand extractions also occur within the lagoon, and contribute towards its high economic value.

Around the lagoon other activities are impacting on the lagoon. The major town to the lagoon is that of Faro, with a population of about 58,664 residents (INE, 2006), but other towns include Olhão, Tavira and Villa Real de San Antonio. Together, they have an average resident population of 146,624 (INE, 2006). There is the presence of an international airport on the border of the lagoon, and several golf courses. Tourism activities include boat tours within the lagoon, and ferries to the barrier islands.

**Figure 14: Economic uses of the Ria Formosa. (**Left: Shellfish harvesting (Photo Courtesy of Girija Pavatkar; Right: Aquaculture ponds in the Parque Natural de Ria Formosa, Olhão (Original Photo)

The Ria Formosa and some of its hinterland has been included in a Natural Park (18 400 ha) and accepted as a Natura 2000 network and a Ramsar site, due to the recognition of its environmental importance. Today, it is managed as a natural park (Natural Park of Ria Formosa). Other legislations govern the management of the lagoon including the Water Framework Directive of the European Union.

The main characteristics, of the Ria Formosa are summarized in Table 4, obtained from Ramsar Reports. The uses of the goods and services of the Ria Formosa, and their importance are outlined in Table 5.

## Table 4: Ramsar report for Ria Formosa[7]

Country: Portugal — Ramsar Site No.: 212
Region: Europe — Wetlands International Site Reference No.: 3PT002

*General and Geographical site information:*

Subregion: Southern Europe
Geographical position: Marine & coastal wetlands
Designation Date: 24-11-1980
Coordinates of site center (degrees): 37°02'N 007°47'W
Coordinates of site center (decimal lat long):37,03 -7,78
Total site area: 16000 hectares
Maximum elevation: 25 meters
Transboundary: no
Boundary changes: no
Number of separate units: 1
Administrative region: Algarve

**Uses and Threats:**

Current land use:
Within the site's surroundings/catchment:
- Transport route
- Urban development
- Tourism (unspecified)
- Agriculture (unspecified)

Within the Ramsar site:
- Tourism (unspecified)
- Gathering of shellfish
- Fishing (unspecified)
- Habitat/nature conservation
- Marine/saltwater aquaculture
- Agriculture (unspecified)

Threats:
Within the site's surroundings/catchment:
- Industrial waste pollution
- Disturbance from transport artery
- Tourism-based /recreational disturbance (unspecified)
- Domestic sewage pollution
- Urban development (unspecified)
- Agricultural development impacts

Within the Ramsar site:
- Tourism-based /recreational disturbance (unspecified)
- Over-fishing
- Drainage/reclamation for agriculture
- Conversion to intensive aquaculture projects

Social and cultural values:
- Tourism
- Non-consumptive recreation
- Archaeological/historical site
- Unspecified fishing

Land tenure/ownership:
Site's surroundings:
- Private owner(s)

Within the Ramsar site:
- Private owner(s)
- National/federal

**Information on Conservational Issues:**

Management plan status:
- A site-specific plan exists but has not yet being (has not been) implemented

International conservation designation:
- EC Special Protection Areas

National conservation designation:
- natural park

**Ecological Data:**

Wetland Category:
- Man-made wetlands
- Inland wetlands
- Marine & coastal wetlands

Wetland Type (dominant type in **bold**):
- Salt exploitation sites; salt pans, salines, etc. (5)
- Irrigated land; includes irrigation channels and rice fields (3)
- Aquaculture (e.g. fish/shrimp) ponds (1)
- Seasonal/intermittent saline/brackish/alkaline marshes/ pools (Ss)
- Permanent saline/brackish/alkaline marshes/pools (Sp)
- Permanent saline/brackish/alkaline lakes (Q)
- Permanent rivers/streams/creeks; includes waterfalls (M)
- **Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea (J)**
- Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes (H)
- **Intertidal mud, sand or salt flats (G)**
- Sand, shingle or pebble shores; includes sandbars, spits and sandy islets; includes dune systems and humid dune slacks (E)
- Marine subtidal aquatic beds; includes kelp beds, sea-grass beds, tropical marine meadows (B)
- Permanent shallow marine waters in most cases less than six metres deep at low tide; includes sea bays and straits (A)

Biological Values:
Fauna type:
- waterbird wintering/non-breeding/dry season area
- staging area for migratory waterbird species
- breeding area for waterbirds

Flora type:
- supports endemic species

Ecological Changes:
- Significant negative changes are likely to occur
- Significant/substantial negative changes are occurring

[7] www.ramsar.org

## 2. The Goods and Services of the Ria Formosa

The main goods and services provided by the Ria Formosa are summarized in Box 4.

**Box 4: Summary of the main Goods and Services of the Ria Formosa.**

*GOODS*

**Shellfish:** shell fish farming occupies more than 1000 ha in the Ria, and is responsible for nearly 80% of Portuguese exports. The clam (*Ruditapes decussatus*), and the oyster (*Crassostrea angulata*) are cultivated in the lagoon inter-tidal areas, and have the most economic value. Average annual production of clams 5000 tons year $^{-1}$ and oyster production 2000 tons year $^{-1}$ (Falcão *et al*., 2003). In February 2008, clams had a market price of €13/ kg, and oysters €2.5/ kg. (Anonymous- shellfish producer)

**Salt and sediment extraction**: the salt extracted in the Algarve represents 50% of the national salt production. A significant part of Algarve's salt is produced in the Ria Formosa saltpans. Based on the mean price for industrial salt (0.30 €/kg), at production of 77955 tons (in 2001), salt extraction in the Ria Formosa yields about 23 million euros (Serpa *et al.,* 2005).Sand extraction is mainly for the maintenance of the system's hydrodynamics, but the dredged material goes to the construction sector (Serpa *et al.*, 2005). In 2004, the value of sand dredged from the Ria Formosa was €8,394,441 (Serpa *et al*., 2005).

**Fisheries:** mostly a nursery for juveniles of oceanic fish species. Annual fish production of 2700 tons year $^{-1,}$ but some feel this potential for fish farming is not fully exploited (Falcão *et al*., 2003). Most important commercial species include seabass (*Dicentrarchus labrax*), soles (*Solea ssp.*) (Serpa *et al*., 2005). This activity contributes to 20% of registered fishermen in Portugal (Serpa *et al.*, 2005).INE (2007) reports that for Olhão alone for 2006 had an income of €9,805,000 from sea fish.

*SERVICES*

**Water purification**: has an intensive exchange of 50-75 % (until 90 %) of the water mass in each tidal cycle (Newton & Icely, 2002). However, some areas under direct impact of untreated wastewaters have poor water quality, due to combined effect of weak renovation of lagoon water (Falcão *et al*., 2003.)

**Nutrient retention:** although the lagoon has limited exchange with the Atlantic, it still flushes well, but yet retains some nutrients, contributing to its primary productivity (Newton & Mudge, 2005). Also affected by sediment bottom influence.

**High Primary Productivity:** primary production in the Ria Formosa is due to the combined effect of phytoplankton microphytobenthos macroalgae, macrophytes, and salt marsh plants (Newton & Mudge, 2005). This in turn leads to high fisheries production. (Seasonal productivity).

**High biological diversity**: it comprises of many diverse environments such as barrier islands, extensive mud flats, sand banks, dune systems, salt marshes, and substantial *Zostera* beds (Michler, 2003), which promotes a high species and biological diversity.

**Wildlife habitat:** provides shelter for many threatened species whose habitats are receding in Europe eg. (*Sterna albifrons*). It is also home to important species such as the purple gallinule (*Porphyrio porphyrio*), which is rare in Portugal. It accommodates wintering birds from Northern and Central Europe, and acts as a stop over point on migration routes between Europe and Africa.

**Protection against action of sea**: the borders of the 5 barrier islands protect the lagoon, and thereafter the hinterland from direct action of the sea.

**Tourism:** it has become the base of the region's economy over the last few years. Ria Formosa contributes to bird watching tourists; beach attraction etc. and indirectly supports restaurants, hotels, sports clubs, car rentals etc. In 2002, tourism in the Ria Formosa contributed €25,850,000 to Portugal's economy (Serpa *et al*., 2005). The cost a 2hr bird watching trip in the Ria costs €25/ pers.[8]

**Cultural Heritage:** some methods of fish and clam production are cultural activities e.g. culturing of bivalves on ground plots is a traditional activity, and these fishing activities has supported many families in the region over generations. There are signs of Phoenicians, Carthaginians, Greeks, Romans and Arabs in the lagoon, an important heritage value.

**Water transport**: the channels of the Ria Formosa are used to support tourist boat tours, fishermen and ship navigation to the industrial ports of Faro, and Olhão. A 2 hr boat trip in the Ria's channels cost an average of €18/ pers.[9]

**Research & Education:** The Ria provides numerous opportunities for research and education. For example, it is extensively used by researchers and scientists from the University of Algarve, and the Centro de Educação Ambiental de Marim (CEAM).

[8] &[10] www.formosamar.pt

**Table 5: Use of the Ria Formosa (Adapted from Barbier et al., 1997)**

| Economic Values | direct | indirect | Non-use |
|---|---|---|---|
| *Goods* | | | |
| 1. Fisheries | ♦♦♦ | | |
| 2. Shell fish (*clams, oysters*) | ♦♦♦ | | |
| 3. Agriculture | ♦♦ | | |
| 4. salt | ♦♦♦ | | |
| 5. sand | ♦ | | |
| *Services* | | | |
| 1. Recreation/ tourism | ♦♦♦ | ♦♦♦ | |
| 2. cultural areas | ♦♦ | ♦♦ | ♦♦ |
| 3. flood and flow control | | ♦♦ | |
| 4. water transport | ♦♦♦ | ♦♦♦ | |
| 5. biological diversity | ♦♦♦ | ♦♦♦ | ♦♦♦ |
| 6. nursery for fisheries | | ♦♦♦ | |
| 7. nutrient retention | | ♦♦♦ | |
| 8. sediment retention | | ♦♦ | |
| 9. shoreline stabilisation | | ♦♦ | |
| 10. water quality maintenance | | ♦♦ | |
| 11. research opportunities | ♦♦♦ | ♦♦♦ | |
| **Key:** | High ♦♦♦ | Medium ♦♦ | Low ♦ |

Similarly to the goods and services in Oropuche, those for the Ria Formosa were ranked, from a combined ecological and economic standpoint. It is seen from Table 5 that the most important direct uses of the lagoon are fisheries, shell fish, and salt. These are the main goods obtained. Agriculture is produced around the lagoon area, so though it is directly obtained as a resource, and of medium importance. Sand is produced as a by-product of dredging, and though sold, is not a very important direct use as compared to the others mentioned. Recreation, water transport, nursery support for the surrounding coastal areas, and nutrient retention, were identified as the most important services offered indirectly by the Ria Formosa. Biological diversity, cultural areas and research opportunities are other important services, but these are used indirectly, directly and are also important even though they may not be used (non- use). The Ria Formosa has been designated a natural park, and this helps to show how important this service is to the lagoon and its use. Although the lagoon's cultural area is not highly important, it still has activities such as traditional fishing and history attached to it.

## *3. The impact of Human Development*

The Ria Formosa supports a wide range of goods and services, both directly and indirectly, and contributes to an important significant amount of Portugal's economy and indeed that of the Algarve region. The level of human development can be classed as medium, and so too are the effects of human development.

The effect can also be looked at in many ways, depending on the focus. For example, if looking the lagoon in its present main management objective, the Ria is conserved as a Natural Park, but the impacts of human development then becomes very evident and large. However, if looking at the Ria from the point of view of tourism, then the impact of human development seems little, and the system appears to be well managed supporting and providing a diverse array of activities (Fonseca, personal. communication).

Despite this view, the impact of human development should be looked at as a general all rounded one, so that the goods obtained are maximized, yet sustainable and the services of the coastal lagoon to be also maintained. It can be said then, to look at the effect of human development on the ecosystem functioning of the lagoon, for the provision of goods and services.

Based on the human activities occurring within and around the lagoon (therefore having an indirect impact on it), Box 5 summaries the main reported impacts from the main human activities in the lagoon.

## Box 5: Impacts of human development in the Ria Formosa

**Urbanisation**: Rapid urbanization has been placing the lagoon under stress from the increase in disposal of solid waste and domestic sewerage (Newton *et al*., 2003). Contamination may directly affect fauna and flora living in that water through lethal and sub-lethal effects and can modify their interrelationships and the community structure (Newton & Mudge, 2005). The water quality is affected. Decreased species diversity and ultimately mass mortality of the biota are possible consequences of eutrophication (Newton & Mudge, 2005)

**Tourism**: Runoff from golf courses can lead to high nutrient inputs into the lagoon, and if severe, can lead to eutrophication. The high number of tourists, particularly during the summer, places increased stress on the sewerage disposal system (Loureiro *et al*., 2005; Mudge *et al*., 2007; DITTY Project, 2002)

**Agriculture**: The catchment hosts farms of pigs and poultry farming, and fields of crops. Runoff from these areas contributes to sewerage water entering the Ria, and also contains loads of antibiotics, medicine and trace metals (Padinha *et al*., 2000). Contamination of the lagoon by pathogenic micro-organisms where people bathe and where bivalves are harvested further represents a public heath risk (Newton & Mudge, 2005). This may then lead to a reduction in economic clam productivity and loss of tourism potential. High contents of N & P from fertilizers and pesticides also contribute to the incidences of eutrophication in the lagoon.

**Port and shipping transport**: Alien species are being introduced into the lagoon from these activities, which can succeed over the native species, changing the ecosystem structure (Ramos, 2008). These species may arrive attached to the boats as fowling, or in ballast water. Oil spills may occur from the ships.

**Dredging**: This activity can physically damage important components of the plant ecosystem such as the sea grasses in the Ria Formosa, and also temporarily increase turbidity. Sea grasses can also be affected by the growth of epiphytic algae (Newton & Mudge, 2005), resulting in higher loads of unfixed sand in the system. Sea grasses are very important for the trapping of bivalve-larvae and its disappearance could be of a long term problem for the recruitment of many species. Dredging also affects the bivalves. On the other hand, it can improve the tidal dilution and flushing of the nutrients from the lagoon. The opening of a new inlet in the west of the lagoon should also improve the tidal dilution and flushing of the nutrients (Pacheco *et al*., 2007). In the Ria, the major effect on the littoral physiography caused by the inlet opening was the reduction of the down drift sediment budget, making the down drift barriers more vulnerable to erosion and decreasing the sediment supply to the eastern inlets (Pacheco *et al*., 2007). However, dredging inside the navigable channels and inlets is often needed in order to ensure navigational safety.

**Aquaculture:** Foreign species of fishes and clams were brought to the lagoon to be cultured (Ramos, 2008). However, attached to these species, were others such as algae which can contribute to causing a change the ecosystem structure. Excess nutrient inputs can lead to eutrophication of surrounding waters.

**Fishing**: Alien species are being brought to the Ria by fishing activities (Ramos, 2008).Local fishermen fish, not only in Portuguese waters, but other areas such as Morocco. Upon return, unwanted by catch is discarded into the harbor and local waters, releasing alien species into the lagoon ecosystem. A high incidence of illegal fishing activities is putting pressure on natural banks and juvenile stages (Michler, 2003). The group of the razor shells is particularly under threat, and due to their high market price, tons of this species are collected from the wild.

**Clam harvesting**: The physical disturbance of sediment caused by harvesting induces the oxygenation of reworked layers and causes the disturbance of microphytobenthos distribution, and of macro/micro fauna burrows (Falcão *et al.,* 2006).

# Chapter 4 : The Venice Lagoon, Italy

## 1. Site Description

The **location** of Venice Lagoon lies in the North East of Italy, between 45° 26' N latitude and 12° 19' E longitude. It has been characterized[10] as a lagoon which includes dunes, tidal channels, bare mudflats, sea grass beds, salt marshes, and barrier islands (Figure 15 & Figure 16). It represents one of the world's best known lagoons, both in terms of usage and cultural heritage, and also one that has survived and sustained humans for many centuries (Salzano, 2005). The Venice lagoon is an extremely complex area in which cultural, social, and environmental features of international significance coexist (UNESCO, 1995).

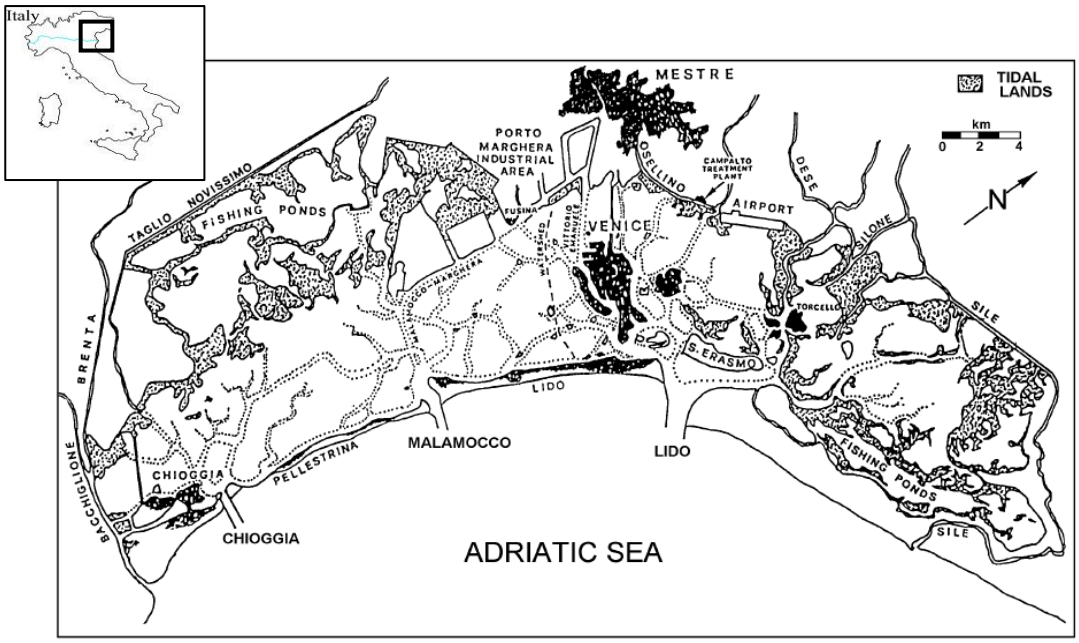


**Figure 15: Geographic location of the Venice Lagoon, Italy. (Modified from: Ravera, 2000).**

[10] www.corila.it

The lagoon covers an area of 550 $km^2$, and is shallow, with a 1.5m average water depth (Suman *et al*., 2005). Two long barrier islands heavily defended by seawalls separate the lagoon from the Adriatic Sea to the east, however, it is connected to the sea, by three large entrances, from which it is influenced by the tides. These tides have mean amplitude of 20 cm during neap tides to 100 cm during spring tides (Suman *et al*., 2005). The hydrological pattern created within the lagoon creates a typical brackish environment, with a salinity gradient that ranges from 10% near the mainland border to 32% at the inlets.

The lagoon has been termed by Salzano (2005) as 'an accident in nature', because it is in an unstable equilibrium, sustained by man. The Serenissima Repubblica has managed the natural and anthropogenic forces acting upon the lagoon and has sustained it for centuries. The lagoon was recorded to be first used about 1000 years ago, for protection against attacks, fisheries and for transportation access. There are many studies and reports which document Venice's **history**, and therefore no detailed account will be made in this site description. From the point of view of its origins, it should be noted that the Lagoon of Venice is similar to others in the Mediterranean, but the subsequent natural evolution and human impact is what differentiates it from other sites[11].

The natural **ecosystem** of Venice includes endemic plant species, and breeding ground and over wintering for bird species and other significant biodiversity. Ornithological surveys carried out over many years clearly demonstrate that the Lagoon of Venice is one of the most important wetlands in Italy for wintering,

[11] www.ramsar.org

migrant and breeding water birds (Smart & Viñals, 2004). The site consists of brackish and freshwater wetlands with woodlands and wetland meadows.

**Figure 16 : Ecosystems of the Venice Lagoon: sat marshes and mudflats (Source: www.ramsar.org)**

The lagoon has a broad range of **economic uses**. Fishing has been a cultural activity of the lagoon, but more importantly shellfish production in the lagoon is one of the most productive in Europe, due to its tidal influences[12]. Clam aquaculture in the lagoon accounts 60% of national production, but its actual sustainability is uncertain (Anonymous).This activity is being threatened by pollution from heavy metals, illegal harvesting, and sediment re-suspension. Tourism is also a very important feature of the lagoon, but tourist pressure is undoubtedly putting pressure upon the ecosystem. The number of tourists is around 20 million per year. The lagoon of Venice is one famous for its traditional water transport (Figure 17), which is what helps to attract tourists to the lagoon. These are by no means the only uses of the lagoon, but some of the major ones.

[12] http://www.ramsar.org/wn/w.n.venice_lagoon2.htm

**Figure 17: An economic use of the Venice Lagoon: the gondola rides** (Source: Sorosh-Wali, UNESCO)13.

Around the lagoon, there are refineries and a nearby industrial port (Porto Marghera), which in turn facilitates large tourist cruise ships, and merchant goods. Intensive agriculture occurs in the drainage basin. Two main cities (Venezia, Chioggia) and a number of towns and villages (400,000 residents) are distributed around its perimeter and on some islands; and a resident population of 60,000 in the historical centre (CORILA). Urbanization is therefore high, if not for the resident population, but for facilities to support tourism. There is also the third busiest Italian airport (CORILA) and the relics of the core of Italy's petrochemical and chemical industry. Therefore, it can be seen that human development both in terms of age and activities are high.

A summary of the lagoon's characteristics is given in Table 6, as summarized by a Ramsar report, which highlights the uses and threats to the lagoon.

[13] http://whc.unesco.org/en/list/394/documents/

## Table 6: Ramsar report for Laguna di Venezia: Valle Averto (Venice Lagoon)[14]

Country: Italy
Region: Europe
Ramsar Site No.: 423
Wetlands International Site Reference No.: 3IT042

General and Geographical site information:

Sub region: Southern Europe
Geographical position: Marine & coastal wetlands
Designation Date: 11-04-1989
Coordinates of site center (degrees): 45°21'N 012°09'E
Coordinates of site center (decimal lat long):45,35 12,15
Total site area: 500 hectares
Minimum elevation: -1 meters
Maximum elevation: 1 meters
Transboundary: no
Boundary changes: no
Number of separate units: 1
Administrative region: Veneto and Venezia

**Uses and Threats:**

Current land use:
Within the site's surroundings/catchment:
- Hunting (unspecified)
- Recreational/sport fishing
- Commercial fishing
- Aquaculture (unspecified)
- Agriculture (unspecified)

Within the Ramsar site:
- Research
- Education site
- Tourism (unspecified)
- Habitat/nature conservation
- Aquaculture (unspecified)
- Agriculture (unspecified)

Threats:
Within the site's surroundings/catchment:
- Inappropriate management practices
- Disturbance to vegetative community through cutting/clearing
- cessation of traditional land management practice with adverse effect
- Excessive hunting of species

Within the Ramsar site:
- Inappropriate management practices
- Disturbance to vegetative community through cutting/clearing
- cessation of traditional land management practice with adverse effect

Social and cultural values:
- Aquatic vegetation (reeds, edible plants, mangrove prods.)
- Tourism
- Current scientific research
- Conservation education

Land tenure/ownership:
Site's surroundings:
- Provincial/region/state
- Private owner(s)
- National/federal

Within the Ramsar site:
- Private owner(s)
- Foundation/non-governmental organization/trust
- National/federal

**Information on Conservational Issues:**

Management plan status:
- Implemented/ing approved site-specific plan/measures

International conservation designation:
- EC Special Protection Areas

National conservation designation:
- wildlife sanctuary

**Ecological Data:**

Wetland Category:
- Man-made wetlands
- Inland wetlands
- Marine & coastal wetlands

Wetland Type (dominant type in bold):
- Aquaculture (e.g. fish/shrimp) ponds (1)
- Seasonal/intermittent freshwater marshes/pools on inorganic soil; includes sloughs, potholes, seasonally flooded meadows, sedge marshes (Ts)
- **Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea** (J)
- Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes (H)

Biological Values:
Fauna type:
- supports rare/endangered bird species
- water bird wintering/non-breeding/dry season area
- staging area for migratory water bird species
- important for reptiles
- breeding area for water birds
- important for mammals
- important for amphibians

Flora type:
- outstanding variety of species present

Ecological Changes:

- Significant negative changes are likely to occur

[14] www.ramsar.org

## 2. The goods and services of Venice Lagoon

The main goods and services provided by the lagoon of Venice is summarised below:

**Box 6: Goods and Services in Venice Lagoon**

*GOODS*

**Fishing:** Apart from commercial fishing, recreational fishing also occurs within the lagoon. Strong traditional linkages of the fishing activity are present in the lagoon. Although its activity has declined (Ravera, 2000) it still provides a social and economic role in the lagoon (Silvestri *et al*. 2006).

**Clam production:** Clam fishing activity in the lagoon involves two endemic species: *Tapes decussatus*, and *Scrobicularia plana,* and a new introduced species *Tapes philippinarum.* Today more than 2000 people are employed in the clam fishery sector (Nunes *et al*. 2004), with an estimated annual production of clams in the lagoon at about 4,000 tons (Silvestri *et al*. 2006). This accounts to 60% of the national production.

**Hunting:** At present, hunting is generally pursued as a sport and mostly involves aquatic birds.

**Agriculture:** Intensively occurs within the lagoon's perimeter and watershed. The main crops are vegetables and fruit trees (Ravera, 2000).

*SERVICES*

**Water and other Transport**: Venice has one of the most important *ports* in Italy (30 million of tonnes of goods per year and 1 million cruise ship passengers[15]. The lagoon also supports in its catchment, the third busiest Italian airport and the relics of the core of Italy's petrochemical and chemical industry (Marghera). Apart from these, the lagoon itself is famous for its dependence on water transport, especially within the historic centre, and attracts many tourists for 'gondola' rides.

**Tourism and recreation:** Venice is visited each year by more than 20 million people (CORILA). This makes tourism, an activity producing high economic value. It is also important recreational site in itself providing services for fishing and boating. Its aesthetic beauty and heritage attracts as a result, these economic activities.

**Research and Education:** Being a very unique system, many research and education activities are conducted on the lagoon for a wide range of fields. Some important organisations include University of Padova, CORILA, SPICOSA, ISMAR, and Provincia di Venezia.

[15] www.corila.it

**Supports a wide range of biodiversity:** The area comprises of a wide range of environments including mud flats, salt marshes, and lagoon islands. As a result, it supports rare/endangered bird species, as well as wintering birds, and migratory water bird species[16]. Lagoon fish fauna also shows a great variety of species.

**Protects against storms and flooding**: The lagoon's mud flats, which form marshy areas, emerging from the water only at low tide; acts as a sponge, and has a certain regulatory effect on the water level of the lagoon. The lagoon also protects the hinterland from direct action of the sea, and buffers against the immediate effects of sea level rise. The efficiency of the natural barriers (sandbars) was improved with various works (Ravera, 2000).

**Traditional, historical and cultural:** Declared a World Heritage Site by UNESCO in 1987, it is one of the most important natural areas in Italy due to the richness and variety of the flora, fauna and biotypes. Has a very rich and well preserved history.

**Supports a productive fishing environment**: Biological production is high, but enhanced by sewerage and fertilizers. The lagoon plays an important role in the fishery production of the Mediterranean, being a nursery area and feeding ground for many fish exploited commercially (Aspden *et al*., 2004)

**Sediment and nutrient retention:** The sediment dynamics within the lagoon are critical for the ecological status of the system, and are controlled mainly by wave energy, river flow and coastal currents (Aspden *et al*., 2004).

The uses of these goods and services offered by the Venice Lagoon and their importance, is outlined in Table 7.

[16] www.ramsar.og

**Table 7 : Use of Venice Lagoon (Adapted from Barbier et al. (1997)**

| Economic Values | direct | indirect | Non-use |
|---|---|---|---|
| *Goods* | | | |
| 1. Fisheries | ♦♦ | | |
| 2. Shell fish farming (*clams*) | ♦♦♦ | | |
| 3. Agriculture | ♦♦ | | |
| *Services* | | | |
| 1. Recreation/ tourism | ♦♦♦ | ♦♦♦ | |
| 2. cultural/traditional area | ♦♦♦ | ♦♦♦ | ♦♦♦ |
| 3. flood and flow control | | ♦♦ | |
| 4. water transport | ♦♦♦ | ♦♦♦ | |
| 5. biological diversity | ♦♦ | ♦♦♦ | ♦♦ |
| 6. nursery for fisheries | | ♦♦♦ | |
| 7. nutrient retention | | ♦♦ | |
| 8. sediment retention | | ♦♦ | |
| 9. shoreline stabilisation | | ♦ | |
| 10. water quality maintenance | | ♦♦ | |
| 11. research/ scientific area | ♦♦♦ | ♦♦♦ | |
| **Key:** | High ♦♦♦ | Medium ♦♦ | Low ♦ |

The most important goods (direct use) derived from the Venice lagoon are: fisheries, shell fish, and agriculture (around lagoon). Agriculture and fisheries ranked medium, when compared to clam production, which had the highest importance. Recreation, water transport, and a nursery area for fisheries were the highly ranked services indirectly offered by the lagoon. As an example, tourism has a very high use, but it is a result of the features of the lagoon and its functions. Other services such as flood and flow control, nutrient retention, water quality maintenance etc. were of medium importance indirectly used, but this is in relation to the numerous services the lagoon offers. Cultural/ traditional areas, biological diversity and research are used indirectly and directly with high importance and cultural and biological diversity are important even though the lagoon may not be used (non-use).

## *3. The impact of human development*

The Venice Lagoon is characterized by a high concentration of human activities (CORILA). The system is a unique one, which has been sustained for many centuries, despite the high level of human development of the lagoon. This high level has even prevented the lagoon ecosystem from evolving as it naturally would if left unhindered. As such, the level of human development is classed as high, even to extreme to say that the lagoon ecosystem of Venice is exploited. Despite this, the lagoon still provides a high economic output for the country, and still maintains some essential goods and services that it has been providing from the beginning of its human use.

Lasserre & Marzollo (2000) expressed this: 'the Venice Lagoon is unique: 'there is no other lagoon in the world where the mingling of human action and natural ecology has been so enduring, complete, complex and profound'. Similar to the case of the Ria Formosa, the condition of Venice have to be looked at in terms of what aspect is being considered. Dalla Riva (personal communication) commented that some parts of the lagoon can be said to be good, and others poor.

Lagoon morphology changes, sediment and turbidity, use depreciation, geomorphic changes, bio-chemical pollution, eutrophication, erosion, biodiversity loss and habitat destruction, trophic web change, and groundwater system changes are only some of the effects of human development on the Venice Lagoon ecosystem. According to the Water Framework Directive (WFD) (EU, 2000), it is a heavily modified system. The main impacts of human development on the lagoon ecosystem of Venice are summarized in Box 7.

## Box 7: Impacts of human development in the Venice Lagoon

**Tourism:** Each year, there are about 20 million tourists to the city, in contrast to the 400,000 residents on its perimeter, and 60,000 in the historic centre. This high number places stress upon the natural system and the city in many forms. Among them are pollution, habitat destruction, and increase in boat transport. 'It has been reported ( Dalla Riva, personal communication) that because of the high demand for tourism, local residents are moving out of the city because of the increase in taxes (for waste treatment etc) and the decline in the provision of basic services. Many activities are concentrated around tourism, and so it is said that Venice is loosing is "city status", because of an only-tourism-economy culture and city population ageing and decrease. Ravera (2000) reports that even then, the untreated sewage produced by the inhabitants of Venice and its numerous tourists is directly discharged into the city's canals and then dispersed in the lagoon by the tidal cycle. This leads to high nutrient levels which can result in eutrophication. In the past, this increase of N & P levels has caused great changes in the structure of the marophyte association in the lagoon.

**Clam farming/ fishing:** Several problems in the ecosystem have occurred from the result of human use of the lagoon for this purpose. The exotic species *Tapes philippinarum* is the most commonly cultured bivalve in the lagoon. However, it originally comes from the Indo-Pacific region and it has rapidly adapted to the lagoon environment. It is now responsible for colonizing large shallow areas and competing directly in the ecological niche with the endemic clam species. It nevertheless has a high market price and very profitable. As a result of this, and the diversion from traditional fishing, new fishing methods are used, which scrape the lagoon bed, causing damage to the marine ecosystem including destruction of clam nurseries (Nunes *at al*. 2004). The resistance of the surface sediments from erosion is affected (Aspden *et al*., 2004). The re-suspension of sediments and subsequent release into the water column of organic material previously buried can create an oxygen deficit. These impacts will in turn have an adverse effect on future clam production and quality, and the economy The resistance of the surface sediments from erosion is affected (Aspden *et al*., 2004).

**Port and Shipping activities:** Venice receives 30 million of tons of goods per year and 1 million cruise ship passengers (CORILA). This activity has contributed to the increase of eutrophication and pollution of water and sediment in the lagoon (e.g. from oil spills, and chemical liquids). Inlets were created for navigational channels and to allow large vessels to navigate some parts of the lagoon. As a result, there is enhanced impact from the tidal action of the sea and a consequent increase in the erosion of the lagoon (Ravera, 2000). These activities also affect the resistance of the surface sediments from erosion, which reduce the bed shear strength or indirectly by disturbing or removing biological components such as mirophytobenthos which promote stabilization (Aspden *et al*., 2004).

**Land reclamation**: Reclamation for agriculture and industry led to a reduction of the lagoon area. Some areas are presently being recovered and converted back to natural areas, because of the recognized importance of them for flood protection. It has also resulted in loss of bird habitat, and a decline in their population (Ramsar).

**Dredging:** Areas of the lagoon have been dredged since the Venetian Republic to prevent the excessive accumulation of sediments and activate the circulation of tidal currents, with a consequent cleaning of the canals.

**Agriculture:** Industrialized agriculture needs fertilizers, biocides, irrigation and fuel, which have a more or less marked impact on the lagoon environment (Ravera, 2000).As a result of this agriculture in some areas of the lagoon, organic and inorganic toxic pollutants have been accumulated in the surface sediments. It has led to an increase in N & P in the lagoon and caused some eutrophication.

**Urbanisation:** Although the resident population of Venice is declining, there is still some pressure placed on the lagoon from their contribution to sewerage inputs. Domestic heating and motor emissions contributes to air pollution by N & P. These chemicals form acid rain which damage the historic monuments and artistic masterpieces which are the treasures of Venice, and which form part of the landscape and aesthetics of the lagoon. However, because of the great buffering capacity of the sea water, no evident effects from acid depositions have been recorded in the lagoon (Ravera, 2000). Water extractions, which once occurred in the lagoon (now forbidden), from wells, have contributed to the risk of land subsidence in the lagoon.

# Chapter 5 : Assessing the changes in goods and services

The major goods and services derived from the Oropuche, Ria Formosa and Venice Lagoons are compared and shown in Table 8**.**

**Table 8: Comparison of the Goods and Services from the three lagoons**.

| | OROPUCHE LAGOON | RIA FORMOSA | VENICE LAGOON |
|---|---|---|---|
| **Human Development Level** | Low | Medium | High |
| **Impact to Lagoon** | High | Medium | High |
| **Goods** | | | |
| ▪ Minerals (oil, salt, sand) | ✓ (oil) | ✓ (salt, sand) | |
| ▪ Agriculture | ✓ | ✓ | ✓ |
| ▪ Fisheries | ✓ | ✓ | ✓ |
| ▪ Wildlife (hunting) | ✓ | | ✓ |
| ▪ Shellfish | | ✓ | ✓ |
| **Services** | | | |
| ▪ Water and other Transport | ✓ | ✓ | ✓ |
| ▪ Tourism | | ✓ | ✓ |
| ▪ Recreation | ✓ | ✓ | ✓ |
| ▪ Research and Education | | ✓ | ✓ |
| ▪ High biological diversity | ✓ | ✓ | ✓ |
| ▪ Wildlife habitat | ✓ | ✓ | ✓ |
| ▪ Protects against storms and flooding | ✓ | ✓ | ✓ |
| ▪ Traditional, historical and cultural support | ✓ | ✓ | ✓ |
| ▪ Supports a productive fishing environment/ High Primary productivity | ✓ | ✓ | ✓ |
| ▪ Sediment and nutrient retention | | ✓ | ✓ |
| ▪ Water purification | | | |
| ▪ Nursery for juvenile fish | ✓ | ✓ | ✓ |

Despite the different levels of human development, Table 8 shows that there are not many differences between the three lagoons. However, when looked at in detail, the quantity and quality of the goods and services do differ. Because of the many similarities between the lagoons in terms of the goods and services derived, the ecosystem has some resilience to the impact of human activities (Vergano & Nunes, 2007). Pressures from these activities affect the lagoon environment and the functioning of the ecosystem resulting in decreased biodiversity as well as impacting the ecosystem goods and services.

The Venice and Ria Formosa lagoons both have management plans, and it is seen that they continue to contribute significantly to the national economy. The Oropuche lagoon has a high biodiversity, and rich cultural heritage that offers valuable support to the local community and contributes to the national economy. However, the potential of the lagoon is not fully utilised and it is possible for its uses and economic benefits to be maximised, in a sustainable way. In order to realize this, some management intervention is necessary to balance economics with the ecosystem; so that the lagoon's sustainable capacity can be carried over many generations.

The Venice lagoon has been used by humans for thousands of years, for living, commercial fishing, hunting, transport and protection from enemy empires (Ramsar). Today, it still continues to be important and used for many of the original uses. Similarly, the Ria Formosa has been used for centuries, for fishing, transport, living, and it too continues today, to perform the original ecosystem services, and produce similar goods. The activities of both have essentially been maintained over the years, but new aspects have become more economically important than may have originally

been. However, again, it reflects on the management of the lagoons that have allowed this. Perhaps it is the management that has sustained the lagoons for this time. Several authors (Ravera, 2000; CORILA, Lasserre & Marzollo, 2000) say that the Venice Lagoon is absolutely unique, for continuing to exist after so many years and alterations, but they stress the potential for man to manage and sustain the lagoon for future generations.

In order to further investigate the goods and services and their change with the level of human development, a questionnaire was applied to several scientists present at the recent Science and Policy Integration for Coastal System Assessment (SPICOSA) 4th Internal Workshop (4-9 February 2008, University of Algarve, Faro). The questionnaire asked scientists about the goods and services obtained from a lagoon in their country, and their perception of the lagoon. The results are given in Tables 9–13 and the questionnaire is attached in the Appendix II. These responses were based on expert judgement, which could have been Bayesian or heuristic in each separate case. This simply means that responses could be based on standard definitions and values, or based on non-standard ones (Fischer & Verrecchia, 1998). The Water Framework Directive (EU, 2000), has outlined that this type of judgement is perfectly acceptable, and justifiable. Sometimes expert judgement is important because ‘‘in many cases, information or evidences are not known with certainty, and very often they are not consistent, and conflict with one another to some extent’’ (Shrestha & Rahrnan, 1989).

Notwithstanding the definition of coastal lagoons already outlined, an observation of the responses proved that there are many differing concepts of ‘coastal lagoons’ used by scientists. Consequently, when the responses were given, these may refer to

estuaries and even enclosed bays that display similar features of coastal lagoons. For example, some published papers refer to Mar Piccolo as a lagoon (Prato *et al*, 2000) and others as an enclosed bay, but it displays some features of coastal lagoons (IAMC, 2008). One of the short falls of the questionnaire is therefore recognised, that the definition of a coastal lagoon should have been given to the respondents. Nevertheless, it was good to identify that the difference exists. However, coastal lagoons share many characteristics with other regions of restricted exchange (Tett *et al*., 2003) and so the responses were considered in the study.

The responses of the experts are presented in a simplified format for ease of communicating the science to stakeholders, which in this case range from different societal backgrounds. Several tables are used, but each focuses on a different aspect asked by the questionnaire. The computation of the number of uses, services and threat, shows the number of these variables present in the particular lagoon. The score given at the bottom of the table is shown as the number of times the particular aspect was present in the lagoons. The Oropuche Lagoon was included in the SPICOSA tables of results for comparison.

**Table 9: Summary of the main goods and uses of a variety of coastal lagoons.** (▲- present)

| Coastal lagoon | Fish | Rec/ Tor[17] | Shell fish | Agri.[18] | Urban[19] | Industry | Water transport | Other transport | Min. ext.[20]: oil, salt | Military | Land recl.[21] | No. of uses |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Venice, NE Italy | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | | | ▲ | **9** |
| Ria Formosa, S. Portugal | ▲ | ▲ | ▲ | ▲ | ▲ | | ▲ | ▲ | ▲ | | | **8** |
| Thau, SE France | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | | ▲ | | | | **7** |
| Marennes Oleron, W. France | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | | | | | | **6** |
| Mar Piccolo, S. Italy | | | ▲ | ▲ | ▲ | ▲ | ▲ | | | ▲ | | **6** |
| Oropuche Lagoon, SW Trinidad | ▲ | ▲ | ▲ | ▲ | | | | | ▲ | | | **5** |
| Bages-Sigean, S. France | ▲ | ▲ | | | ▲ | ▲ | | | ▲ | | | **5** |
| Vistula, Baltic Sea, Poland | ▲ | ▲ | | | | ▲ | ▲ | | | | | **4** |
| Papas Lagoon, NW Penloponnisos, Greece | ▲ | | ▲ | ▲ | | | | | | | | **3** |
| Szczecin (Order) Lagoon, Germany/Poland | ▲ | ▲ | | | | | ▲ | | | | | **3** |
| **SCORE** | $^{9}/_{10}$ | $^{8}/_{10}$ | $^{7}/_{10}$ | $^{7}/_{10}$ | $^{6}/_{10}$ | $^{6}/_{10}$ | $^{5}/_{10}$ | $^{3}/_{10}$ | $^{3}/_{10}$ | $^{1}/_{10}$ | $^{1}/_{10}$ | |

(Symbols for diagrams courtesy of the Integration and Application Network (ian.umces.edu/symbols), University of Maryland Centre for Environmental Science.)

[17] Recreation/ Tourism
[18] Agriculture
[19] Urban Development
[20] Mineral Extraction
[21] Land reclamation

The responses from the SPICOSA workshop illustrate that the lagoons provide essentially the same goods in all cases. Table 9 shows that all the lagoons analysed had multiple uses, demonstrating some of their values for human benefit. The Venice Lagoon, with a high level of human development, provided the greatest number of goods and uses. Many uses and activities occur around and within the lagoon as given in the case study.

The main goods and uses provided by these coastal lagoons were therefore identified as: fish, recreation/ tourism, shell fish and agriculture. The Oropuche scored in the middle of all the lagoons in terms of its goods and uses, and yet it should be stated that its full potential is not utilised, thereby implying that if sustainably used and managed, these use benefits can also be increased.

**Table 10: Summary of the main services offered by the lagoons (▲- present)**

| Coastal lagoon | Supports a productive fishing area | Support high biodiversity | Research & Edu. | Water quality maint. | Sediment & nutrient retention | Historical, cultural, traditional area | attractive landscape | Mineral production | Protects against flooding and Storms | shoreline stability | No. of services |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Venice, NE Italy | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | | ▲ | | **8** |
| Ria Formosa, S. Portugal | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | | | **8** |
| Thau, SE France | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | | | | **7** |
| Marennes Oleron, W. France | ▲ | ▲ | ▲ | ▲ | ▲ | | ▲ | | | ▲ | **7** |
| Bages-Sigean, S. France | ▲ | ▲ | ▲ | | ▲ | ▲ | | | | | **5** |
| Oropuche Lagoon, SW Trinidad | ▲ | ▲ | | | | ▲ | ▲ | ▲ | | | **5** |
| Mar Piccolo, S. Italy | | ▲ | ▲ | ▲ | ▲ | ▲ | | | | | **5** |
| Szczecin (Order) Lagoon, Germany/ Poland | ▲ | ▲ | ▲ | ▲ | ▲ | | | | | | **5** |
| Vistula, Baltic Sea, Poland | ▲ | ▲ | ▲ | ▲ | | ▲ | | | | | **5** |
| Papas Lagoon, NW Penloponnisos, Greece | ▲ | | ▲ | ▲ | | | | | | | **3** |
| **SCORE** | $^{9}/_{10}$ | $^{9}/_{10}$ | $^{9}/_{10}$ | $^{8}/_{10}$ | $^{7}/_{10}$ | $^{7}/_{10}$ | $^{5}/_{10}$ | $^{2}/_{10}$ | $^{1}/_{10}$ | $^{1}/_{10}$ | |

(Symbols for diagrams courtesy of the Integration and Application Network (ian.umces.edu/symbols), University of Maryland Centre for Environmental Science.)

Table 10 shows that the three main services offered by the lagoons are: support for a productive fishing environment, supports a high biological diversity, and provision of research and education opportunities. Again, as with the goods obtained, the Venice lagoon had a top score among the other lagoons, but ranked the same with the Ria Formosa, a lagoon of medium impact and human development. The Oropuche lagoon scored in the middle.

The table shows that the lagoons also provide multiple services. Shoreline stability and protection against storms were seldom reported services. However, they are included in the main services that humans derive from lagoons. It can be said that in the context of the questionnaire, they were not the main reported services obtained, though the lagoon may provide it, or that the value of these services may have been overlooked. The outcome of the response may well have been different if the expert population of the workshop had been Marine Geologists.

All but the Oropuche lagoon, provided research and education opportunities, and water quality maintenance. In the case of research and education, the lagoon does provide these opportunities, for example use in this study, but its potential to provide this service is not widely utilised. Similarly, its water quality service is not one of its main current services, but this can be attributed to the lack of understanding of this as a service provided by the lagoon.

**Table 11: Causes of damage and threats to the lagoons.** (▲- present)

| Coastal Lagoon | Urban develop.  | Agri.  | Pollution  | Poor mgt.  | Over fishing  | tourism  | Salt intrusion  | Neglect  | Siltation  | floods  | erosion  | No. of threats/ causes of damage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oropuche Lagoon, SW Trinidad | ▲ | ▲ | ▲ | ▲ | ▲ | | ▲ | ▲ | ▲ | ▲ | | **9** |
| Venice, NE Italy | | | | ▲ | ▲ | ▲ | ▲ | | ▲ | ▲ | ▲ | **7** |
| Vistula, Baltic Sea, Poland | ▲ | ▲ | ▲ | ▲ | ▲ | ▲ | | | | | | **6** |
| Papas Lagoon, NW Penloponnisos, Greece | | ▲ | | ▲ | ▲ | | | ▲ | | | | **4** |
| Mar Piccolo, S. Italy | ▲ | | ▲ | ▲ | | | | | | | | **3** |
| Marennes Oleron, W. France | ▲ | ▲ | ▲ | | | | | | | | | **3** |
| Bages-Sigean, S. France | ▲ | | ▲ | | | | | | | | | **2** |
| Thau, SE France | ▲ | ▲ | | | | ▲ | | | | | | **2** |
| Szczecin (Order) Lagoon, Germany/ Poland | | ▲ | | | | | | | | | | **1** |
| Ria Formosa, S. Portugal | ▲ (***change in land use***) | | | | | | | | | | | **1** |
| **SCORE** | **$^{7}/_{10}$** | **$^{6}/_{10}$** | **$^{5}/_{10}$** | **$^{5}/_{10}$** | **$^{4}/_{10}$** | **$^{3}/_{10}$** | **$^{2}/_{10}$** | **$^{2}/_{10}$** | **$^{2}/_{10}$** | **$^{2}/_{10}$** | **$^{1}/_{10}$** | |

(Symbols for diagrams courtesy of the Integration and Application Network (ian.umces.edu/symbols), University of Maryland Centre for Environmental Science.)

Table 11 shows that the damages and threats to these lagoons are varied. However, the most commonly reported threat was urbanisation. Urbanisation puts many pressures on coastal lagoons, and it is commonly seen in the three case studies, including Oropuche lagoon. In the Ria Formosa for example, urbanisation is the main threat in a broad sense, but can more specifically be regarded as a change in land use. This included threats from building on the barrier islands, development around the lagoon, a reduction in agricultural use; but a change towards more intensive methods and golf developments, increasing the nutrient loads to the lagoon[22]. It was also reported that many of the threats acting upon the lagoons are indirect from activities within the catchment area.

The Venice lagoon, that has previously been shown to provide more goods and services than the Oropuche Lagoon, has less threats and damages than the Oropuche. The resilience of the lagoon may be partly attributed to past and present management practices (Vergano & Nunes, 2007). Therefore, though the general human development of Oropuche is low, the damages are high. This lagoon however has several opportunities for management, so that these damages and potential threats can be minimised and reduced.

[22] Prof. Alice Newton- Personal Communication

**Table 12: Changes within the lagoon during the past 10-20 years.**

| Coastal Lagoon | Ecosystem Changes | | | | Anthropological changes | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Shell fisheries | Fisheries | Water quality | salinity | Tourism/ recreation | Management intervention | Industrial pollution | Resident Population | Agriculture | Shipping |
| Oropuche Lagoon, SW Trinidad | | ↓ | | ↑ | | ↓ | | | ↓ | |
| Bages-Sigean, S. France | ↓ | | | | ↑ | ↑ | ↑ | | | |
| Mar Piccolo, S. Italy | ↑ | | ↑ | | | | | | | |
| Marennes Oleron, W. France | | | ↑ | | | ↑ | ↓ | | | |
| Papas Lagoon, NW Penloponnisos, Greece | ↓ | ↑ ↓ | ↓ | | | | | | | |
| Ria Formosa, S. Portugal | ↓ | ↓ | ↓ | | ↑ | ↑ | ? | ↑ | ↓ | |
| Szczecin (Order) Lagoon, Germany/Poland | | ↓ | | | ↑ | | | | ↓ | ↑ |
| Thau, SE France | | | | | | | | ↑ | | |
| Venice, NE Italy | | | | | ↑ | | | ↓ | | |
| Vistula, Baltic Sea, Poland | ↑ | ↑ | | | ↑ | | | | | |

↓ Decrease; ↑ Increase

Table 12 shows the changes within the lagoon systems over the last 10-20 years. It helps to support the importance of the fishery and shell fishery use of the lagoons, and shows that changes within the lagoon can be such as to either increase or decrease production. Whereas the management interventions in most lagoons increased; in the case of Oropuche, management decreased. This occurred because of several factors, but mainly as a result of a decrease in economic benefits. Management was present when agricultural production was high, but when there was a decrease in production (as a result of poor management!), this intervention was neglected. In the Ria Formosa, there has been a loss in sea grasses and an increase in green algae[23].In the Papas lagoon, there was the commencement of semi-intensive fish aquaculture, and also a subsequent decrease in production from anoxic events. In all relevant cases, the change in tourism was an increase. This can help demonstrate the recognised value of coastal lagoons by the general population that chose these environments for their recreation and vacation time.

[23] Prof. Alice Newton- Personal Communication

**Table 13: Summary of the legislations, perceptions and first uses of the lagoons**

| Coastal Lagoon | First Recorded use & purpose | Main legislations, and policies acting | | | | | | Perception of general state and comments of the lagoon |
|---|---|---|---|---|---|---|---|---|
| | | Ramsar Conv. | WFD (EU) | NATURA 2000 | Local Policies | National Policies | other | |
| Venice, NE Italy | 1000 yrs ago, fishing, protection, transport | ▲ | | | | | ▲ [24] | Generally in a good condition, but some parts are good and others poor, so would class between good and poor. |
| Ria Formosa, S. Portugal | Centuries, fishing, port | ▲ | ▲ | | ▲ | | | Good, but at critical state where can easily 'tip' over. |
| Mar Piccolo, S. Italy | Around 1800, mussel culture. | | | | | ▲ | ▲ [25] | Good |
| Bages-Sigean, S. France | 19th Century, Fisheries | ▲ | ▲ | | ▲ | ▲ | | Poor |
| Thau, SE France | 1950's ; shell fishing and fishing | | ▲ | | ▲ | ▲ | | Good, but some areas good and other poor, depending on the season. |
| Vistula, Baltic Sea, Poland | 50 yrs ago, science research data | | | ▲ | | | | Generally Poor, but between good and poor. |
| Szczecin (Order) Lagoon, Germany/Poland | 30 yrs ago, fisheries | | ▲ | ▲ | | ▲ | | Poor: biodiversity is high, but also highly euthrophied. |
| Marennes Oleron, W. France | Oyster/fish farming | | ▲ | | ▲ | ▲ | | Poor generally, but between good and poor depending on the service. |
| Papas Lagoon, NW Penloponnisos, Greece | Historically known as fish and shellfish production area. | | | ▲ | | | | Poor |
| Oropuche Lagoon, SW Trinidad | 1878, agriculture, fisheries | | | | | ▲ [26] | | Poor |

Under the European Union

[24] UNESCO
[25] Site of European Importance
[26] Present in the legislation, but not enforced

Table 13 shows that the main kind of legislation or governance commonly acting upon the lagoons, including Oropuche, is at the national level. Among the lagoons in Europe, the Water and Framework Directive (WFD) was reportedly a main intervention in lagoon management. It may therefore demonstrate that within the regional area of Trinidad and Tobago; the Caribbean, common frameworks and legislations among the islands, may stimulate improved conditions in the ecosystem management.

The perceptions ranged between poor and good conditions (see Appendix II), and generally, the 'older' lagoons (Column 2, Table 13) were given good status. Two lagoons: the Marennes Oleron and the Papas Lagoon could not be ranked in terms of age because of a gap in the information. Nevertheless, all recorded historical first human uses of the lagoon were based on fisheries. This is still the most common use today, and it reveals that fisheries goods and services are the key driver of human use of coastal lagoons.

The study showed that perhaps the definition of human development used in terms of age, may not have been very useful, but maybe a better definition could have been solely based on the magnitude of the human impact. This magnitude of impact is directly related to the size of the human population using the lagoon's services and the intensity and type of impact. It is also seen that the management of the lagoon is the key player in its overall ecological status.

## *1. Improving the Management of Oropuche Lagoon*

The impacts of several human activities have already been outlined in the report. Tables 9-13 show that the Oropuche lagoon can be compared to other lagoons, and it has a lot of potential for increased benefits to humans. The impact of the human development on the Oropuche lagoon is high, even though the lagoon has only been used recently (since late 1800's). In spite of this, the lagoon supports a productive system (Ramsundar, 2005) that has sustained many uses, but uses that are declining. Therefore, since there is potential for the Oropuche lagoon to be more sustainably used, and used so that it can give more support for the local communities, several lessons can be adopted as warning signs or prevention of some effects of human developmental activities from other case studies. As such, management plans for the area can use, and adapt plans and studies from 'more developed' and used lagoons.

It has been identified (MEA, 2005b) that the proficiency of a country to manage socio-ecological aspects, has implications for whether they persist, and how they progress. This socio-ecological aspect can include the lagoon goods and services, and the impacts of human development.

The value for the Oropuche lagoon has been estimated, to place the lagoon in the context of the national economy, so that management can intervene to sustain the lagoon goods and services. However, now that the value of the lagoon is known, the philosophical question posed here is: ''*do we want to sacrifice the ecosystem, for economic gain, or do we want sustainable economic growth*?''. In order to put management for the Oropuche lagoon into perspective, three possible scenarios for the lagoon are given in Box 8**.**

**Box 8: Scenarios in the Oropuche Lagoon**

These scenarios are similarly adopted from the MEA (2005a; 2005b). They tell a historical story from the point of view of a journalist for the general public in 2050. They are presented to show future possible conditions for the Oropuche lagoon.

**Scenario 1: Economy Rules- Full development**

In this scenario, the Oropuche lagoon is utilised maximally for economic growth and output. Since 2008, the gross economic benefits offered by the lagoon have multiplied by several factors, but the net benefits are not marginally greater, than the value in 2007. However, there have not been any management interventions governing the natural environment, and permission was granted for activities which brought high economic rewards.

"There was once a lagoon in the south west of Trinidad. This lagoon provided the local population with recreational opportunities, food subsidies from agriculture, and supported an important fishing site. Today, if driving to this area, one would be surprised to know that such a valuable and beautiful ecosystem previously existed. Since that time, the lagoon was regarded as 'a wasteland'. Subsidies were no longer supporting the traditional agricultural use, and so people lost their interest in this activity as the profits were minimal.

In order to maximise economic growth, the lagoon was then slowly converted to other land uses, and many areas were reclaimed. The mangrove area was cleared, and urban development projects were built as seen today. There are no more agricultural lands, as the state owned land was used to build the existing Oropuche Industrial area. The reclaimed Otaheite Island was built after 2008, and brought high economic returns. The fishing area of Otaheite no longer exists, and many people from the area are employed in the industrial sector, mainly as labourers.

Today, many problems exist in the area. During the rainy season, the area experiences many flooding events in the lagoon, which reduces the profits made. The effects of sea level rise are already being seen on the Otaheite Island, and many of the profits are now being spent in coastal protection. There have been many reported events of erosion and sediment deposition on Trinidad's south west coast, and, in order to protect the many coastal structures, numerous activities occur to transfer sediments between sites, at very high costs. The Godineau Industrial Port poses several problems, as the effects of heavy metal, and chemical pollution has severely altered the coastal ecosystem. The port is subjected to high occurrences of storm events, which often damage existing facilities.

Apart from these problems, there are social ones. With the reduction in agriculture, there has been an increase in overall food prices. There is a high incidence of crime, mainly committed by youths. A recent police report has concluded that the crimes are gang related, and occurs because of a lack of recreational opportunities in the area, especially for young males. Many people still remain unemployed due to the limited jobs offered by the industrial and other sectors, and these numbers are also contributing to the high crime rate. There is no opportunity for self employment based on natural resources. The health of the population is in a poor state, and the costs of treatment bared by the local hospital are high".

**Scenario 2: Ecosystem Rules-No development**

In this scenario, the Oropuche lagoon is not utilised for any economic growth, or development, and it is preserved in its natural state. Management plans became important, and many polices were formed and acted upon the lagoon.

"As one drives along the south west, one encounters the beautiful preserved natural area of Oropuche lagoon. There is a large population of the national Scarlet Ibis present, rivers teeming with crabs, and fishes, and an overall rich biodiversity. However, be warned!! There are many policies and legislations governing the lagoon, so resist temptations, it is a no-take zone. No animal or plant can be removed, and no damages to this ecosystem will be tolerated.

Prior to 2008, this ecosystem was not as it appears today. Before then, the lagoon had been highly modified by human activities, but after 2008, underwent many restorations to attempt to reconvert it to its original state. It presently supports eco-tourism, but these visitors are the only real beneficiaries of the lagoon's ecosystem. Tours are offered by specially trained experts brought in from outside the Oropuche area, and only non-motor powered boats are allowed in designated areas of the lagoon, offering value only to a small registered number of these experts.

While, it appears to be a system in harmony, a closer look today, shows that it is not. The ecosystem consists of biological, physical, chemical and human interactions. While the first three systems are in balance, the human interaction factor of this lagoon is not. The restoration activities and its protected status have resulted in the relocation of many families out of the area. People who once depended on the lagoon for their income had to seek alternative employment. Many of these people were uneducated. Today, the crime rate in the surrounding towns is high, and has increased only after the relocations. There are high psychological problems among youths, and studies have shown that this is due to a lack of local recreation.

There are illegal extractions reported from the lagoon, and despite the already highly maintained cost of Park Rangers, these extractions appear to be an organised activity. The present food prices have since increased, due to a reduction in production, but increase in demand. The poverty in the area has also increased".

**Scenario 3: Both economy and ecosystem rules- Development balanced with ecosystem management**

In this scenario, the Oropuche lagoon has received management interventions, and there is balance between economic uses with maintenance of ecological goods and services.

"

Ramsar Special Report: World Wetlands Day-2050

…The Oropuche lagoon celebrates 40 years of sustainable management. Today, the lagoon and its management plan are used as a classic example in the global education system, of an ecosystem that has the harmony of economic benefits to society and ecological function. This

has been achieved through the implementation of several management interventions, and local involvement.

Fisheries in the Otaheite bay, which the lagoon supports, has increased over the past 20 years, and is at a steady state, posing to be the most productive fish landing site in the country. Eco-tourism is however the most popular activity in the lagoon, with its diverse array of avifaunal and other species.

The local people are the main players in this lagoon, taking an active management role of its uses and the impacts from the surrounding uses. In some areas of the lagoon, agriculture is present, and they have one of the highest productions in the country. The riparian vegetation around the lagoon stops nutrient pollution from reaching the water, and provides rich yields for paper manufacture. The mangrove swamp retains sediment and stabilizes the coastline.

All activities are done in a sustainable way, and before any development around the lagoon is undertaken, proposals are made and approved by the Environmental Management Authority.

The lagoon and its uses alone contribute a significant amount to the GDP, as it once did when it produced oil. There is a strong link between the economic gain, and the condition of the lagoon, and this has been recognised both at the local and national levels…"

From the scenarios it is seen that there are several options for the Oropuche lagoon, depending on what the underlying aim is. From the management perspective, I would recommend that Scenario 3 be pursued. It may not be in the exact sense, but in general, with the principal idea of managing both the economy with ecology so that the benefits from both can be maximised. However, it should be recognised that the ecosystem is constantly changing, and a management plan effective for today, may not be effective in 50 years. This is especially true in a world that is undergoing many global changes (MEA, 2005b). Therefore management should not only intervene, but should be one that is adaptive. Several recommendations for improved management of the Oropuche Lagoon can be made, but, only the main ones will be put forward in this report.

## *2. Recommendations for management of Oropuche lagoon*

1. **Management** actions must intervene within the lagoon and its catchment. The lagoon cannot be managed by itself as one entity, because activities occurring 'outside of it will have effects on it'. As such, there needs to be proper integrated management plans, such as an Integrated Watershed Management Plan that will manage inputs to the lagoon. There should be a management team. This team should include: a territorial manager (for land use); a fishery manager; a water quality manager; and an Oropuche Manager, operating both at the local and national level.

2. The **local people** should be fully engaged in participatory management plans, and environmental education should be a priority, so that they can make informed choices and decisions about their impacts and use of the lagoon. There should also be a dialogue between the locals and the policy makers who may learn from each other and exchange ideas. Encouragement and support should be made for the establishment of Community Based Organisations (CBOs) and Non Governmental Organisations (NGOs), to empower sustainable use and care of the lagoon.

3. It has already been recommended that the Oropuche lagoon can be used to **develop eco- tourism** in the southern region of Trinidad. However, it is important that the potential threats and effects be recognised and analysed, and the lessons and current impacts of lagoons from the Ria Formosa and Venice be used to prevent the impacts on this small lagoon. Some of this includes having a fixed tourist capacity number at any one time in the lagoon to

minimise the impacts, controlling the catch of fisheries to prevent over exploitation and extraction of juveniles, and proper control of waste water in the lagoon. These are just some of the many applications that can be made.

4. Other current aspects of the lagoon also need management schemes. These include the fishery catches in the lagoon itself, such as promotion of less damaging fishing methods, and introduction of a closed season in the area. Fishery catches in the lagoon should be monitored, to establish the species changes, assemblages, and the production. A list of other recommendations for **fisheries management** in the lagoon is outlined by Ramsundar (2005).

5. The main local economic use of **agriculture** in the lagoon is on a decline. The age structure of the lagoon's residents is also changing, and therefore the young should be given some incentive to continue to maintain, but use the lagoon. Even if the original use of agriculture changes to something with less impacts, it is felt that if the lagoon is not giving benefit to the people around it, it will lose its context as being important to them, and they may lose the cultural and historical attachment to it. Indirectly, the value of the lagoon will be lost. Some areas which are constantly flooded can be turned into a positive outcome, by utilising it for **aquaculture**. This potential use can be further researched, because the type of aquaculture employed is important. The research should also examine which harvesting method is more suitable for the Oropuche lagoon, and the level of impact. If the agricultural use is maintained and aquaculture employed, then new, but low environmental impact technologies can be used to obtain high benefits from the lagoon. Subsidies

may offer incentives to maintain the lagoon's production. However, proper expert technical support should be available to the users of the system, so as to reduce the negative possible impacts on the ecosystem.

6. **Education and research** should be encouraged so that more can be learnt from this ecosystem, and again, can be used to form or improve lagoon management. Research can be in the form of monitoring, so that adaptive management can be achieved. Although a value has been estimated, this is a value given by declining ecosystem services, and as such, a value that would be obtained if it was returned to its original state, would be more relevant for initiating policy changes. Benefit transfer can be applied to the more indirect ecological services provided by Oropuche, to emphasize the value of this ecosystem.

# Chapter 6 : Conclusions

The economic value for the Oropuche lagoon was calculated to be worth **€9,250,686.25** in 2007. This is a rough estimate, to put the lagoon in the national context as to the benefit, and potential benefit of this important natural resource. This value implies that the lagoon has a high potential to help support the local economy. The major goods obtained are oil, fisheries and agriculture, whereas the main services derived were recreational opportunities, biological diversity, cultural provisions, and support for a productive fishing area.

The report has shown that coastal lagoons have the ability to adjust themselves to the impacts of human development. This observation is supported by lagoons that have been used for centuries and more recently used lagoons; and whether the systems have been used for few or many activities. The assessment showed that, despite the different levels of human development; there are key goods and services maintained by coastal lagoons. These goods and services have been outlined in Chapter 5.

The lagoon of Venice is exceptional in that it still continues to provide the key goods and services offered by these coastal lagoons. This shows the importance of management on a system, and what humans can achieve, even on natural ecosystems. Venice lagoon has been used as a classical example in environmental education, of what impacts human activities can have on the lagoon ecosystem, and what must not be done to other lagoons. However, despite the many anthropological alterations, and impacts, the Venice lagoon proves to be one of the most valuable lagoons in the world, in economic and other values.

It is true that many of the effects of human development may be looked at as having very negative impacts on the ecosystem, but the goods and services offered by these lagoons were generally the same from all the lagoons studied. It is also true that pollution, agricultural and urban development pressures are some of the common problems of human development, but from the study, it is seen that the basic services and goods offered by these lagoons are generally maintained. The quality and quantity of these goods and services will of course differ from an ecosystem that has no human development and use. However, this is why sustainable use should be stressed, so that humans can benefit while making minimal damages to the ecosystem, and why management is necessary in all systems. It is recognized (Jewitt 2001), that 'ecosystems are complex systems, which are "adaptive", or "self organising" and that management systems must be able to adapt to change or surprise in the system.' In this context, management of these coastal lagoon goods and services must also be both anticipatory and adaptive, and err on the side of precaution.

The study suggests that many management interventions can be adapted from lagoons in developed countries such as the Ria Formosa and Venice, to those in developing countries such as the Oropuche lagoon. The lagoon use and support to the local community can be sustained for the upcoming generations. The Oropuche lagoon has a great potential to further increase its present economic value, and this can be achieved with management that balances economics and the ecosystem well being. This balance will allow the lagoon, and its country, to persist and progress.

Indeed, human development is important, but it is in the best interest of humankind to respect, appreciate, and maintain the goods and services of coastal lagoons.

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# Appendices

Appendix I.

Questionnaire

## Economic Valuation of the Ecosystem Goods obtained from the Oropuche Lagoon.

This questionnaire is aimed at accessing the economic value of the marketed goods (e.g. fish, timber) provided by the lagoon ecosystem. Please answer the questions truthfully. It is being conducted for an MSc thesis at the University of Algarve, Portugal, with co-supervision from UWI, St. Augustine. Responses will be kept confidential.

**SECTION 1:** Background Information

1. Your Gender: [ ] Male [ ] Female

2. What is your date of birth? _____/_____/ _____
   Day Month Year

3. What is your Occupation? _____

4. Number of years living in the area_____

5. Total number of persons living in your household_____

6. What is your highest education level? (*tick one only*)

   [ ] none
   [ ] Primary School
   [ ] Secondary School
   [ ] Higher Level Diploma
   [ ] University/ Technical Degree
   [ ] Post Graduate

7. Which **best** describes your household average monthly income?
   (*Tick **one** only*) *(Values are in TT dollars before TAX).*

   [ ] $1000 or less
   [ ] $1001 - $3000
   [ ] $3001- $5000
   [ ] $5001- $7000
   [ ] $7001- $9000
   [ ] $9001 or more

**SECTION 2:** Use of the Lagoon

8. Do you use the Oropuche Lagoon? [ ] Yes [ ] No

**If no, please go to Section 4**.

9. How often do you use the lagoon on average? (*tick one only*)

   [ ] Everyday
   [ ] Weekly
   [ ] Fortnightly
   [ ] Monthly
   [ ] Other *(please specify)* _____

10. What do you use the lagoon for? And when? (*tick as appropriate*)

| What Use | When: seasons, months |
|---|---|
| [ ] fish | |
| [ ] shell fish e.g. muk, conch | |
| [ ] other food resources | |
| [ ] leisure: walks/ bird watching | |
| [ ] boating and kayaking | |
| [ ] domestic use e.g. washing | |
| [ ] drinking water/ cooking | |
| [ ] agricultural irrigation | |
| [ ] resources for handicraft | |
| [ ] hunting wild meat eg. Lappe, Manicou | |
| [ ] wood | |
| [ ] growing agriculture | |
| [ ] other *(please specify)* _____ | |

11. How much of the following have you obtained from the lagoon this year?

| *e.g. oysters* | Amount<br>*10* | Unit<br>*kgs* |
|---|---|---|
| Fish<br>Oysters and other shell fish<br>Other food resources (*please specify*)<br><br>Water for domestic use e.g. drinking, cooking<br>agricultural water<br>resources for handicraft (*please state what resources*)<br><br>wild meat (*please give animal/s*)<br><br>crop harvest (e.g. rice)<br><br>wood<br>others *(please specify)* | | |

12. Has there been a change in how much you obtained over the last 2, 5 and 10 years? (Tick yes **or** no for each year). Can you explain what has changed?

| | **Yes & What change** | **No** |
|---|---|---|
| 2 yrs | | |
| 5 yrs | | |
| 10 yrs | | |

13. Do you use the goods (e.g. fish, timber) from the lagoon for personal / household use or do you sell them?

    [ a ] Sell

    [ b ] Personal/ Household use

    **If you have answered only [ b ] to the above question, please go to Section 4.**

14. What percentage of the goods is sold? _____%

**SECTION 3:** Economic Gain from the Lagoon

15. Is your household income based **solely** on the goods and services derived from the lagoon?

    [ ] Yes [ ] No

16. On average, how much (TT$) does your household earn from the lagoon per month?

    $_____ TT / month

**SECTION 4:** Your perception of the Lagoon

17. Do you consider the lagoon to be in a (*tick one only*)

[ ] Excellent Condition (*Very clean water suitable for all uses, supports wide range of biodiversity, continuous resources obtained*)

[ ] Good Condition (*Slightly polluted, but suitable for wide range of uses and still maintains a range of biodiversity, range of resources obtained*)

[ ] Poor Condition (*Dirty, uses are restricted, little biodiversity, low resources obtained*)

[ ] Degraded or Damaged Condition (*Extremely dirty, cannot be used by humans, very minimal biodiversity, provides no resources*)

18. What do you think is causing damage or threatening the lagoon? (*tick as appropriate*)

| | |
|---|---|
| [ ] Over fishing | [ ] Oil pollution |
| [ ] Salt Intrusion | [ ] Pollution e.g. solid waste |
| [ ] Agriculture | [ ] Urban development |
| [ ] Tourism | [ ] Drought |
| [ ] Erosion | [ ] Fires |
| [ ] Flooding | [ ] Siltation |
| [ ] Deforestation | [ ] Other _____(*please specify)* |

**SECTION 5:** Your Questions and Comments

19. What will happen to you if the lagoon was degraded, so that it no longer provides the resources and services obtained?

_____

_____

_____

20. Do you have any suggestions for better use and conservation of the lagoon?

_____

_____

_____

21. Is there anything you would like to ask or any comments you would like to make?

_____

_____

_____

**Thank you for your time and corporation in completing this questionnaire.**

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**Further Information and Contact:**

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Appendix II.

Questionnaire

## Ecosystem Goods and Services obtained from European Lagoons.

This questionnaire is aimed at determining the goods and services obtained from your lagoon. These goods and services obtained from coastal lagoons will be compared according to the level of human development. Please answer the questions truthfully.

**Your Lagoon**

1. Please state the name and location of your lagoon.

_____

_____

2. When was the first recorded use of the lagoon reported, and for what use?

_____

**Goods and Services Derived**

3. What is the lagoon used for?

[ ] Fishing
[ ] Shell fishing
[ ] Mineral extraction: oil, salt, sand etc.
[ ] Military
[ ] Water transport
[ ] Other transport e.g. highways, airports
[ ] Water extractions (*state for what use*)
[ ] Agriculture/ aquaculture
[ ] Urban development
[ ] Industry
[ ] Land reclamation
[ ] Local recreation e.g. swimming, bird watching
[ ] Tourism
[ ] Flora harvesting
[ ] Other *(please specify)* _____

4. What kind of services does it currently provide?

   [ ] Research and education

   [ ] Supports a varied range of biodiversity

   [ ] Supports a productive fishing environment

   [ ] Protects against flooding and Storms

   [ ] Provides historical, cultural or traditional use

   [ ] Produces fuel and/ or minerals

   [ ] Sediment and nutrient retention

   [ ] shoreline stabilisation

   [ ] water quality maintenance

   [ ] other (*please state*)

**Your Perception of the lagoon**

5. Do you consider the lagoon to be in a (*tick one only*)

   [ ] Excellent Condition (*Very clean, suitable for all uses, supports wide range of biodiversity, continuous resources obtained*)

   [ ] Good Condition (*Slightly polluted, but suitable for wide range of uses and still maintains a range of biodiversity, range of resources obtained*)

   [ ] Poor Condition (*Dirty, uses are restricted, little biodiversity, low resources obtained*)

   [ ] Degraded or Damaged Condition (*Extremely dirty, cannot be used by humans, very minimal biodiversity, provides no resources*)

   [ ] no response

6. What do you think is causing damage or threatening the lagoon? (*tick as appropriate*)

| | |
|---|---|
| [ ] Over fishing | [ ] Oil pollution |
| [ ] Salt Intrusion | [ ] Pollution e.g. solid waste |
| [ ] Agriculture | [ ] Urban development |
| [ ] Tourism | [ ] Drought |
| [ ] Erosion | [ ] Fires |
| [ ] Flooding | [ ] Siltation |
| [ ] Deforestation | [ ] Poor Management |
| [ ] Neglect | [ ] Other _____(*please specify)* |

**Lagoon Management**

7. What kind of governance, legislation or policies are acting upon the lagoon? (E.g. a Ramsar Site or is it a national park etc.)

_____

_____

_____

_____

_____

**Changes**

8. Please state any changes in the lagoon's use and services provided in the last 10 and 20 years.

_____

_____

_____

_____

_____

**Thank you for your time and corporation in completing this questionnaire.**

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**Further Information and Contact:**

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Appendix III.

Summary of the results of the Oropuche questionnaire and survey.

**Table 14: Summary of some of the responses of the questionnaire.**

| | **Average (SD)** |
|---|---|
| Age | 47.56 ± 18.82 |
| Years in area | 37.97 ± 20.93 |
| No. in Household | 4.27 ± 2.14 |
| Education Level (Mode) | Secondary |
| Average income range | $3001-$5000 |
| Percent who used the lagoon | 62% |
| Average Frequency of use | fortnightly |
| Main class of use | personal (76%) |

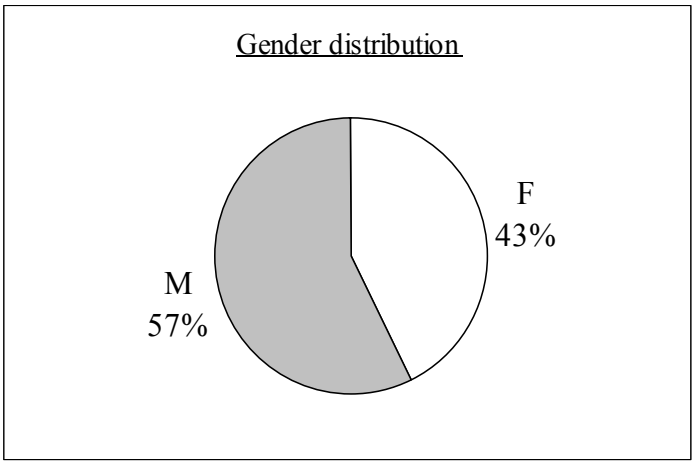


**Figure 18: Gender distribution of the survey in the Oropuche Lagoon**

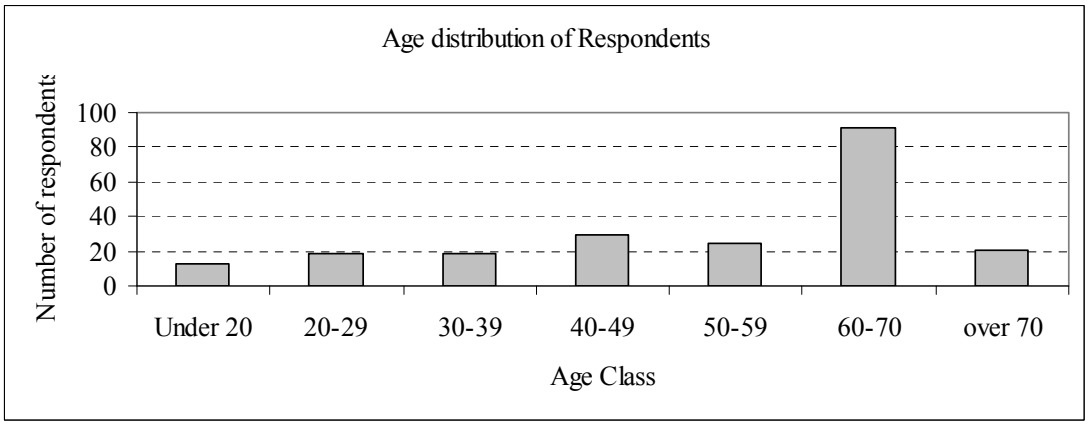


**Figure 19: Age distribution of respondents in the Oropuche Lagoon**

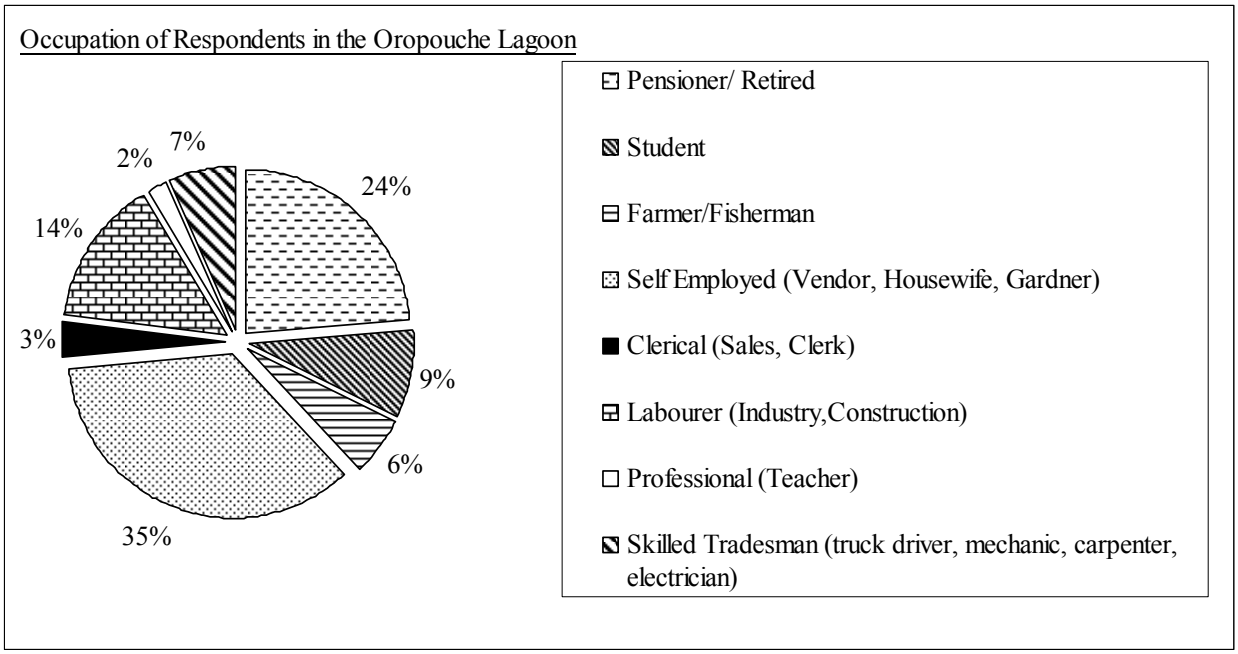


**Figure 20: Occupations of the respondents in the Oropuche Lagoon**

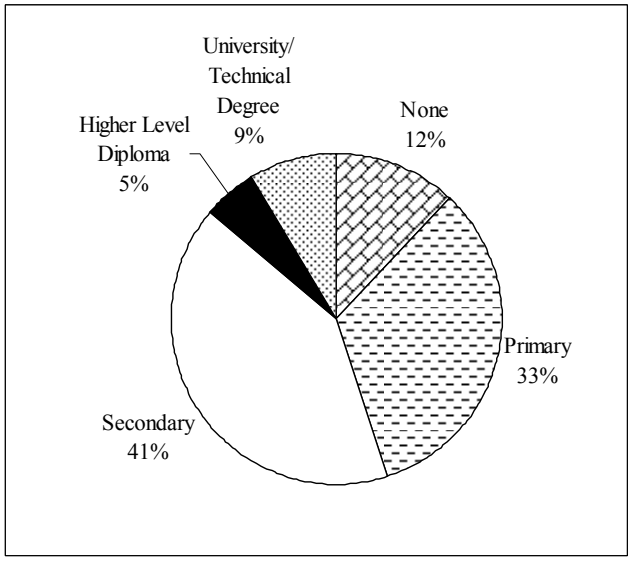


**Figure 21: Education level of survey respondents**

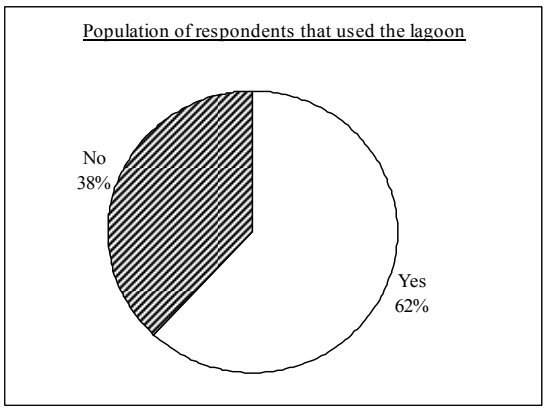


**Figure 22: Percentages of respondents who use the lagoon**

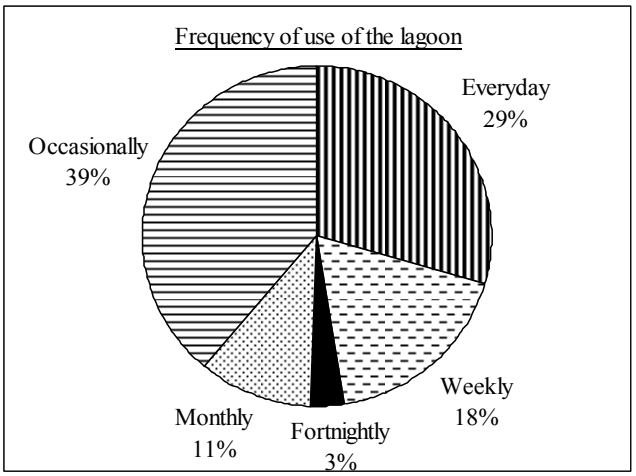


**Figure 23: Frequency of the lagoon use by the respondents**

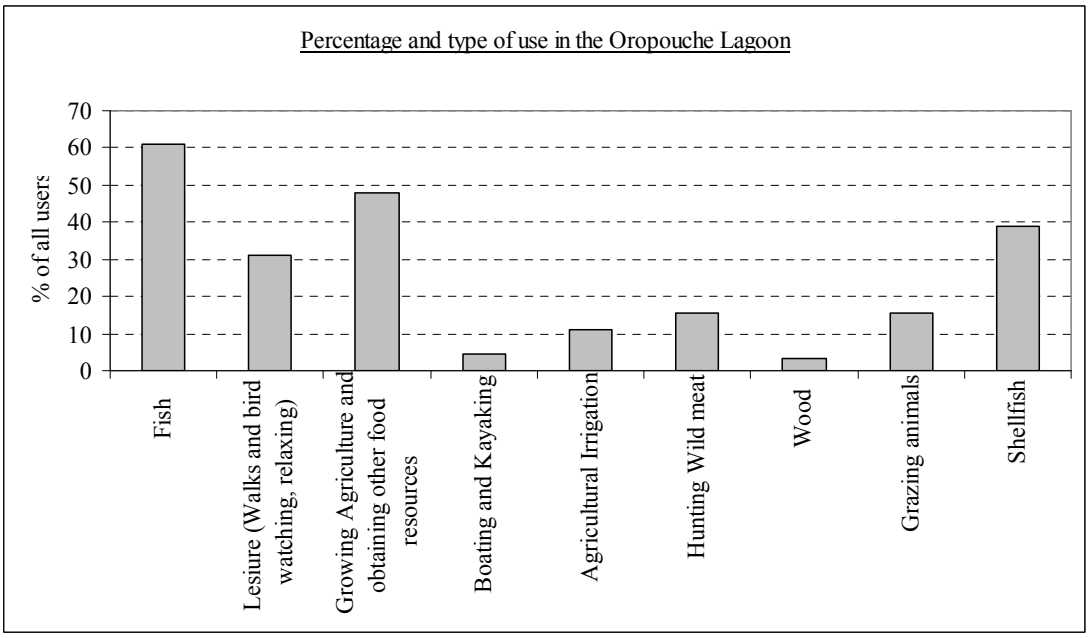


**Figure 24: The various uses of the lagoon and their percentage from the respondents**

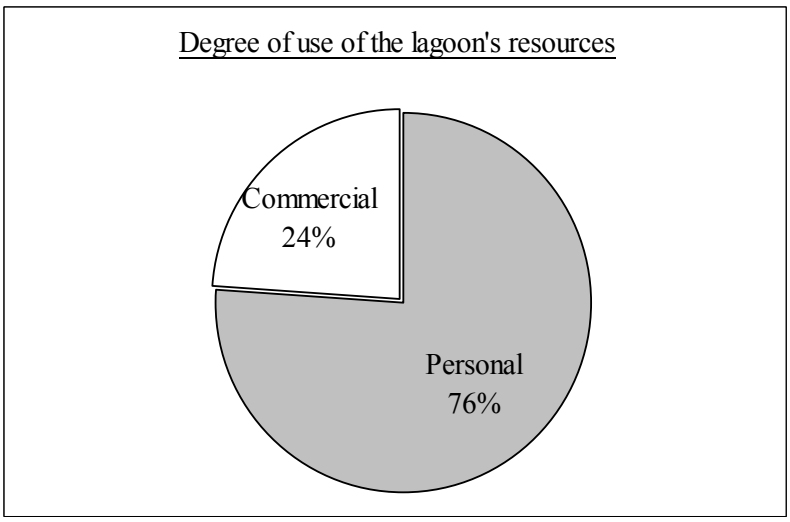


**Figure 25: Type of usage of the lagoon's goods and services**

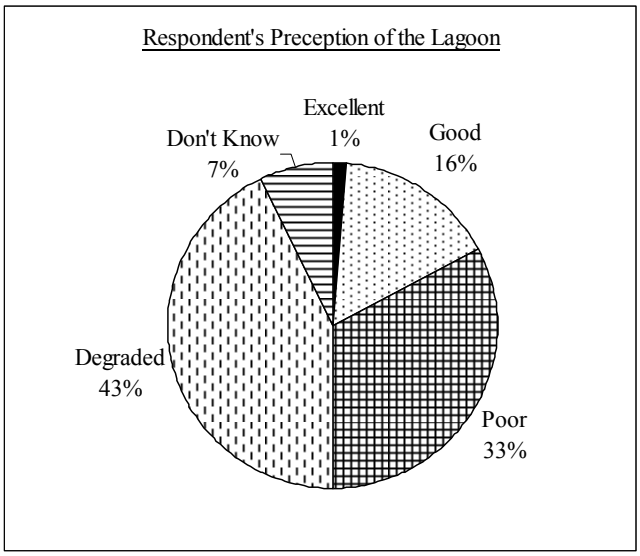


**Figure 26: Perception of the Oropuche lagoon**

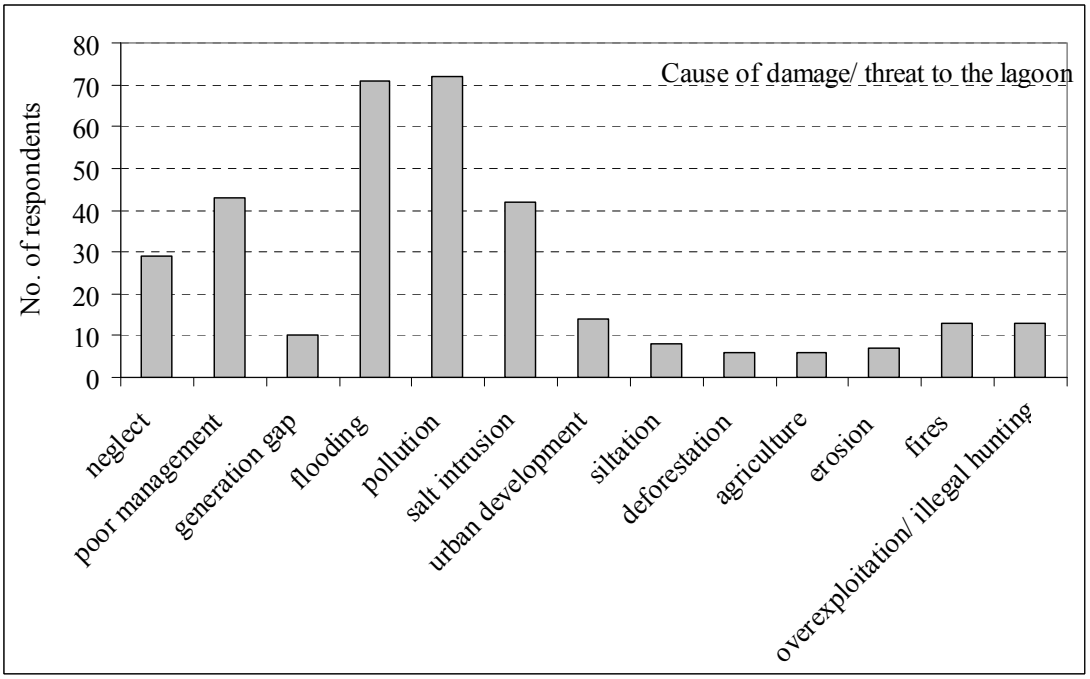


**Figure 27: Respondents' view as to the cause of threat or damage to the Oropuche Lagoon**