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Economic Assessment of Ecosystem Services Provided by the Sangomar Marine Protected Area in the Saloum Delta Biosphere Reserve (Fatick, Senegal)

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Abstract

The Sangomar Marine Protected Area (AMPS) plays an important socio-economic, ecological and cultural role. However, since its creation, little information exists on its total economic value, which is generally difficult for local people to perceive. This study is a contribution to the assessment of the economic value of the AMPS. To do this, surveys were carried out in three villages of Dionewar (Dionewar, Falia and Niodior) using focus groups for all types of ecosystem service with specific socio-professional categories, fisheries services and managers. The criteria measured concerned the identification of stakeholders, the population's perception of the services and their monetary value. The results show that the majority of stakeholders in the AMPS are fishermen (48%), carters (42%) and women who process fish and forest products (29%). A total of 19 ecosystem services were inventoried, and divided into 4 categories (provisioning, regulating, cultural and supporting services). The most important services in terms of scores were nursery (8.71), soil formation (8.43) and the water cycle (8.38). The total economic value of the AMPS was estimated at 2,808,323,563 FCFA, with regulating services having the highest value (61.87%), followed by provisioning services (22.53%). These results should serve as a decision-making tool to raise awareness of the importance

of the AMPS among the population and political decision-makers.

Keywords

Ecosystem Services, Total Economic Value, Sangomar Marine Protected Area, Economic Valuation, Dionewar Municipality

1. Introduction

The preservation and maintenance of livelihoods, as well as human development, depend largely on biodiversity [1]. Since the 1970s, global biodiversity has declined by around 52% [2]. This decline in biodiversity led, at the Earth Summit in Rio in 1992, the establishment of several international commitments to protect the environment, such as the Convention on Biological Diversity (CBD) [3]. Nevertheless, the loss of biodiversity is still being felt around the world, prompting the international community to draw up a set of twenty objectives known as the "Aichi Targets", which should be achieved by 2020. These targets were adopted at the 10th Conference of the Parties (COP) to the CBD at the Nagoya Summit in 2010. These targets aimed to enhance the benefits derived from ecosystems and ecosystem services [4].

Wetlands are among the richest and most productive ecosystems on the planet due to their high biological diversity [5]. They provide a wide range of goods and services essential to human well-being. People around the world have long benefited from the ecosystem services provided by wetlands [4]. This is one of the major conclusions of the Millennium Ecosystem Assessment (MEA) and one of the key messages of the Ramsar Scientific and Technical Review Panel (STRP) [6] cited by NOUMEYI [4].

The integration of the notion of biodiversity into the jargon of economics began in the mid 1990s [7] with the creation of the economics of biodiversity movement with the publication of the article by COSTANZA *et al.* [8]. This publication proposed, for the first time, an approach for calculating the monetary value of the world's biodiversity and demonstrated the importance of economic valuation in informing and guiding biodiversity conservation policies by translating the benefits of biodiversity into economic gains [9].

The United Nations Millennium Ecosystem Assessment (MEA) programme formalised this role in 2005 [10]. The MEA aims to raise awareness among policymakers of the importance of protecting the environment to safeguard economic activity and the well-being of the population. It does this by identifying all the ecosystem services provided by natural areas and estimating their economic value in order to assess their contribution to human well-being [9].

Since then, valuing the ecosystem services provided by ecosystems has been a way of convincing political decision-makers to protect ecological units threatened by human actions, particularly in Africa [4].

The total economic value of the ecosystem services provided by biodiversity is very poorly assessed in Africa [11]-[13]. Indeed, according to a study based on online publications [13] cited by [9], developing countries apply few economic valuation methods for biodiversity [8]. The few studies conducted in Africa on the economic valuation of ecosystems have often used models from Northern countries without taking into account the realities of developing countries (DCs) in the choice of valuation methods to be applied [13]. Moreover, the bibliographical research carried out by HAMID [9] revealed that even the application of the contingent valuation method to quantify Consent to Pay (CTP) in favour of biodiversity conservation is very rare on the African continent. Ultimately, the Environmental Valuation Reference Inventory (EVRI) database showed that out of 265 contingent valuation studies listed, only 3.39% originated from the African continent [9].

Despite the difficulties mentioned above, the total economic valuation of ecosystems is today an essential tool for explaining to African leaders and local communities the role of marine protected areas in the production of human well-being [14] cited by HAMID [9], and a justification of the need to ensure their integral protection, particularly in Africa where economic development takes precedence over nature conservation [9]. It is in this context that this study focuses on the evaluation of ecosystem services in the Sangomar Marine Protected Area (AMPS). The main objective of this study is to contribute to the economic evaluation of the ecosystem services provided by the Sangomar Marine Protected Area (MPA) in the Saloum Delta in Senegal.

2. Materials and Methods

2.1. Study Area

The study has been conducted in the Fatick region, in the Sangomar Marine Protected Area (AMPS), located between latitudes 13˚35' and 14˚10' north and longitudes 16˚50' and 17˚00' west, and covering the communes of Palmarin and Dionewar. The AMPS is bounded to North by the Joal Fadiouth MPA, to the South by the Saloum Delta National Park and to the East by the Palmarin Community Nature Reserve (RNC) and the Communes of Bassoul and Djirnda [15] (**Figure 1**). The main activities are fishing and malacological gathering, processing of fish products, agriculture and livestock farming [16]. Temperatures range from 17˚C in January to 37˚C in June, with an average of 27˚C. A short rainy season lasting around four months, with low intensity in July and August, with average rainfall of 155.1 to 265.7 mm following the arrival of the monsoon, the hot, humid wind that blows from mid-June to mid October and brings rain (Foundiougne weather service, 2016). The commune is characterised by the presence of leached and slightly leached tropical ferruginous soils, low-lying areas or basins and halomorphic soils. Surface water in the area is mainly made up of the Atlantic Ocean, which runs alongside the western part of the local authority. The Saloum River is also a major source of water, feeding several bo-

longs and ponds in the region. Vegetation in the AMPS varies from mangrove forests to dryland forests, shrub savannahs and herbaceous ground cover. The AMPS is also rich in wildlife. These include migratory birds (pink flamingos, pelicans, terns, green bee-eaters, grey herons, etc.), mammals such as hyenas, jackals, raptors, genets, patas monkeys, etc, reptiles (marine turtle, crocodile, Nile monitor, python, snake, etc.) and aquatic fauna (fish, arches, shrimp, murex cymbium, etc.) [16].

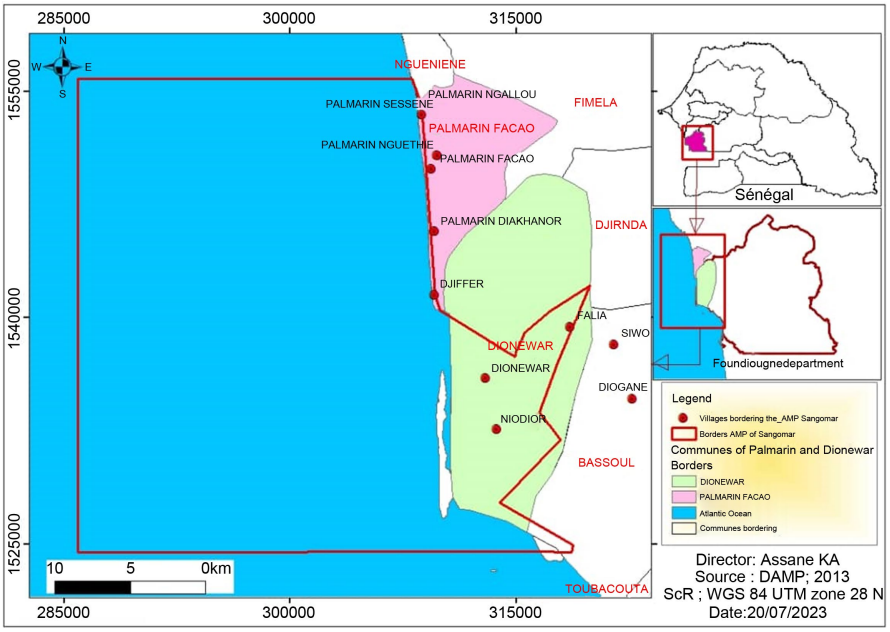

Figure 1. Location of the SMPA.

2.2. Sampling Method

The study was conducted in the villages of Niodior, Falia and Dionewar in the Dionewar municipality, which is centred on the AMPS. The choice of this commune was justified by the activities carried out by its population in the AMPS. Purposive sampling was adopted for this research. Taking into account the ecosystem services provided by the AMPS, all socio-professional categories were surveyed. These included women who process fish products, gatherers of non-timber forest products (NTFPs) grouped together in the Resource Management Committee (COGERE), pirogue operators, hoteliers, carters, fishmongers, farmers, stockbreeders, honey producers, tourist guides, salt producers and households affected by high winds. Given the difficulty of assessing ecosystem services, and in order to ensure the reliability of the information, focus group interviews were conducted in each village and for each category of service targeting the specific socio-professional group. For each socio-professional category, the focus group involved 10 members chosen, with the help of the manager, on the basis of their experience in the field (over 3 years), their strong involvement and their knowledge of the field. In addition, semi-structured individual surveys were carried out among AMPS agents and those of the fishing service in the said villages. To assess the importance

of the various types of service, each focus group participant was assigned a score (ranging from 1 to 10) to each type of service.

2.3. Data Collection

The study assessed the total economic value of 4 categories of ecosystem services: provisioning, cultural, regulatory and support services. The general information gathered was the identification of the types of stakeholders and the frequency of use of the services. To assess the total economic value, a specific questionnaire was drawn up for each category of service. For supply services, the questionnaire provided information on the different types of products harvested and processed, the frequency and quantity harvested and the unit market price. For the regulation services, the information requested included the number of houses located within 300 m of the coast in order to quantify the cost of avoided damage to these houses, as well as the number of houses or infrastructures damaged by violent winds and the expenditure incurred in repairing them (replacement cost method). As for the support service, the questionnaire provided information on the AMPS budget and investment by its various partners. With the cultural service, the tourist campaign, the price and duration of stays and the price to be paid for walks were the main information collected.

2.4. Data Analysis and Processing

The importance of the different types of services (scores) was submitted to Anova using R 4.3.1 software. The Excel spreadsheet was used for the calculations and figures.

To assess the annual economic value of the supply service, NTFPs harvested and processed, fishery products and agriculture were considered. Formula 1 was used:

$$\text{Annual economic value ofsupply services} = \sum \text{annualquantity harvested}\ (i) * \text{market cost}(i) \quad (1)$$

where i is the service provided.

Livestock services were estimated using the replacement cost method. The quantity of fodder was estimated on the basis of the work of NDIAYE [17], according to whom the minimum consumption of concentrated feed is estimated at one to two bags of concentrates per month, depending on the size of the herd. It should be noted that in these villages, the animals are left to graze freely.

In the case of cultural services, tourism, including walking, and shipping were taken into account. They were evaluated by equations 2 and 3 respectively:

$$\text{Annual economic value of tourism} = \text{number of days in the tourism campaign} * \text{average daily number of tourists} * \text{average daily rate} \quad (2)$$

$$\text{Annual economic value of shipping services} = \text{Number of average daily passengers} * \text{number of daily journeys} * 365 * \text{price per person} \quad (3)$$

Given the remote and rural nature of the study area, local people are not aware of the cultural services associated with education and contemplation. As a result,

it was not possible for the local people, the main beneficiaries, to assess the economic value of these services.

With regard to regulating services, carbon sequestration, erosion regulation and strong winds were taken into account. For carbon sequestration, a land use map of the AMPS was designed using QGis software. According to PROGED-2; KAUFFMAN and BHOMIA [18] [19] mangroves sequester 55 t x ha^{-1}x yr^{-1}, open forests 52.60 t x ha^{-1}x yr^{-1} and wooded savannahs 30 t x ha^{-1}x yr^{-1} and shrublands 45.21 t x ha^{-1}x yr^{-1}. The average price of ton of carbon sold on the voluntary market is between 1850 and 5250 FCFA, i.e. an average of 3550 FCFA.t^{-1} [4]. Thus, the annual value of sequestration was given by formula (4).

$$\text{Annual Economic value of carbon sequestration} = \sum \text{Annual sequestrated quantity per ecological unit } (i) * \text{Voluntary carbon market cost } (i) \quad (4)$$

where i is the service provided.

With regard to the regulation of erosion and flooding, the assessment was made using the method of the replacement cost of infrastructure, particularly houses located less than 300 m from the coast. According to NOUMEYI [4], mangroves reduce by three quarters the destructive effect of erosion and strong winds for houses located less than 300 m from the coast. According to AJONINA *et al.* [20], the gains in restoration costs allocated to mangrove ecosystems for protection against flooding and moderation of the effects of high winds amount to 40%. On the other hand, for the regulation of the effects of violent winds, the economic evaluation of the expenditure incurred for the repair of damaged houses or infrastructures was carried out. Formulas 5 and 6 were therefore applied.

$$\text{Annual economic value of Flood and erosion protection} = \sum \text{Total cost of infrastructures located from 300 m less than the mangroves } (i) * 40\% \text{ of protection due to mangroves } (i) \quad (5)$$

where i is the service in question.

$$\text{Annual economic value of moderate violent winds} = \sum \text{expenses on wind-damaged homes } (i) * 40\% \text{ of protection due to mangroves } (i) \quad (6)$$

where i is the service provided.

To assess the economic value of each category of service, the sum of the different types of service making up the category was calculated.

The support service was evaluated using the method of NDIAYE [17], according to which the value of this service is equal to the sum of the WHPA budget and the amount of investments made by partners for biodiversity conservation.

The total economic value was assessed by adding together the values of the 4 service categories.

3. Results

3.1. Key Actors at the SMPA

Fishermen are in the majority (48%), followed by women who process fish and

forestry products (29%). On the other hand, tourist guides, hoteliers, livestock farmers and fishmongers account for the smallest proportions (1, 1, 2 and 2% respectively) (Figure 2).

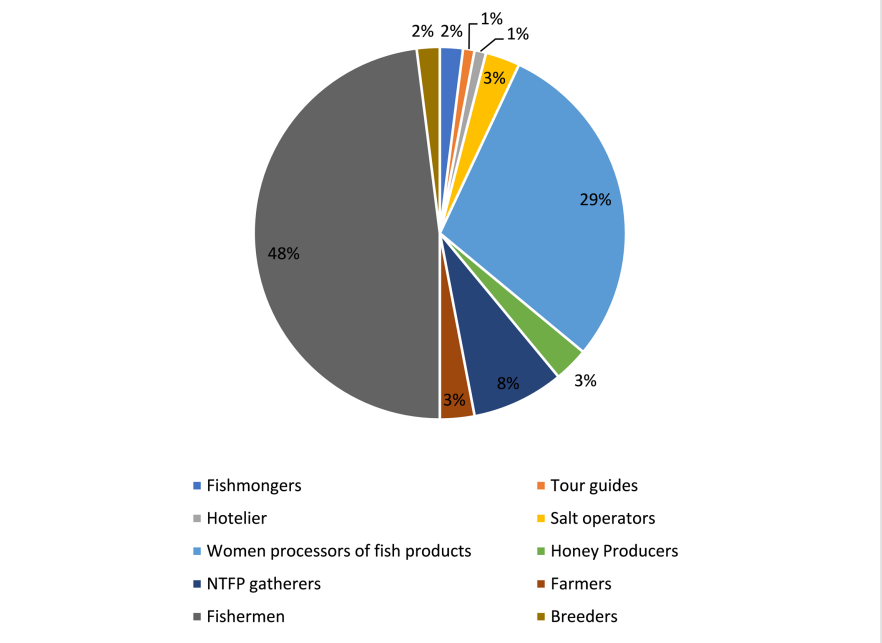

Figure 2. Breakdown of actors per activity.

Indirect actors in the AMPS—carters—are in the majority (42%), followed by box hire companies and resellers with the same proportion (16%). However, conservation and development NGOs are in the minority (4%) (Figure 3).

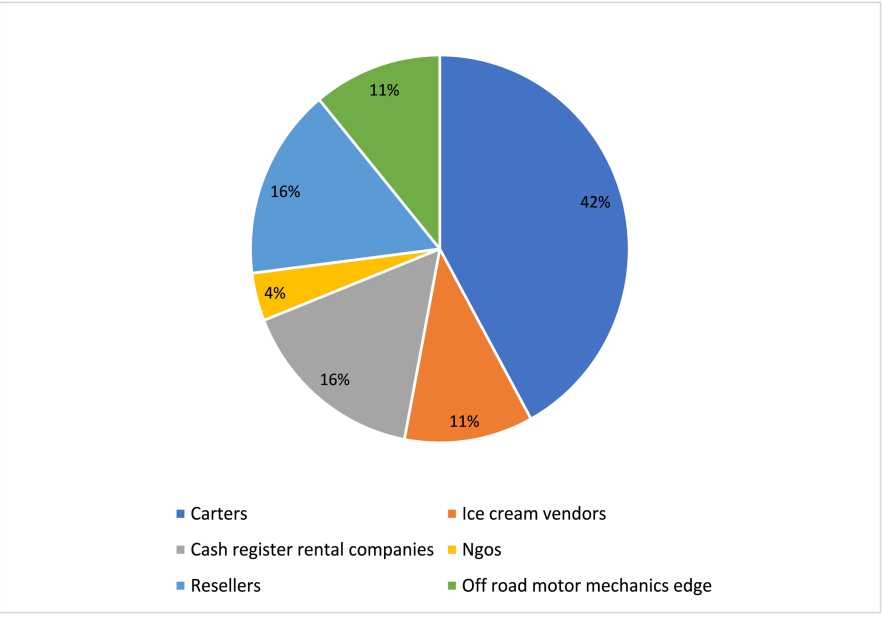

Figure 3. Breakdown of indirect actors per activity.

3.2. Ecosystem Services Types at SMPA Ecological Units

The Sangomar Marine Protected Area (SMPA) provides a total of four ecosystem services to the inhabitants of the Dionewar municipality. These include: provisioning services, which are the goods that people obtain directly from the MPA, such as collecting firewood, fishing, gathering NTFPs, food and medicines. Regulating services, which serve to regulate the ecosystem and combat flooding, coastal erosion and violent winds. Support services, which serve to support the other services. Cultural services, which are the intangible products that communities derive from the MPA, such as tourism, walking, education and research (Table 1).

Table 1. Different types of ecosystem services provided by the AMPS according to users.

Typology of ecosystem services	Ecosystem services
Procurement services	• Fishing; • Collecting wood; • NTFP harvesting; • Shellfish; • Oyster fishing; • Agriculture; • Breeding; • Food (fish, oysters); • Pharmacopoeia.
Regulatory services	• Physical barrier (moderates violent winds and combats flooding and erosion); • Carbon sequestration; • Climate regulation.
Cultural services	• Education and research; • Recreational activities (walks, etc.); • Navigation (Taxi pirogue); • Tourism; • Aesthetics (mangroves, bolongs, islands, etc.).
Support services	• Soil formation; • Water cycle; • The Nursery.

3.3. Residents' Perceptions of Ecosystem Services at SMPA

People's perception of the importance of the types of ecosystem services, expressed as a score ranging from 1 to 10. Analysis of the figure shows that the highest score is given to nursery (8.71), followed by soil formation (8.43) and the water cycle (8.38). However, the population attaches less importance to salt mining, pharmacopoeia and animal husbandry, with respectively a scores of 7.15, 6.92 and 5.77 (Figure 4).

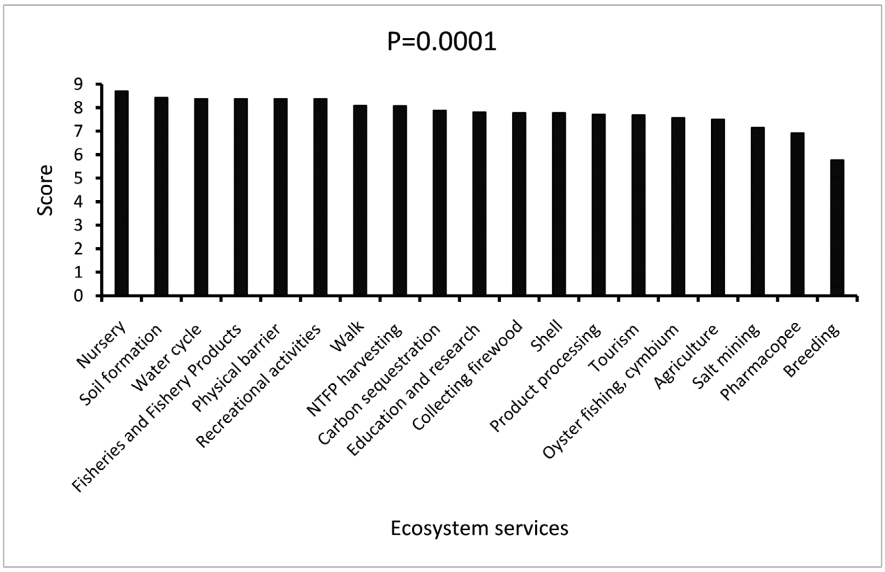

Figure 4. Public perception of the ecosystem services provided by the AMPS.

3.4. Total Economic Value of the SMPA Ecosystem Services

3.4.1. Fishing

The total economic value derived from fishing is estimated at **CFAF 528,600,000 per year^{-1}** for the three villages, with **CFAF 484,000,000 per year^{-1}** for Niodior, **CFAF 36,200,000 per year^{-1}** for Dionewar **and CFAF 8,400,000 per year^{-1}** for Falia (Table 2).

Table 2. Incomes from fishing and fish products.

Villages	Uses	Quantity (t)	Unit price FCFA	Annual value FCFA
Niodior	Fish	90	400,000	36,000,000
	Molluscs	100	800,000	80,000,000
	Crustaceans	30	1,000,000	30,000,000
	Subtotal 1	**220**	**2,200,000**	**484,000,000**
Dionewar	Fish	100	250,000	25,000,000
	Molluscs	10	700,000	7,000,000
	Crustaceans	7	600,000	4,200,000
	Subtotal 2	**117**	**1,550,000**	**36,200,000**
Falia	Fish	7	400,000	2,800,000
	Molluscs	4	1,000,000	4,000,000
	Crustaceans	2	800,000	1,600,000
	Subtotal 3	**13**	**2,200,000**	**8,400,000**
GENERAL TOTAL		**528,600,000 FCFA**		

3.4.2. Revenue from the Three Fish and Forestry Product Processing Sites

The total economic value of processing fish and forestry products in the three villages is estimated at **45,161,000 FCFA.year^{-1}** with the highest value **(22,300,000 FCFA.year^{-1})** recorded in Dionewar followed by Falia **(11,475,000 FCFA.year^{-1}) and** Niodior **(11,386,000 FCFA.year^{-1})** (Table 3).

Table 3. Incomes from processing fish and forestry products in the three villages.

Villages	Uses	Total weight (kg)	Number of bags processed	Unit price (FCFA)	Annual value (FCFA)
Niodior	Arch or shell (loincloths)	780	2340	2000	4,680,000
	Murex (Tufta)	360	728	2000	1,456,000
	Cymbium (Yett)	360	1080	2500	2,700,000
	Oysters	200	400	2000	800,000
	"Ditakh	1800	700	2500	1,750,000
	Subtotal 1		**11,386,000 FCFA**		
Dionewar	Arch or shell (loincloths)	960	2800	2000	5,600,000
	Murex (Tufta)	1000	1800	2000	3,600,000
	Cymbium (Yett)	2500	1400	2500	3,500,000
	Oysters	2000	1500	2000	3,000,000
	(Yokhoss "Ditakh)	480	300	2500	750,000
	Dakhar	1440	800	2500	2,000,000
	Sipax prawns Tamarind	480	500	4000	2,000,000
	Khéthiakh" smoked fish	1 000	700	1500	1,050,000
	Bissap sorrel	100	200	2500	500,000
	Honey	240	150	2000	300,000
	Subtotal 2		**22,300,000 FCFA**		

3.4.3. Incomes from Fishing Licences

The amount payable for fishing licences varies according to the type of licence:

Permit B, reserved for pirogue owners with canoes between 1 and 13 m long. They pay a fee of **15,000 FCFA.year^{-1} per canoe**.

Permit C, reserved for pirogue owners with canoes longer than 13m. They pay an **annual fee of 25,000 FCFA^{-1} per pirogue**.

The fishing services station registers a total of 90 type B fishing licences and 55 type C fishing licences each year. The total monetary value generated by the grant-

ing of fishing licences for the three villages is estimated at FCFA 2,725,000 per year^{-1}. This total value conceals disparities within the villages, with the highest amount recorded in Dionewar (1,225,000 FCFA), followed by Niodior (950,000 FCFA.year^{-1}) and Falia (550,000 FCFA.year^{-1}) (Table 4).

Table 4. Incomes from fishing licences.

Villages	Types of licence	Number	Cost per unit	Annual value FCFA
Niodior	B licence (1 to 13 metres)	30	15,000	450,000
	C licence (13 metres and over)	20	25,000	500,000
	Subtotal 1		**950,000**	
Dionewar	B licence (1 to 13 metres)	40	15,000	600,000
	C licence (13 metres and over)	25	25,000	625,000
	Subtotal 2		**1,225,000**	
Falia	B licence (1 to 13 metres)	20	15,000	300,000
	C licence (13 metres and over)	10	25,000	250,000
	Subtotal 3		**550,000**	
GENERAL TOTAL			**FCFA 2,725,000**	

3.4.4. Revenues from Non-Timber Forest Products (NTFPs)

The total economic value of NTFPs is estimated at **20,607,000 FCFA.year^{-1}** for all three villages, with the highest value noted in Dionewar **(9,320,000 FCFA.year^{-1}), followed by** Falia **(8,000,000 FCFA.year^{-1}) and Niodior (3,287,000 FCFA.year^{-1})** (Table 5).

Table 5. Income from NTFP collection by local people.

Villages	NTFPS	Quantity (30 Kg breakdowns)	Unit price (FCFA)	Annual value (FCFA)
Niodior	"Ditakh	400	4000	1,600,000
	Pain de singe (Bouy)	100	15,000	1,500,000
	Coco	1500	125	187,000
	Subtotal 1		**3,287,000**	
Dionewar	"Ditakh	1080	4000	4,320,000
	Pain de singe (Bouy)	800	6000	4,800,000
	Coco	100	2000	200,0000
	Subtotal 2		**9,320,000**	

Continued

	"Ditakh	1000	4000	**4,000,000**
Falia	Pain de singe (Bouy)	800	5000	**4,000,000**
	Subtotal 3		**8,000,000**	
GRAND TOTAL (FCFA)			**20,607,000 FCFA.year^{-1}**	

3.4.5. Women's Income at Salt Extraction Sites in Niodior

In total, salt production in the village of Niodior alone is estimated at **12,000,000 FCFA per year^{-1}** (Table 6).

Table 6. Income from salt production in niodior.

Salt mining	Quantity (t)	Unit price (FCFA)	Annual value (FCFA)
Puits du sel 1	7	1,000,000	7,000,000
Puits du sel 2	5	1,000,000	5,000,000
GENERAL TOTAL		**12,000,000**	

3.4.6. Farming Recipes at Falia

The total monetary value of agriculture is estimated at **8,100,000 FCFA.year^{-1}** (Table 7).

Table 7. Revenue from agriculture.

Speculation	Quantity (t)	Unit price (FCFA)	Annual value (FCFA)
Peanut	20	180,000	3,600,000
Cowpeas	5	300,000	1,500,000
But	7	400,000	2,800,000
Tomato/Crate	50	4000	200,000
TOTAL			**8,100,000**

3.4.7. Livestock Income at Falia

The total monetary value of livestock production is estimated at **CFAF 9,600,000 per year^{-1}** (Table 8).

Table 8. Revenues from the livestock sector.

Speculation	Quantity (t)	Unit price (FCFA)	Annual value (FCFA)
Meat and livestock products (cattle)	30	320,000	**9,600,000**

Revenue from firewood at Dionewar

The total monetary value of fuelwood is estimated at **6,000,000 FCFA.year^{-1}** (Table 9).

Table 9. Incomes from firewood collection.

Speculation	Quantity/drug/cargo	Unit price (FCFA)	Annual value (FCFA)
Firewood	300	20,000	**6,000,000**

3.4.8. Cultural Services

Incomes from shipping (pirogue operators)

There are a total of 04 shuttles, called "couriers" by the inhabitants of the three villages. The pirogue boats run the shuttles throughout the week, with an average of 2 trips per day and **35 passengers per pirogue per day.** Prices vary from **350 to 1000 FCFA.** The total monetary value of navigation is estimated at **66,977,500 FCFA per year^{-1}** (Table 10).

Table 10. Revenue from shipping.

Journeys	Number of journeys/day	Number of passengers/Pirogue	Unit price/Passenger (FCFA)	Annual value (FCFA)
Djiffere-Niodior	2	35	500	12,775,000
Niodior-Djiffere	1	55	1000	20,075,000
Subtotal 1			**32,850,000**	
Dionewar-Falia	2	55	350	**14,052,500**
Falia-Dionewar	2	55	500	**20,075,000**
Subtotal 2 (FCFA)			**34,127,500**	
GRAND TOTAL (FCFA)			**66,977,500**	

3.4.9. Paillote Recipes (Tourism)

A total of 08 straw huts were found along the shores of the villages of Dionewar and Falia, run by local people to accommodate tourists. The monetary value of tourism was estimated at **60,840,000 FCFA.year^{-1}**, with the highest amount recorded in Dionewar (47,160,000 FCFA) and the lowest in Falia (13,680,000 FCFA) (Table 11).

3.4.10. Regulatory Affairs

Carbon sequestration

Land use in the AMPS is dominated by aquatic environments (freshwater and marine) (85.09%), although the uses and activities are not comparable between the different environments, the marine environment being largely represented. This is followed by mangroves (8.24%), savannahs (4.58%) and tannas (0.86%). Crops occupy the smallest area (0.001%). Thus, the total monetary value of carbon sequestration in the AMPS is estimated at **1,450,105,563 FCFA.an^{-1}** with **796,004,963**

FCFA.an^{-1} for mangroves, **604,872,963 FCFA.year^{-1}** for savannahs (trees and shrubs) and **49,227,637 FCFA.year^{-1}** for forests (Table 12).

Table 11. Incomes from straw huts.

Villages	Hotels/Camps	Average number of tourists/week	Average length of stay	Average room/night and restaurant rates (FCFA)	Annual value (FCFA)
Dionewar	Camp 1 Dionewar	7	5	35,000	29,400,000
	Camp 2 Dionewar	3	4	20,000	5,760,000
	People working for accommodation				12,000,000
	Subtotal 1 (FCFA)			**47,160,000**	
Falia	Falia camp	6	4	17,500	10,080,000
	Employees				3,600,000
	Subtotal 2 (FCFA)		**13,680,000**		
GRAND TOTAL (FCFA)			**60,840,000**		

Table 12. Incomes from carbon sequestration by ecological units.

Ecological unit	Average stock of carbon (t·ha^{-1})	Area of each ecological unit (ha)	Total quantity stored in the AMPS (t·ha^{-1})	Total monetary value of carbon (FCFA.year^{-1})
Mangroves	55	4076.85	224226.75	796,004,963
Shrubby savannahs	45.21	2265.48	170386.75	604,872,963
Wooded savannah	30			
Forests	52.60	263.63	13866.94	49,227,637
GRAND TOTAL (FCFA)			**1,450,105,563**	

3.4.11. Protecting Mangroves from Strong Winds

The estimated monetary value for the moderation of the effects of violent winds by the mangrove ecosystem of the AMPS was **16,680,000 FCFA.year^{-1}** for all three villages. The highest value was recorded in Niodior (**10,800,000 FCFA.year^{-1}**), followed by Falia (**1,280,000 FCFA.year^{-1}**) and Dionewar (**4,600,000 FCFA.year^{-1}**) (Table 13).

3.4.12. Protecting Mangroves against Erosion and Flooding

The monetary value of the AMPS mangrove ecosystem for protection against coastal erosion and flooding is estimated at **270,800,000 FCFA.year^{-1}** within the three villages. The village of Dionewar has the highest value at **164,000,000 FCFA.year^{-1}** (Table 14).

Table 13. Incomes from carbon sequestration by ecological units.

Villages	Infrastructure and homes affected	Quantity	Average expenditure/infrastructure/year in FCFA	Total expenditure (FCFA.year^{-1})
Niodior	Inhabited houses	30	300,000	9,000,000
	Mosques	2	5,000,000	10,000,000
	Processing unit	1	8,000,000	8,000,000
	Subtotal 1	33	13,300,000	27,000,000
	After correction (40% protection due to mangroves)		**5,320,000**	**10,800,000**
Dionewar	Inhabited houses	20	250,000	5,000,000
	Mosques	1	2,000,000 (Town Hall grant)	2,000,000
	Lycée	1	1,500,000	1,500,000
	Electricity pole	3	1,000,000	3,000,000
	Subtotal 2	55	6,750,000	11,500,000
	After correction (40% protection due to mangroves)		**2,700,000**	**4,600,000**
Falia	Inhabited houses	10	400,000	400,000
	Mosque	1	2,000,000	2,000,000
	Electricity poles	2	400,000	800,000
	TOTAL	13	2,800,000	3,200,000
	After correction (40% protection due to mangroves)		**1,120,000**	**1,280,000**
Grand total for the three villages after correction			**16,680,000 F**	**CFA**

Table 14. Incomes from protecting mangroves from coastal erosion and flooding.

Villages	Types Infrastructure	Number	Average total construction cost/ infrastructure/year (FCFA)	Total construction cost/year (FCFA)
Niodior	Stone houses	10	6,000,000	60,000,000
	Mosques	3	10,000,0000	30,000,000
	Processing unit	1	20,000,0000	20,000,000
	Drinking water points	1	2,000,000	2,000,000
	TOTAL	15	38,000,000	112,000,000
	After correction (40% protection due to mangroves)		**15,200,000 F**	**44,800,000**

Continued

Dionewar	Stone houses	40	8,000,0000	320,000,000
	Mosques	1	15,000,000	30,000,000
	Processing unit	1	20,000,000	20,000,000
	Lycée	1	40,000,000	40,000,000
	TOTAL	43	83,000,000	410,000,000
	After correction (40% protection due to mangroves)		**33,200,000**	**164,000,000**
Falia	Stone houses	30	4,000,000	120,000,000
	Mosque	1	15,000,000	15,000,000
	Processing unit	1	20,000,000	20,000,000
	TOTAL	32	39,000,000	155,000,000
	After correction (40% protection due to mangroves)		**15,600,000**	**62,000,000**
Grand total for the three villages after correction			**270,800,000 FCFA**	

3.4.13. Support Services

Analysis of Table 15 shows that the total monetary value of support services is estimated at **276,000,000 FCFA.year^{-1}, most of which (247,000,000 FCFA) comes from Financial and Technical Partners (FTPs)** who finance conservation, restoration and processing activities.

Table 15. Incomes from technical and financial partners and the Senegalese government for the operation of the AMPS.

Financing structures	Annual value (FCFA)
State of Senegal (operating and investment)	**29,000,000**
PTF	**247,000,000**
TOTAL	**276,000,000**

3.4.14. Total Economic Value of MPAS Ecosystem Services

The total economic value of the ecosystem services provided by the AMPS is estimated at **2,808,323,563 FCFA.year^{-1}.** This value is separated into use values, which contain the highest regulatory services, estimated at **CFAF 1,737,585,563.year^{-1}** (61.87%), provisioning services, estimated at **CFAF 632,793,000.year^{-1}** (22.53%), and cultural services, estimated at **CFAF 161,945,000.year^{-1}** (5.77%). The non-use values include only support services estimated at **276,000,000 FCFA.year^{-1}** (9.83%) (Table 16).

Table 16. Summary table of the total monetary value of ecosystem services provided by the WHPA.

Types of values	Ecosystem services	TEV in FCFA.year^{-1}	Share of each SE (%)
Use values	Procurement services	**632,793,000**	**22.53**
	Cultural services	**161,945,000**	**5.77**
	Regulatory services	**1,737,585,563**	**61.87**
	Sub-total use values = 2,532,503,563		
Non-use values	Support services	**276,000,000**	**9.83**

4. Discussion

4.1. Key Actors Identification

This study shows that the majority of stakeholders (48%) are fishermen who ply their trade in the AMPS. Fishing is the main activity in the Dionewar municipality, and most of the young people in the municipality are involved in this activity. At AMPS level, we find the following players: fishermen, women who process fishery and forestry products, NTFP gatherers, firewood collectors, hoteliers, carters, fishmongers, salt producers, honey producers, breeders, farmers, ice-cream sellers, crate hirers, outboard mechanics and resellers who make a profit from the AMPS. The latter contribute to the management of AMPS resources. These results corroborate those of FALL [21], for the Saint Louis AMP, where all these actors are found. In addition, women, who represent 29% of stakeholders, are much more active in the processing of fish and forest products. These results corroborate those of NDIAYE *et al.* [22] for the Kayar MPA, where 23% of women are involved in processing. According to a study by DEME [23], more than 80% of the fish and forest products processing sector is managed by women.

4.2. Public Perception on the SMPA's Ecosystem Services

This study shows that the entire population of the Dionewar municipality is aware of the AMPS. The population's knowledge of the AMPS is obvious because the Dionewar is a peninsula located within the AMPS. In addition, almost all the inhabitants of the Dionewar municipality gave a higher score (8.71/10) to the nursery of fish species. This is due to the fact that fishing is the main activity in the area and, according to them, the mangroves are a breeding ground for fish. This result corroborates that of HAMID [9] in the Banc d'Arguin-Mauritania National Park, where people gave a score of 9.10/10 to the nursery. In fact, all the respondents gave good scores to soil formation (8.43/10) and the water cycle (8.38/10) because, according to them, soil and water support all the other existing services, as shown by HAMID [9] in the Banc d'Arguin-Mauritanie National Park. However, this dependence of the population on mangroves has been shown by DIOP *et al.* [24] in the Delta du Saloum National Park in Senegal.

4.3. Economic Value of SMPA's Ecosystem Services

The regulating services estimated at 1,737,585,563 FCFA.year^{-1} are the most important ecosystem services offered by the AMPS. This result is due to the fact that the AMPS has mangrove ecosystems as well as tree and shrub savannahs and forest that sequester a significant amount of carbon also playing an important role in protecting against coastal erosion and flooding and moderating violent winds. These results corroborate those of SALL [25] for the Gandoul.

Marine Protected Area (AMPG), where regulatory services are more important, estimated at FCFA 5,203,055,447 per year^{-1}. In addition, the total economic value of fishery products in Dionewar fell from 982,732,100 FCFA.year^{-1} in 2017 to 528,600,000 FCFA.year^{-1} in 2023, a decrease of 454,132,100 FCFA.year^{-1} [15]. This decline is due to the destruction of the mangrove ecosystem, the increase in the number of fishermen in the area, the effects of climate change and the abandonment of fishing by many young people because of illegal emigration. These results corroborate those of NDIAYE *et al*. [22], who found the same reasons (destruction of mangroves, increase in the number of fishermen, etc.) for the decline in fish products in the Kayar MPA. In addition, supply services estimated at CFAF 632,793,000 per year^{-1} are also important in the AMPS, helping to achieve food security and increase people's incomes, thereby enabling them to improve their living conditions. These results are in line with those of SALL [25] for the AMPG and the Palmarin Community Nature Reserve (RNCP), and those of BADIANE *et al*. [26]; DIEDHIOU *et al*. [27] for the Abéné MPA, where provisioning and regulating services have the highest economic value. In addition, these same studies have been carried out in many MPAs in Senegal, such as the Aire Marine Protégée de Gandoul (AMPG), the RNCP by SALL [25] and in the AMPS by MBODJ [15]. The same work has also been carried out in the sub-region of Mauritania, in the Banc d'Arguin National Park by HAMID [9] and in the mangroves and associated forests of the Douala-Edéa coastal landscape in Cameroon by NOUMEYI [4]. The total economic value of the ecosystem services provided by the AMPS estimated at 2,808,323,563 FCFA.an^{-1} is much higher than that found 1,102,474,400 FCFA.an^{-1} by MBODJ [15]. This is due to the fact that he estimated only the direct use values of the AMPS, whereas the present study focused on all the values (use and non-use). This total economic value is much lower than that found by FALL [21] for the Saint Louis MPA, estimated at 13,395,318,050 FCFA.year^{-1}. This is due to the fact that Fall's sample was larger than ours because the Saint Louis MPA encompasses more than 08 villages that act directly on the MPA's resources whereas at the AMPS level, only three villages benefit directly from the AMPS. Given the total economic value of the ecosystem services provided by the AMPS, the latter still deserves to be better protected.

5. Conclusion and Perspectives

This study focuses on the economic evaluation of ecosystem services provided by the Sangomar Marine Protected Area (AMPS). The study shows that the most

common stakeholders in the AMPS are fishermen, carters and women who process fish and forest products, while the least represented are honey producers, salt producers, farmers, livestock breeders and hoteliers. These respondents cited 19 ecosystem services, which were divided into regulatory services, provisioning services, support services and cultural services. In the opinion of the people, the most important types of service were nursery services, with a score of 8.71, followed by soil formation (8.43) and the water cycle (8.38). In monetary terms, the highest value was recorded for regulation services (1,737,585,563 FCFA.year^{-1}), followed by supply services (632,793,000 FCFA.year^{1}), support services (276,000,000 FCFA.year^{-1}) and cultural services (161,945,000 FCFA.year^{1}). This gives a significant value of 2,808,323,563 FCFA.year^{-1} for the AMPS. The results of this study should be a means of convincing the political authorities and local communities to better protect the Protected Areas (PA).

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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