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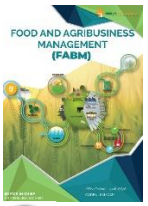

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RESEARCH ARTICLE

ECONOMIC VALUE ESTIMATION OF SHRIMP (*MACROBRACHIUM SPP.*) AND OYSTERS *(OSTREA EDULIS)* IN THE MANGROVES MARINE PARK (PMM), DEMOCRATIC REPUBLIC OF THE CONGO (DRC)

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ABSTRACT

Wetlands provide several Ecosystem services to most of the populations which are linked. They significantly contribute to their economic subsistence. However, it is very difficult to estimate their economic value while they impact on the ecosystem development of human well-being. This study aims to estimate the economic value of *Macrobrachium spp*. and *Ostrea edulis* in the MMP and assess fishermen's perceptions of the contribution of fish products to their well-being using the market price approach. The results revealed that the economic value of both products was estimated at 1,280,030 USD (2 816 066 200 FC). *Macrobrachium spp*. accounted for 31.12%, or 398 359 USD (876 390 200 FC), while Ostrea edulis accounted for 68.88%, or 881,671 USD (1 939 67 000 FC). Additionally, the results showed that the exploitation of *Macrobrachium spp*. and Ostrea edulis remains an important source of income for fishermen's households. Then, the profits from fishing mainly enable fishermen to meet their food requirements, access medical care, and send their children to school. Furthermore, it has been demonstrated that there is a need of reconciling conservation and sustainable use. Finally, monitoring and assessment of fish stocks harvested, the number of fishermen, the level of water pollution, and the development of a management plan are important to improve the sustainable management of all the provided ecosystem services from the wetlands.

KEYWORDS

Mangrove Marine Park, Economic value, Ecosystem, *Macrobrachium spp*, *Ostrea edulis*, Democratic Republic of the Congo, sustainable conservation.

1. INTRODUCTION

Mangroves are essential ecosystems because of many benefits which they offer to coastal areas (Mark and Maricé, 2021). They perform economic, social, and environmental functions that benefit mankind (Mbengue, 2012). They are also strategic points for the development of fishing, that is the main source of food and income for the coastal population (Diedhiou et al., 2021). In the DRC, Mangrove Marine Park (PMM) is an ideal breeding and growth habitat not only for fish but also for shellfish. It abounds in potential sites for fishing, that is an important socio-economic activity for many households (N'tambu et al., 2018). Ecosystem services are benefitting those humans derive from healthy, properly functioning ecosystems (IUCN/PAPACO, 2024; MEA, 2003).

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Nevertheless, PMM faces several threats (direct and indirect) and they are under pressures. These include overfishing, deforestation, poaching, and pollution from oil refineries, which significantly affect its resources (IUCN/PACO, 2010; ICCN, 2016). The link between these services and human well-being has been used to raise awareness among managers and decision-makers about the actions and decisions needed to better protect biodiversity (Carrière et al., 2014; Estrada et al., 2015). As a result, economic concepts are used to estimate the monetary value of ecosystem goods and services to assess the impact of ecosystem development on human well-being (Kosmus et al., 2013; Reid, 2005).

This demonstrates the crucial importance of assessing the economic value of ecosystem services to justify the investments needed to protect an ecosystem (Geoffroy et al., 2016). Yet knowledge of the economic value of *Macrobrachium spp*. and Ostrea edulis in the PMM is still limited. The aim of this study is therefore to estimate the economic value of the PMM, with a view of understanding the economic value of shrimp (*Macrobrachium spp*.) and oysters (*Ostrea edulis*), as well as fishermen's perceptions of the contribution of the services to their well-being. A better understanding of the economic value of ecosystem services in the PMM is needed to help implementation policies and strategies for the sustainable management of its fishery resources.

2. Materials and Methods

2.1 Study area

Mangrove Marine Park is a nature reserve created in May 1992 by ministerial decree number 044/CM/ECN/92 to protect the special biotope of the Atlantic coastline and the biological resources characteristic of wetlands, and to contribute to promoting tourism. Located at the estuary of the Congo River, in the territory of Moanda, Bas Fleuve District, Kongo-Central Province, it covers an area of 76,000 ha and includes the entire DR Congolese coastline. Its geographical coordinates are between 5°45'-6°55' South latitude and 12°45'-13° East longitude, with an altitude of less than 500 meters (IUCN, 2014; ICCN, 2016). Managed by the Institut Congolais pour la Conservation de la Nature (ICCN), the PMM also boasts magnificent fauna including, among others, the African manatee (*Trichechus senegalensis*) and five species of marine turtle (*Caretta caretta*, *Dermochelys coriacea*, *Eretmochelys imbricata*, and *Chelonia mydas*). Protecting these flagship species and safeguarding the unique biotope of the Congo River delta and the Congolese Atlantic coastline fully justified the creation of this park. In addition, this protected area was registered under the RAMSAR convention in 1996, making it a wetland of international importance (ICCN, 2016).

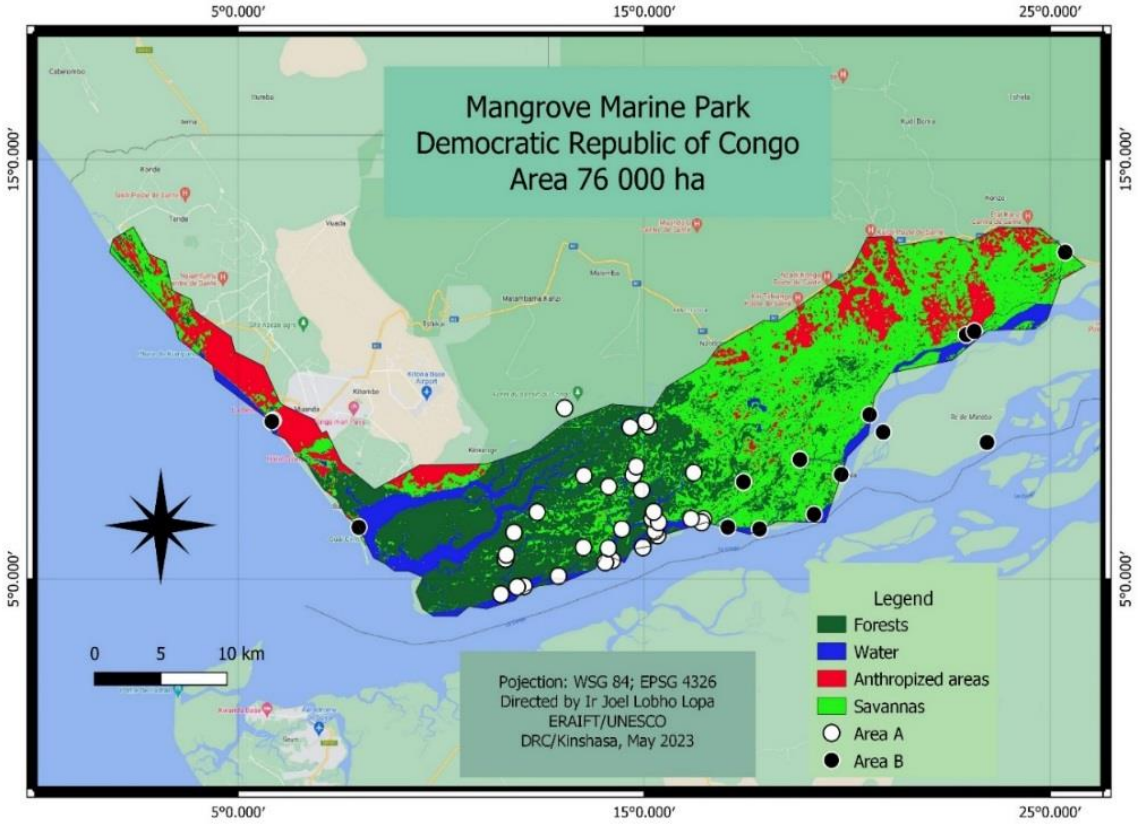

Figure 1: Data collection sites in the Mangrove Marine Park in 2023

2.2 Method for estimating economic value

Fishing belongs to the category of supply services (MEA, 2003). Consequently, the market price approach, using the so-called market value method, has been used to estimate the economic value of shrimp and oysters in the PMM that represents the value of ecosystem services which are marketed (Kosmus et al., 2013; MEA, 2005). Several other researchers have used this approach, including in their study on the "Economic Analysis of a Replanted Mangrove Plantation in Kenya"; in his study on estimating the economic value of Xuan Thuy National Park in Nam Dinh Province, Vietnam; in estimating the socio-economic value of Virunga National Park, Democratic Republic of Congo; and in their report on shellfish fisheries based on estuary and mangrove ecosystems in West Africa (Kairo et al., 2009; Montero, 2017; Bwami, 2018; Chuku et al., 2021).

2.2.1 Data collection

Data collection initially involved surveying fishermen in all the sites (villages and camps) around and within the PMM. A total of 329 shrimp fishermen and 243 oyster fishermen were counted. As the number of fishermen in the various sites was not uniform, data were collected on a sample defined by the stratified sampling technique. The sample size was determined as follows:

$$n = \frac{t_p^2 * p(1-p) * N}{t_p^2 * p(1-p) + (N-1) * y^2}$$ (Rea et al., 1997)

With:

- n: sample size.
- N: size of target population (number of households, users, etc.), actual or estimated.
- P: expected proportion of a population response or actual proportion (P = 0.5).
- t_p : 95% sampling confidence interval (t_p = 1.96).
- y: margin of sampling error (y = 5%)

A total of 178 shrimp fishermen and 150 oyster fishermen were surveyed. Data on *Macrobrachium spp*. were collected at 34 sites, while data on Ostrea edulis were collected at 13 sites. Surveys were carried out using individual interview guides, as well as focus group discussions at the various sites. The sample of *Macrobrachium spp*. respondents consisted exclusively of men, most of them married, with tenure ranging from 1 to over 40 years. For Ostrea edulis, the sample comprised 96 men and 54 women, most of them married, with tenure ranging from 1 to 40 years.

2.2.2 Data processing and analysis

Producer surplus is the result of the difference between the price received by the seller for a good produced and the cost of producing that good (Dupras et al., 2013). To calculate the fisherman's surplus, the following variables were considered: number of fishermen, total annual production, self-consumption share, operating costs, and the selling price of the product.

Total annual profit is calculated as the difference between annual production value and total annual operating costs. The average annual profit is equal to the total annual gain divided by the number of fishermen (n). Hence, the fishermen's surplus is equal to the average annual gain multiplied by the total number of active fishermen (N) in the PMM.

The calculations are as follows:

- Annual gain for fishermen: $\sum (\Pi A * PV) - CE_a$
- Average annual grain : $\frac{\sum(\Pi A * PV) - CEa}{n}$
- A surplus of fishermen : $\left(\frac{\sum(\Pi A * PV) - CEa}{n}\right) * N$

With, ΠA: annual production; PV: selling price; CEa: annual operating expenses; n: sample size; N: population size.

A few statistical analyses were used, including:

- Percentage (%) : $\left(\frac{n}{N}\right) * 100$
- The average $(\overline{x})$: $\frac{\sum x_j}{n}$
- Standard deviation(σ) : $\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})^2}$
- Chi-square (X^2) on two proportions (two samples):

$$\sum_{i=1}^{2}\sum_{j=1}^{2}\frac{(n_{ij} - T_{ij})^2}{T_{ij}} \geq \chi^2_{1;\alpha}$$

- Fisher's exact test : $\frac{(a+b)!(c+d)!(a+c)!(b+d)!}{a!b!c!d!n!}$
- 1 USD: 2 200 FC (FC = Congolese Franc)

3. RESULTS

3.1 Annual economic value

This is the value expressed in monetary terms, providing a common indicator for measuring the benefits provided by *Macrobrachium sp* and *Ostrea edulis*.

3.1.1 Annual production and selling prices

The average annual production of *Macrobrachium sp* was estimated at 443.91 ± 166.46 kg in season A (season corresponding to the period of abundance) and 121.25 ± 59.09 kg in season B (season corresponding to the period of shortage). *Ostrea edulis* production was estimated at 1 531.21 ± 470.04 kg in season A and 344.62 ± 128.77 kg in season B.

Table 1: Annual production and average price of shrimp and oysters

F.S	Production (Kg)		Average price (FC/Kg)	
	Period A	Period B	Period A	Period B
Macrobrachium sp	79 016 (443.91 ± 166.46)	21 583 (121.25 ± 59.09)	6 200 ± 1600	9 000 ± 950
Ostrea edulis	229 682 (1531.21 ± 470.04)	51 693(344.62 ± 128.77)	5 200 ± 590	2 800 ± 600

The average price per kilogram of *Macrobrachium spp*. is 6 200 ± 1 600 FC in season A, rising to 9 000 ± 950 FC in season B. However, the average price of a kilogram of Ostrea edulis is estimated at around 5,200 ± 590 FC in season A and drops to around 2 800 ± 600 FC in season B.

3.1.2 Annual load and annual production value

The average annual cost of *Macrobrachium spp* was estimated at 1 179 300 ± 547 500 FC, and that of *Ostrea edulis* at 924 900 ± 218 650 FC.

Table 2: Annual load and production value of shrimp and oysters

[1]F.S	Expenses (FC)		Products (FC)	
	Total	Average	Total	Average
Macrobrachium spp	209 904 800	1 179 300 ± 547 500	684 065 200	3 843 100 ± 1 318 500
Ostrea edulis	138 739 150	924 900 ± 218 650	1 336 042 000	8 906 950 ± 2 857 000

The average annual monetary value of *Macrobrachium sp* production was estimated at 3 843 100 ± 1 318 500 FC, while that of *Ostrea edulis* was 8 906 950 ± 2 857 000 FC.

3.1.3 Fishermen's surplus

Based on the difference between the value of annual production and annual load, the average annual profit for a *Macrobrachium spp* fisherman is estimated at 2 663 800 FC, while that for an *Ostrea edulis* fisherman is estimated at 7 982 000 FC.

Table 3: Surplus for shrimp and oyster fishermen

F.S	Profit (FC)		VE (FC)	%
	Total	Medium		
Macrobrachium spp (n= 178 and N=329)	474 160 400	2 663 800	876 390 200	31.12
Ostrea edulis (n= 150 and N=243)	1 197 302 850	7 982 000	1 939 676 000	68.88
Total			2 816 066 200	100

The economic value (EV) of these two fish products is estimated at 2 816 066 200 FC. *Macrobrachium sp* accounted for 31.12%, or 876 390 200 FC, while *Ostrea edulis* accounted for 68.88%, or 1 939 676 000 FC.

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Figure 2: *Macrobrachium sp* (A1 and A2) and *Ostrea edulis* (B_1 and B)$_2$

3.2 Fishermen's perception of the contribution of SE to their well-being

3.2.1 Needs met and degree of satisfaction among anglers

Most fishers (70.8% of shrimp fishers and 72% of oyster fishers) are satisfied with their activities. However, 28.1% and 24.7% of shrimp and oyster fishermen respectively said they were moderately satisfied, while a minority of fishermen (1.1% of shrimp and 3.3% of oyster fishermen) said they were not satisfied with the benefits derived from fishing. Furthermore, Fisher's exact test showed that shrimp and oyster fishermen had the same level of satisfaction (p-value = 0.3589 > 0.05).

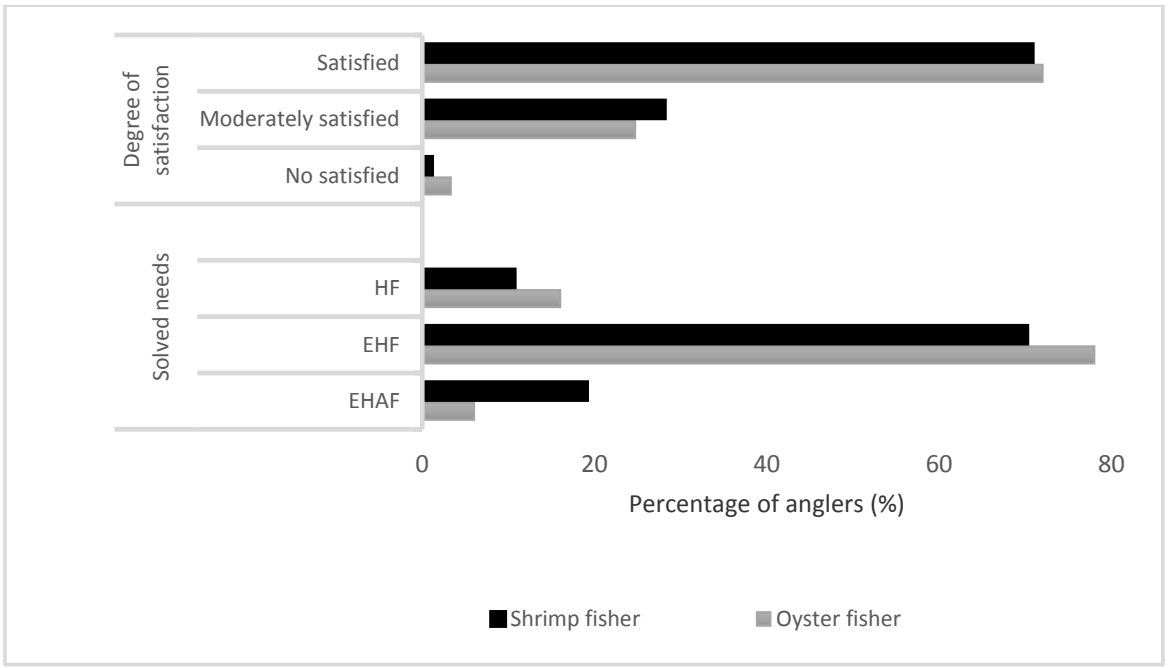

Figure 3: Needs solved and degree of satisfaction (H: Health, F: Food, E: Education, A: Accommodation).

Profits from fishing enable shrimp and oyster fishermen to better meet their needs for food, access to healthcare and schooling for their children. Accommodation and other needs are not considered a priority by fishermen. However, the Chi-square test showed that needs are not solved in the same way between shrimp and oyster fishermen (p-value = 0.00144 < 0.05).

3.2.2 Level of contribution of fishing to household income

Most fishermen declared that fishing contributes between 70% and 90% to their household income. While medium-represented fishermen spoke of a contribution greater than or equal to 90%. A minority, however, reported a contribution of between 50% and 70%.

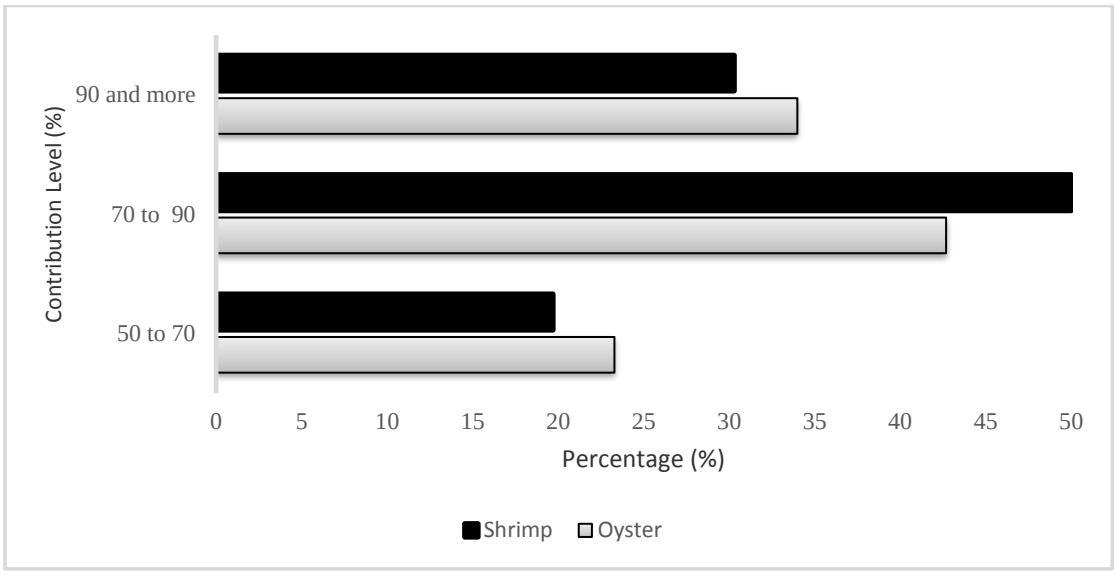

Figure 4: Contribution of fishing to household income.

The Chi-square test showed (p-value = 0.06 > 0.05) that fishing activity contributes equally to the household income of shrimp and oyster fishermen.

3.2.3 Relationship between fishermen and PMM managers

Most fishermen (88.2% of shrimp fishermen and 78% of oyster fishermen) declared that they had a good relationship with the PMM manager.

However, a minority of respondents (11.8% of shrimp fishermen and 22% of oyster fishermen) that, they don't have a good relationship with the manager.

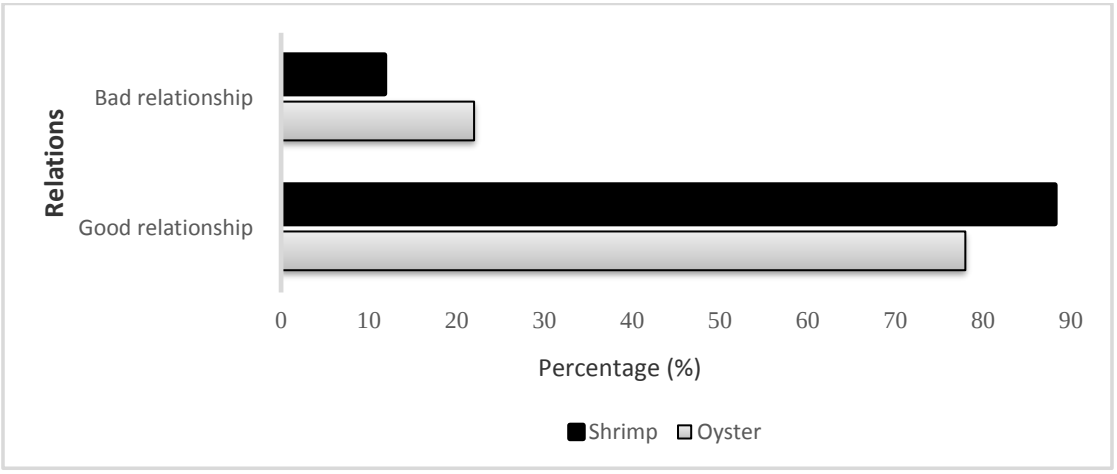

Figure 5: Relationship between fishermen and manager in terms of percentage of respondents to the PMM

3.2.4 Production trends

Shrimp (90.7%) and oyster (83.1%) fishermen say that production is down on previous years. On the other hand, a minority of fishermen (16.9% shrimp and 9.3% oyster) consider that production remains stable compared to previous years.

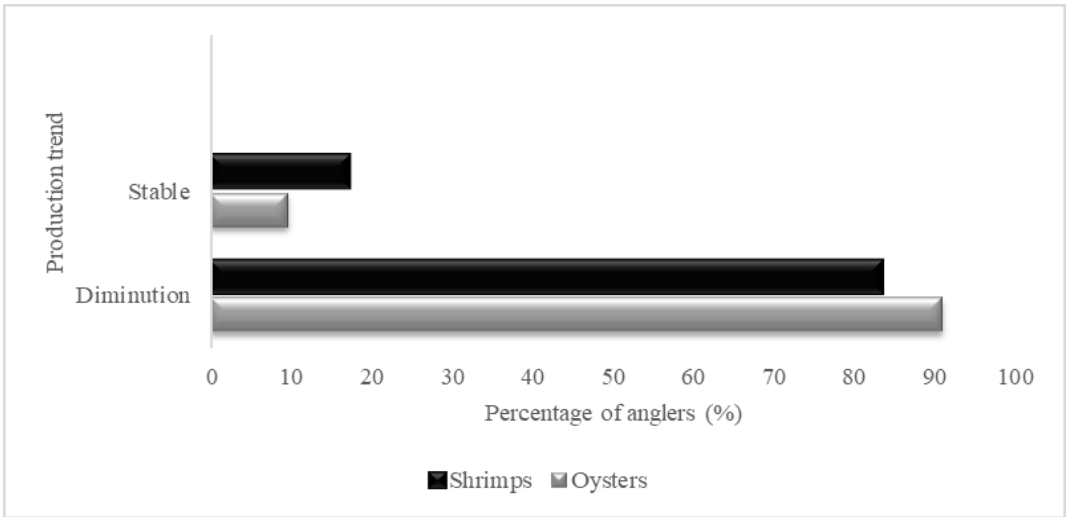

Figure 6: Shrimp and oyster production trends in terms of percentage of respondents to the PMM.

3.2.5 PMM status according to fishermen

Respondents rated the condition of the park as good (41% of shrimp fishermen and 48.7% of oyster fishermen) and average (47.8% of shrimp fishermen and 33.3% of oyster fishermen). However, some fishermen describe the condition of the park as deteriorating (11.2% of shrimp fishermen and 18% of oyster fishermen).

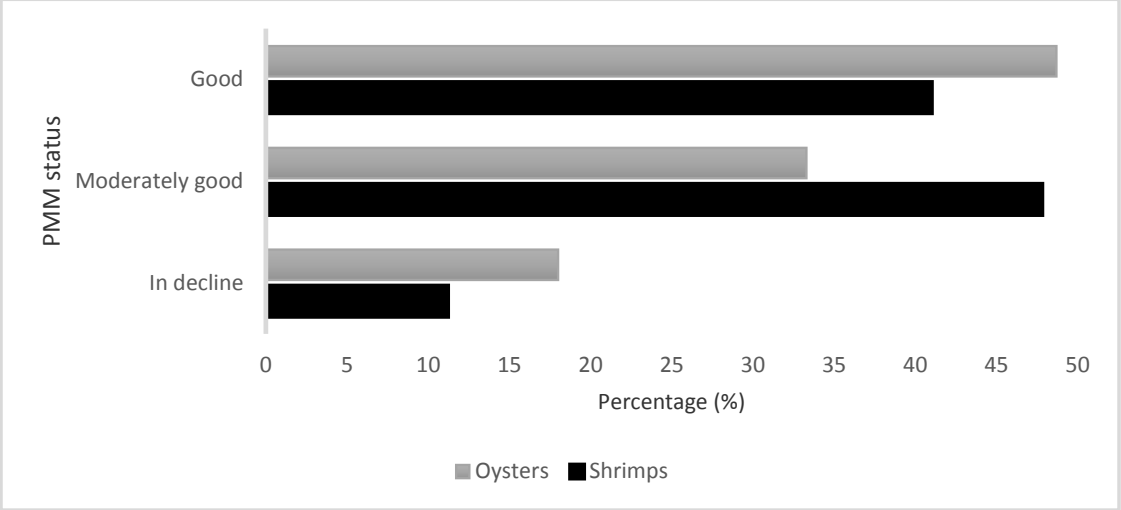

Figure 7: PMM status according to fishermen in terms of percentage of PMM respondents.

4. Discussion

4.1 Economic value

The total economic value (TEV) of *Macrobrachium spp*. and *Ostrea edulis* are respectively estimated at 876 390 200 FC and 1 939 676 000 FC. Both fish products have a total economic value estimated at 2 816 066 200 FC. The value of *Macrobrachium spp*. is lower than the reported value by Kabawu that is 3 992 400 FC (Kabawu, 2021). This disparity is due to the fact that he did not consider certain expenses while estimating the economic value (notably the cost of creels) and to the total number of fishermen, which he estimated at 100, whereas this study counted 329 active fishermen. The difference is also amplified by the variations in the sale prices of fish products. Montero estimated the average annual economic value of shrimp at 77 518 000 FC in Xuan Thuy National Park (PNXT) (Montero, 2017). In PNXT, fishermen engage in shrimp farming, whereas in PMM, shrimp grow naturally without growth control or monitoring. The total value of Ostrea edulis is higher than that obtained by a group researcher in the Densu Delta (Ghana), estimated at 61 813 400 FC (28 097 USD) (Osei et al., 2020). It can be justified that the total annual quantity offered by the PMM is higher than the one for Densu Delta, i.e., 455 827 kg versus 352 000 kg. In addition, there are differences in selling prices and operating costs.

The TEV of the present study depends on the various operating costs and the fishermen's operating income. Several factors influence the estimation of the value of *Macrobrachium spp.* and *Ostrea edulis* in the PMM. These include the level of fishermen's investment and other associated costs, which vary from one fisherman to another; the selling price of fish products, that varies from one fisherman to another or from one season to another; the fishing season, that influences yield; the number of working days, that determines the level of annual productivity; fishing sites with different resource abundances; and the experience of fishermen. These can impact the accuracy of results and real value of these fishery resources. For example, some researchers have shown that the quality of market data can lead to a disparity between actual prices and real marginal preferences (Binet et al., 2016). Similar observations regarding factors influencing the economic value of fishery products have already been made (Kabawu, 2021; Chuku et al., 2021). The TEV of the present study is controversial, as it may vary from year to year.

4.2 Fishermen's perception of the contribution of SE to their well-being

Estimating economic value is not enough to determine fishermen's well-being. It is important to consider other variables that can further explain how this value affects community well-being. Most fishermen declared themselves satisfied with being able to meet their needs, mainly in terms of food, access to healthcare, and education for their children. Furthermore, Fisher's test with a p-value of 0.3589 (>0.05) indicates that fishermen have the same degree of satisfaction. Nevertheless, the Chi-square test analysis shows that the needs are not resolved in the same way between the two groups of fishermen (p-value = 0.00144 < 0.05). Factors such as household size, household composition, and the level of education of the fishermen contribute to this difference, as they determine the level of household needs. Similar observations were made by on the allocation of fishing income to the satisfaction of basic household needs (Mbotekola et al., 2018). They noted that fishermen allocate their income to food (38.2%), schooling for children (9%), and medical care (35.3%).

The resulting gain contributes between 50% and 100% to the fishermen's income. Furthermore, the Chi-square test shows that the fishing activity contributes equally to the household income of shrimp and oyster fishermen (p-value = 0.06 > 0.05). Oyster and shrimp fishing is an important source of income for many individuals and households in the PMM. The same finding was made by (Chuku et al., 2021; UNEP, 2007). Show that mangrove constitute an important source of income through activities such as fishing, which are a means of subsistence for local communities.

Most fishermen claim to have good relations with the PMM managers, while a minority of fishermen claim to have bad relations. According to the latter, they are denied the right to exploit certain resources and do not benefit from development projects, which would be at the root of illegal fishing in the spawning area. This observation is out of step with the results of Daley-Hassen, which show that all fishermen (100%) have very good relations with the teams in charge of managing the Ichkeul National Park (Daley-Hassen, 2017). According to Montero, the relationship between the local community and the manager of a protected area is an important factor in the implementation of existing and future projects (Montero, 2017).

Almost all fishermen reported lower production than in previous years. This observation was also made by in the PMM and by in southern Senegal (N'tambu et al., 2018; Ndiaye et al., 2022). The main cause of this decline is the increase in the number of fishermen. According to Kutshukina and Micha, the increase in the number of fishermen favors the decline in fish stocks (Kutshukina and Micha, 2013).

The condition of the park was rated as good to moderately good by most respondents. However, some fishermen feel that it is deteriorating. The deterioration is mainly due, according to the latter, to an increase in the number of fishermen causing overexploitation, an increase in sand deposits choking the habitats of fishery resources, and the dumping of waste by oil companies polluting the waters. The data collected from fishermen on the state of the park is similar to that of Daley-Hassen, who mentioned several causes of degradation, including overexploitation (92%) (Daley-Hassen, 2017). Other reasons were not mentioned in the present work, such as non-enforcement or non-compliance with rules (38%) or natural reasons such as low rainfall (23%).

5. Conclusion

The exploitation of *Macrobrachium sp* and *Ostrea edulis* plays an important role in the socio-economic life of the populations living in and around the PMM. It is a major source of income for fishermen's households. Profits

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from fishing mainly enable them to meet their food requirements, access medical care and send their children to school. Despite these contributions, much remains to be done to coordinate conservation and sustainable use to promote human well-being.

Due to the lack of secondary data, this work used only primary data. The results of this study are neither sufficiently complete nor exhaustive to be of absolute value. However, they offer managers and decision-makers a better understanding to facilitate decision-making. Monitoring of fish stocks, the number of fishermen and pollution in the waters of the MMP are essential to achieving sustainable conservation and can be carried out in the future. The park's development plan should be drawn up to better manage the impending population explosion due to the construction of the Banana deep-water port.

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Authors' Contributions

Conceptualization: Lobho Lopa Joel, Kalambulwa Nkombe Alphonse, and Bernard Riera; Data collection: Lobho Lopa Joel and Diyazola Vweba Jeancy; Data processing and analysis: Lobho Lopa Joel; Manuscript writing: Lobho Lopa Joel, Kalambulwa Nkombe Alphonse; Kimbembe Jeansy Alverick, Kakule Muleverwa Simeon, Mumba Tshanika Urbain; Review: All authors.

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