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Research article

Monetary evaluation of marine reserve ecosystem services in the Caribbean

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Abstract: The paper presents the findings of an evaluation of the total economic value (TEV) of marine ecosystems of a planned marine reserve in "Le Prêcheur", North of Martinique, Caribbean. Almost 95% of the TEV, estimated at EUR 58 million annually, derives from non-use values, while about 5% are from Direct use values with a predominance of leisure values, and less than 1% percent comes from the Indirect use values despite the high biodiversity interest of the location. In that regards, estimates made in the context of this study are to be considered as orders of magnitude intended to feed the strategic dialogue for the development of the future marine reserve on one hand, and budgetary decisions of public policy guidelines on the other. It is therefore essential to adopt a collaborative approach between all actors involved on the coast. Moreover, public policies must take into account the protection of marine ecosystems and even more of their enhancement in a perspective that combines economic utilitarianism and selflessness. The marine ecosystems of Le Prêcheur have indeed emerged as elements of the identity of the coastal population of Le Prêcheur but also of Martinique as a whole and, as such, must be highlighted.

Keywords: Caribbean; Martinique; monetary valuation; marine protected area

JEL Codes: Q51, Q57

1. Introduction

The management of marine resources is changing due to the decline of fishery resources. There is thus a demand for ecosystem-based management approaches, such as the implementation of marine protected areas (MPAs). MPAs are identified as effective tools for biodiversity protection and they provide a base for the sustainable management of fisheries resource (Sobel et Dahlgren, 2004). The coastal strip of the area of Le Prêcheur was chosen by the Regional Council of Martinique for the establishment of the first marine reserve in the Caribbean region. Prior to its creation, a diagnosis was required to provide socioeconomic background elements including estimating the socio-economic value of marine and coastal ecosystems. The work presented below has been carried on within this framework.

This article aims to present an economic valuation of the marine and coastal ecosystems of Le Prêcheur and the forecasted changes in values due to the implementation of the future MPA. The monetary value of ecological services is measured by the willingness and readiness of a person to acquire it, reduced by its cost of production. So when nature provides services, it is the willingness to pay of individuals which is only likely to translate the value of the resource providing the service in question, with or without real payment (Christmas, 2006). In other words, the monetary value of ecosystems services may be assessed by estimating their contribution to market activities (which costs and benefits) and non-market activities (with only benefits recorded). Therefore, if the estimate of the monetary value of the services that lead to trading activities is done by deducting the costs from revenues in order to define the value added, the one of services related to non-market activities requires a sophisticated estimation method to obtain the potential beneficiary consent to pay. The economic valuation consists then on expressing, through a cash equivalent (in euros), the annual value of uses (direct related to extractive and recreational activities and indirect related to coastal protection, carbon sequestration, water purification and biomass production services) and non-use (corresponding to all the cultural and social values attached to marine ecosystems of le Prêcheur).

Economic valuations of marine ecosystems are nowadays widespread through the scientific literature (Börger et al., 2014; Brouwer et al., 2016; Bartkowski et al., 2015), but there are several methods that differ according to the type of value and the context. The concept of total economic value (TEV) provides a conceptual framework to take into account all of the previously enumerated values and which can be attributed to the ecosystem services. The advantage of such a framework it that allows a monetary evaluation of the majority of the services rendered by the ecosystems that have non market ecological or heritage value or economic value market (Failler et al., 2015). Its intensive use since the end of the 1980s, allow comparisons that contribute to safeguard the results. The review of evaluations on services rendered by coral ecosystems, conducted by P. Blanquet (2008), shows the profusion of studies in this area and the interest to adopt such a TEV framework. The specific methods used for each type of value estimation are the ones developed for IFRECOR (Borot de Battisti et al., 2011; Maréchal et al., 2014).

The added value of this article lies in the fact that the choice experiment method is used to evaluate non-use values, whereas the method based on the willingness to pay is most often used. The choice experiment method allows to reduce significantly the biases created when the usual method is used (Borot de Batisti et al., 2017). Moreover, this article opens a base of discussion on the meaningfulness of valuation in relation with the calculation base that is used.

This article begins with a statement of the conceptual framework and method used to estimate use and non-use values. The results of the valuation, specific to each use and non-use of the marine

ecosystem, are then presented. Finally, the article concludes with a presentation of the main social and economic changes apprehended as a result of the creation of the reserve of le Prêcheur.

2. Economic valuation methods

The concept of Total Economic Value (TEV) provides a conceptual framework capable of taking into account all the values that can be assigned to the marine ecosystems of Le Prêcheur (MEP). The first advantage of such a framework is to provide a monetary valuation of most services rendered by the marine and coastal ecosystems (MCE). Furthermore, due to its abundant use since the late 1980s, it is well suitable to the transfer of values that is essential when there is little ecological data on the production functions of some services. For example, different journals on valuation of goods and services provided by mangrove, seagrass and coral reef ecosystems (Armstrong et al., 2010) clearly show the profusion of studies in this field and the interest to adopt the concept of TEV. The decomposition of this TEV is illustrated in Figure 1. It can be divided into 2 main categories: use values and non-use values (also called passive use values). Use values are associated with the direct use of the ecosystem services, such as recreational swimming and diving activities, or commercial uses such as exploitation of fisheries resources. The non-use values are related to the awareness of the sustainability of the ecosystems (existing values) or more specifically to the need to let the ecosystems in healthy shape for future generations (bequest values) and thus to preserve the intrinsic values of the ecosystems. Non-use values, thus relate to the current values or future (potential) associated with the ecosystem and based simply on their permanent existence, regardless of the use that is made. In some ways they are values of preservation. The following diagram shows the various components of the total economic value.

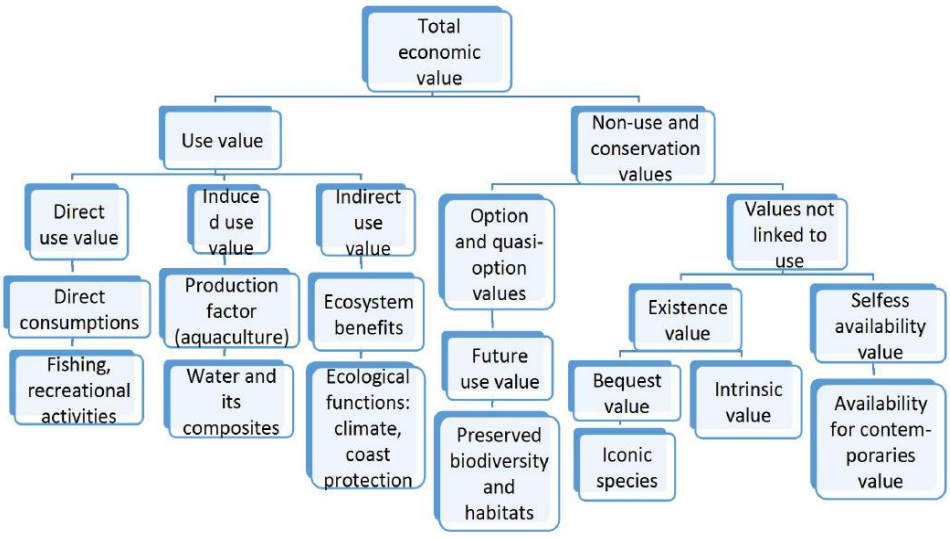


Figure 1. Decomposition of the total economic value. Source: Failler and Pan (2007).

Four methods were used in the evaluation of the economic value of MEP of MPAs.

Gross added value was used to measure the direct use value of market activities: various fishing activities, supervised diving, excursions, etc. The data were collected and obtained from the Regional Office of the National Statistic Institute.

Consumer surplus: to estimate the monetary value that an individual would be willing to pay to continue practicing an activity linked with the MEP in their current state. The data have been obtained from the questionnaire that was passed on to about 500 residents and tourists (questionnaire also used for the non-use values).

Transfer value: to estimate indirect use values (coastal protection, water treatment, carbon sequestration and catchable biomass production). This transfer of value has been used directly with values found in the literature which have been weighted by the gross domestic product per capita of the concerned country, or with production values (Maréchal et al., 2014).

Choice experiments method estimated the willingness to pay of individuals for improving the state of MCE (non-use values), today (existence value) and for future generations (bequest value). Data are coming from the scenario part of the questionnaire.

3. Economic value of marine ecosystems of le Prêcheur

The total economic value of marine ecosystems of Le Prêcheur is estimated annually at about 58 million euros. This value represents the monetary equivalent of the well-being that residents and tourists withdraw from uses linked to these ecosystems (fishing, diving, leisure activities, etc.) and their passive use or non-use (associated with the existence of MEP for themselves and as heritage, their transmission to future generations, culture, etc.). Table 1 shows the details of these results.

3.1. Non-use value

Of all values that form the TEV, non-use values are the most important: they represent nearly 95% of the TEV (about 55 million euro). Their prevalence over other values is explained by the calculation base that is used: more than one million people representing all the resident and tourist population for non-use values against some hundred users (fishermen, divers, excursionists, etc.) for use values in a context of very low degree of industrialization and individual businesses.

Residents contribute to over half of the creation of non-use values (€28 million). The values they assign to the MEP are, per person, one and half times higher than those of visitors, which demonstrates a strong social and cultural attachment (see Figure 2).

Bequest, existence and option values consist almost equally to non-use values (see figure 2). Bequest value reflects the interest of future generations; the existence value expresses the desire to preserve the MEP simply because they exist; the objective of reserving the possibility to enjoy the MEP in the future is finally called option value. The relative importance of these three values is the same for residents and visitors.

Table 1. Distribution of the TEV of MEP.

Nature of use	Type of use	Activities	Value (hundred euros)	Share of the TEV	Participation by category of population		
					Residents	Tourists	Unified
Use	Extractive Direct	Professional fishing	171,443	0.3	171,443	0	-
		Recreational and subsistence fishing	57,005	0.1	57,005	0	-
		Tourist accommodation and catering	327,382	0.6	42,495	284,887	-
	Non-extractive direct	Diving (supervised by clubs)	595,970	1.0	188,220	407,750	-
		Consumer surplus for recreational activities	1,254,900	2.2	465,300	789,600	-
		Research and education	0	0.0	0	0	-
	Indirect	Catchable biomass	44,577	0.1	-	-	44,577
		Carbon absorption/sequestration	9,328	0.0	-	-	9,328
		Water and nutrients purification/treatment	143,598	0.2	-	-	143,598
Subtotal of use value			2,875,883	5.0	1,060,303	1,618,077	197,503
Non-use	Option, bequest, existence and culture		54,966,502	95.0	28,265,650	26,700,852	-
Total of economic values			57,842,385	100.0	29,325,953	28,318,929	197,503

Source: own realisation.

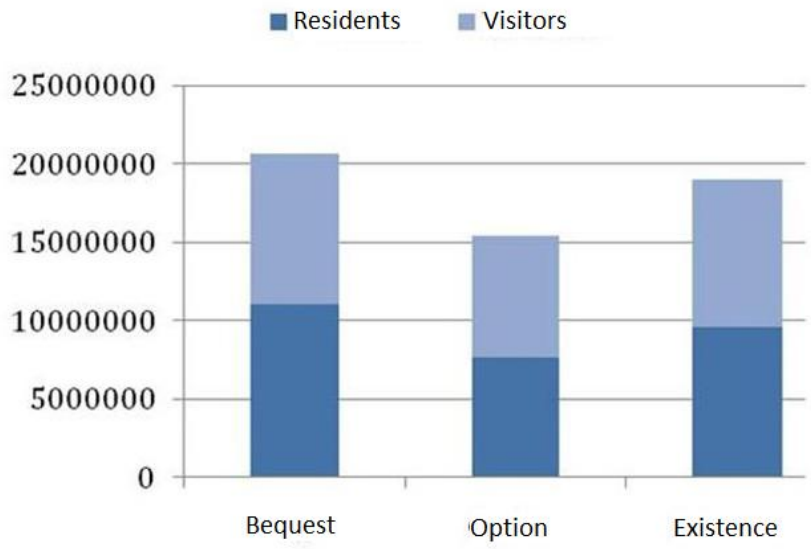


Figure 2. Non-use values (in euros, in 2011). Source: own realisation.

3.2. Direct use values

Direct use values, which reflect the monetary value of all MEP-related activities, amount to almost 3 million euros (see Figure 3). Among them, the direct non-extractive uses represent the largest share. Consumer surplus, related to recreation (swimming in the coves, surfing and freediving), accounts for nearly half of direct use values, i.e. €1.3 million. The tourism industry accounts for over €1 million, allocated as follows: €600,000 for diving with clubs, €270,000 for excursions and €330,000 for accommodation and catering activities. The value of professional fishing is estimated at more than €170,000, while the recreational and subsistence fishing is estimated at about €57,000. These values, lower, represent however the first order of business for the residents of the municipality of le Prêcheur.

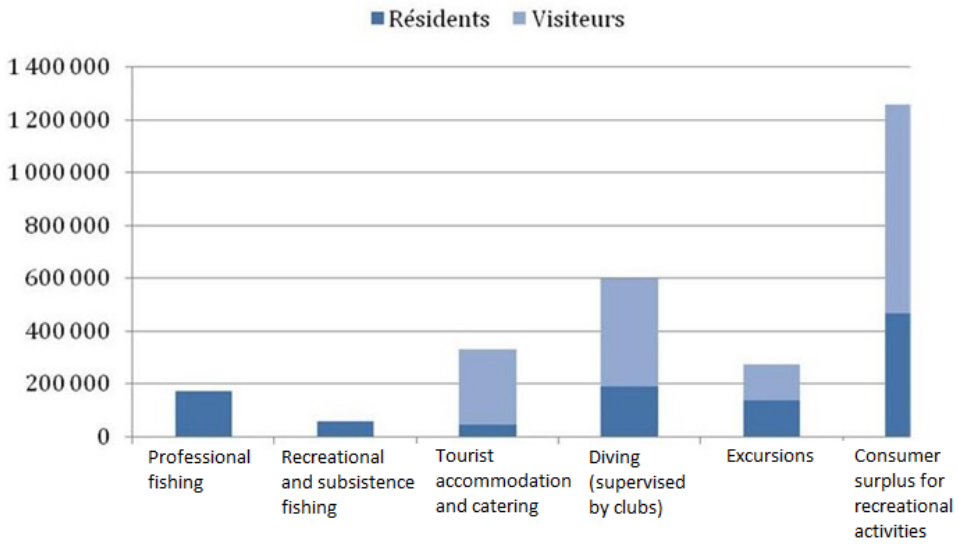


Figure 3. Direct use values (in euros, in 2011). Source: own realisation.

3.3. Indirect use values

Indirect use values, linked to ecological services of MEP, are relatively modest: they represent only 197000 euros (see Figure 4). They are divided as follows: 73% of water and nutrients treatment, 22% of catchable biomass production and 5% of atmospheric carbon sequestration. The treatment of water and nutrients seems to be an important value for the site, particularly concerning terrigenous inputs of streams that can carry large amounts of sediments. Coastal protection service does not exist on the site, because there is no bio-constructed coral reefs and seagrass communities are located too deep to slow the effect of waves on the shore. Atmospheric carbon sequestration represents a low value due to the small area of seagrasses, but mostly of reefs in the MEP.

Seagrasses are the main contributors of indirect use values (80% of the total). They contribute to the major part of the provision of supporting and regulation services. This observation confirms the work done in the context of the economic valuation of coral reefs and associated ecosystems of Martinique which estimated a greater value for seagrass than coral reefs. Seagrasses of Le Prêcheur are therefore an ecosystem not to be overlooked in the context of ecosystem protection.

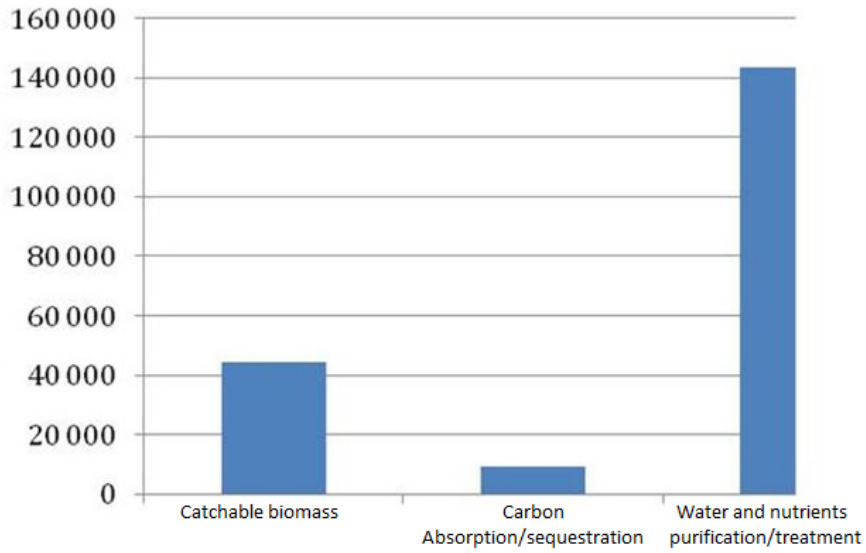


Figure 4. Indirect use values (in euros, in 2011). Source: own realisation.

4. Economic and social valuation of changes resulting from the creation of the reserve

The creation of the marine reserve will first manifest through a change in practices of some categories of users, including fishermen and tourism activities: diving and boating in the first place. Changes may also occur due to creation of new activities (tourism and leisure mainly). It is therefore necessary to assess the magnitude of these changes and to see to what extent they can influence the TEV of the MEP (Thirot et al., 2017). The baseline is given by the estimate of the TEV in 2011, possible scenarios of change can be designed to estimate the differences in TEV obtained (overall and per use).

Three hypothetical management scenarios are considered: 1) a *statu quo* on the regulation of activities and access to the site (i.e. no change from the current situation); 2) the establishment of a completely protected area where all economic activities are prohibited or severely restricted; and 3) the establishment of a managed area where management measures are in place, aiming for sustainable exploitation of marine resources and ecosystem conservation. Table 2 summarizes the changes resulting from the implementation of these three different management scenarios.

For each of these three scenarios, changes in the values composing the TEV of MEP is studied. For direct use values, the estimated results are presented in the table below. Scenario 1 provides a continuous loss of value for all direct uses. For scenario 2, the expected evolution is a significant reduction in extractive and non-extractive direct use values, due to the prohibition of fishing, diving, sea excursions and all free leisure activities. For Scenario 3, a gradual increase in extractive direct use values are expected due to improvement of ecosystem health, as well as a very significant increase in non-extractive direct use values through the tourist attraction for swimming and diving generated by the creation of the reserve.

Table 2. Transformation of uses according to the three management of MEP scenarios considered. Source: own realisation.

Use	Current situation	Scenario 1 "statu quo"	Scenario 2 "wilderness reserve"	Scenario 3 "managed area"
Professional fishing	Offshore fishing: fishing around FADs (in the area), Miquelon fishing Inshore fishing: trap, seine, net (crawfish, saury, garfish), longline, pisine Spearfishing	Decrease in catches Loss of economic profitability	Carryover of fishing effort to the periphery, conflicts of use Redistribution effect of the biomass gain in the periphery Loss of profitability of fishing operators	Limitation of fishing practices that are the most damaging (non-selective, destroying habitats) and benefiting an overexploitation of resources Effect of increasing of biomass in the area under the reserve and the periphery
Subsistence fishing	Inshore fishing: trap, net, longline, line, pisine Spearfishing	Decrease in catches Loss of economic profitability	Carryover of fishing effort to the periphery, conflicts of use Redistribution effect of the biomass gain in the periphery	Limitation of fishing practices that are the most damaging (non-selective, destroying habitats) and benefiting an overexploitation of resources Effect of increasing of biomass in the area under the reserve and the periphery
Recreational fishing	Troll, jig and pisine fishing Line fishing from the shore Spearfishing	Decrease in catches Loss of economic profitability	Carryover of fishing effort to the periphery, conflicts of use Redistribution effect of the biomass gain in the periphery	Limitation of the use of gears specific to professional fishing (crawfish net, traps, etc.) and of authorised total catches Effect of increasing of biomass in the area under the reserve and the periphery
Diving	Diving on eleven sites of MEP	Decrease of the interest for the sites Loss of economic profitability for clubs	Limitation of diving sites to the periphery of the reserve Redistributive effect in the periphery of the reserve	Increase in diving sites visitation Development of new diving themes (basking shark watching, biologist dive, etc.)

Continued on next page

Use	Current situation	Scenario 1 "statu quo"	Scenario 2 "wilderness reserve"	Scenario 3 "managed area"
Excursions	Discovery of the coast, marine mammals watching, traditional fishing trips, comeback of hikers on le Prêcheur-Grande Rivière hike, transportation towards Dominica	Decrease in interest for marine fauna watching Loss of economic profitability for excursion operators	Commercial loss for tourism operators, carryover of tourism activities in neighbouring areas	New activities (whale watching for instance) Enhanced conversion of fishermen in excursion activities
Boating	Mooring in Céron and Couleuvre coves mainly, visitation by sailing and motor-driven ships, jet ski	Unlimited visitation of recreational boats	Prohibited access	Limited visitation due to mandatory mooring on buoys of the reserve
Boat traffic	Passing of sailing or motor-driven ships in MEP without anchoring	Disturbance of traffic for marine fauna (turtles and cetaceans)	Prohibited access	Access limitation in ecologically valuable areas (islet of the Pearl and areas of Acropora palmata) and limitation of speed at close proximity of the shore
Bathing and beach activities	Bathing and freediving, surf	Over-visitation of beaches and loss of the wild character of the area	Carryover of beach activities to surrounding bathing areas	Higher visitation of MEP for bathing and beach activities, interest for a preserved site

Table 3. Mid-term changes of direct use values according to the three management scenarios. Source: own realisation.

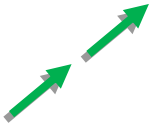
Use	Details	Scenario 1 "*statu quo*"	Scenario 2 "wilderness reserve"	Scenario 3 "managed area"
Extractive direct	Professional fishing	↘	↘ ↘	↘ ↗
	Recreational fishing	↘	↘ ↘	↗
	Subsistence fishing	↘	↘	↗
Non-extractive direct	Tourist accommodation and catering	↘	↘	↗
	Diving (supervised by clubs)	↘	↘ ↘	↗ ↗
	Excursions	↘	↘	↗ ↗
	Consumer surplus for recreational activities	↘	↘	↗ ↗

Note: the trends identified in these tables originate from the protected areas categories of the IUCN and in particular the trends identified for direct extractive uses of scenario 3 depend on the final rules of management of resource exploitation.

The indirect use values increasing proportionally to the MEP health status. However, it is difficult to know precisely the consequences of a limitation of uses and pressures on MEP and the increased indirect use value that results. The catchable biomass value depends on the productivity of ecosystems and the exploitation level of MEP (Trégarot et al., 2017). Also, prohibiting fishing in the area will have the direct consequence of increasing the fish biomass value. For carbon sequestration and purification service, a better MEP health status a priori implies a higher value. Overall, the indirect use values will be little affected by a change in the status of these ecosystems.

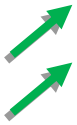
While it is reasonable to think that the non-use value is sensitive to the MEP health status, it is difficult to assume its evolutionary trend according to each of the proposed scenarios. One can imagine that the existence value and the bequest value increase with the preservation of these ecosystems, but nothing allows, however, to make this conclusion without further analysis. Conversely, it is certain that the option value varies in proportion to the improvement of the health status of MEP: preserving them guarantees to offer a wider range of choices for the future. It is possible to say that the option value is certainly more important in scenarios 2 and 3 as in scenario 1. The results of changes of indirect use values are presented in Table 4.

Table 4. Mid-term changes of indirect use values according to the three scenarios. Source: own realisation.

Use	Details	Scenario 1 "*statu quo*"	Scenario 2 "wilderness reserve"	Scenario 3 "managed area"
Indirect	Catchable biomass			
	Carbon absorption/sequestration			
	Water and nutrients purification/treatment			

It is difficult to estimate the evolution of existence and bequest values that vary a priori based on the health status of these ecosystems: the more it is improved, the more non-users grant the MEP a high existence value and even more so a high bequest value. However, this question is difficult and it is not possible to answer here without further investigation.

Table 5. Mid-term changes of non-use values based on the three scenarios. Source: own realisation.

Use	Details	Scenario 1 "*statu quo*"	Scenario 2 "wilderness reserve"	Scenario 3 "managed area"
Non-use	Bequest and existence values	To be determined	To be determined	To be determined
	Option value			
	Research and education			

In contrast, option values vary widely depending on the chosen scenarios and future opportunities available to the use of MEP. However, it is very difficult to estimate option values over time and little valuation exercises venture to do this, because it has too much bias. Table 5 provides, for information purposes only, the direction that should take the three non-use values based on the proposed scenarios.

5. Conclusion

The marine ecosystems of Le Prêcheur are an important economic and social value estimated each year to 58 million euros. They are the foundation of the professional and recreational activities of a substantial part of the northwest of Martinique. In addition, they are responsible for water purification, sequestration of part of the carbon emitted in Martinique and elsewhere, and finally the production of substantial marine biomass. The MEP thus provides a quality of life for their users as well as an insurance of preservation of the natural environment for all residents of Martinique. To the visitors, they offer an underwater biodiversity that makes the delight of divers or just swimmers, and wild landscapes for a great change of scenery for walkers and hikers.

Estimates made in the context of this study are to be considered as orders of magnitude intended to feed the strategic dialogue for the development of the future marine reserve of Le Prêcheur on one hand, and budgetary decisions of public policy guidelines on the other. Regarding the first point, the maintenance of the biodiversity of these ecosystems must be within an evolutionary perspective which attempts to both maintain the existing as a memory of the past and preserve the development potential of future living entities and ecosystem functions. This consists on maintaining the ability of vital processes to transform. It is therefore essential to adopt a collaborative approach between all actors involved on the coast. Regarding the second point, public policies must take into account the protection of marine ecosystems and even more of their enhancement in a perspective that combines economic utilitarianism and selflessness. The MEP have indeed emerged as elements of the identity of the coastal population of the region of Le Prêcheur but also of Martinique as a whole and, as such, must be highlighted. They are also a great source of employment and sustainable economic development and therefore deserve more than a distracted attention.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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