Valuation of marine and coastal ecosystem services as a tool for conservation: the case of Martinique in the Caribbean

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Summary

Martinique possesses 55 km^2 of coral reefs, 50km^2 of sea grass and 20km^2 of mangroves. These three ecosystems produce services to a value estimated at 250 million € per year (valuation recently undertaken under the French initiative for Coral Reef Conservation - the IFRECOR program). It is estimated that around 60% of this value originates from direct uses such as recreational activities (diving, excursions, beach activities, etc.) tourism and fisheries. Ecosystem services (indirect uses) such as coastal protection, carbon sequestration, biomass production and water purification are significant since their total value reaches 94 million € annually (38% of the total economic value). Non-use values linked to improvements in health of coastal ecosystems is estimated to be 10 million € per year. At the ecosystem level, sea grass and mangrove contribute the most (per km^2) to wealth creation (2.16 million €/km^2, 1.87 million €/km^2 respectively, against 1.78 million €/km^2 for coral reefs). They need, therefore, to benefit from protection and management measures in the same magnitude as coral reefs already receive. The valuation also shows that, due to policy inaction, the loss of value is about 2.5 million € per year, which urges politicians to develop a sound conservation policy.

Introduction

Ecosystem valuation finds its justification from the fact that, firstly, what nature produces on its own is not accounted at its true value and, secondly, that damage caused by humans is not recorded, since it is most often considered as *res nullius*. It is, therefore, important to put a price on what nature produces and a cost on what humanity spoils (Costanza et al., 1997; Bateman et al. 2013). In other words, nature should be looked at from an economical perspective (Arrow et al. 1999). For economists, this seems the only means to halt the loss of biodiversity (OECD, 2004, TEEB, 2009), notably that of coral reefs, mangroves and seagrasses (Cesar et van Beukering, 2004; Beaumont et al., 2008; Hilmi et al. 2014). Valuing nature thus makes biodiversity enter the field of public economy (with potential optimization of the choice of economic agents) and policy (efficiency of budget allocations).

The first objective of this article is to present an estimate of the total economic value (TEV) of the services provided by coral reefs and associated ecosystems (CRAE) of Martinique, expressed through a monetary equivalent (in €/km² when monetization is possible). The Millennium Assessment (2003) described Ecosystem services as the benefits people obtain from ecosystems, such as provisioning, regulating, supporting, and cultural services. The second objective of the article is to underlines the main elements to consider for the definition of conservation policies and valorisation of the CRAE and of their services.

The extent of the measures to be taken is suggested by the current health of the CRAE of the island. More than 20% of the reefs have disappeared in recent years, while the mangroves suffer from pollution of the rivers and the urbanization of the coastal zone (Scheupne, 2008 and Saffache, 2009). Further, the sea-grasses are increasingly prone to silting and pollution from various sources, including the chlordecone (Cabidoche et al. 2009). During the budgetary arbitrations on various decisional scales, these measures and more generally the public policies which will have to be implemented (in particular within the framework of the Martinique development scheme of the sea) in order to restore, protect and improve the ecological services of the CRAE, will of course, enter in competition with other political measurements in favour of road infrastructures, industrial development, housing and employment. To quantify the natural heritage is thus of primary importance in order to be able to offer a base of comparison with the other economic and social sectors, where public monies are invested. These have indeed been for a long time the subject of economic and/or social viability study. This work has been done through the French Initiative for the Protection of Coral Reefs (IFRECOR[1]).

The article begins with a description of the coral reefs of Martinique and their associated ecosystems. In particular, their surface, their characteristics and their health status are examined here. The services which they render, as well as the methods used for their quantification, are the subject of the second part. The results, specific to each use and non use of CRAE, are presented in the third part. The two following parts use the results to analyse current management measures and public policy more generally. Management options are defined using the wishes of the residents and the tourists, while the cost of the political inaction is quantified.

[1] A valuation of coral reefs and associated ecosystem is currently being carried out for all French overseas territories (2011-2015).

1. Health status of coral reefs, mangroves and sea-grasses

Resulting from the geographical localization of the island in the inter-tropical zone, coral formations, mangroves and sea-grasses develop along the coasts. The following map (cf. figure 1 below), presents the space distribution of the biotopes (sea-grasses and mangroves) and biological communities (sets of living communities) constitutive of the littoral ecosystems and marine inhabitants of Martinique between 0 and 50 m of depth (OMMM, 2009), while the table below (cf. Table 1 in the supporting material part (SMP)) reveals their surface in km^2.

The total underwater surface represents 452.22 km^2, broken up into communities of bare movable sea floor (202.26 km^2 or 45% of total surface), algae (140.60 km^2 or 31% − primarily on the Atlantic fringe and the south-west of the littoral), coral (5.6 km^2 or 12% south of the island, the North-East of the Atlantic coast and the outer limit of the bay of Fort of France), mixed communities (0,25 ha or 0,6%), and of sponges and gorgonians (0.114 ha or 0,2%) as well as sea-grass (4,974 ha or 11%). Out of the water, mangroves cover 20.63 km^2, of which the major part is localised in the bay of Fort of France.

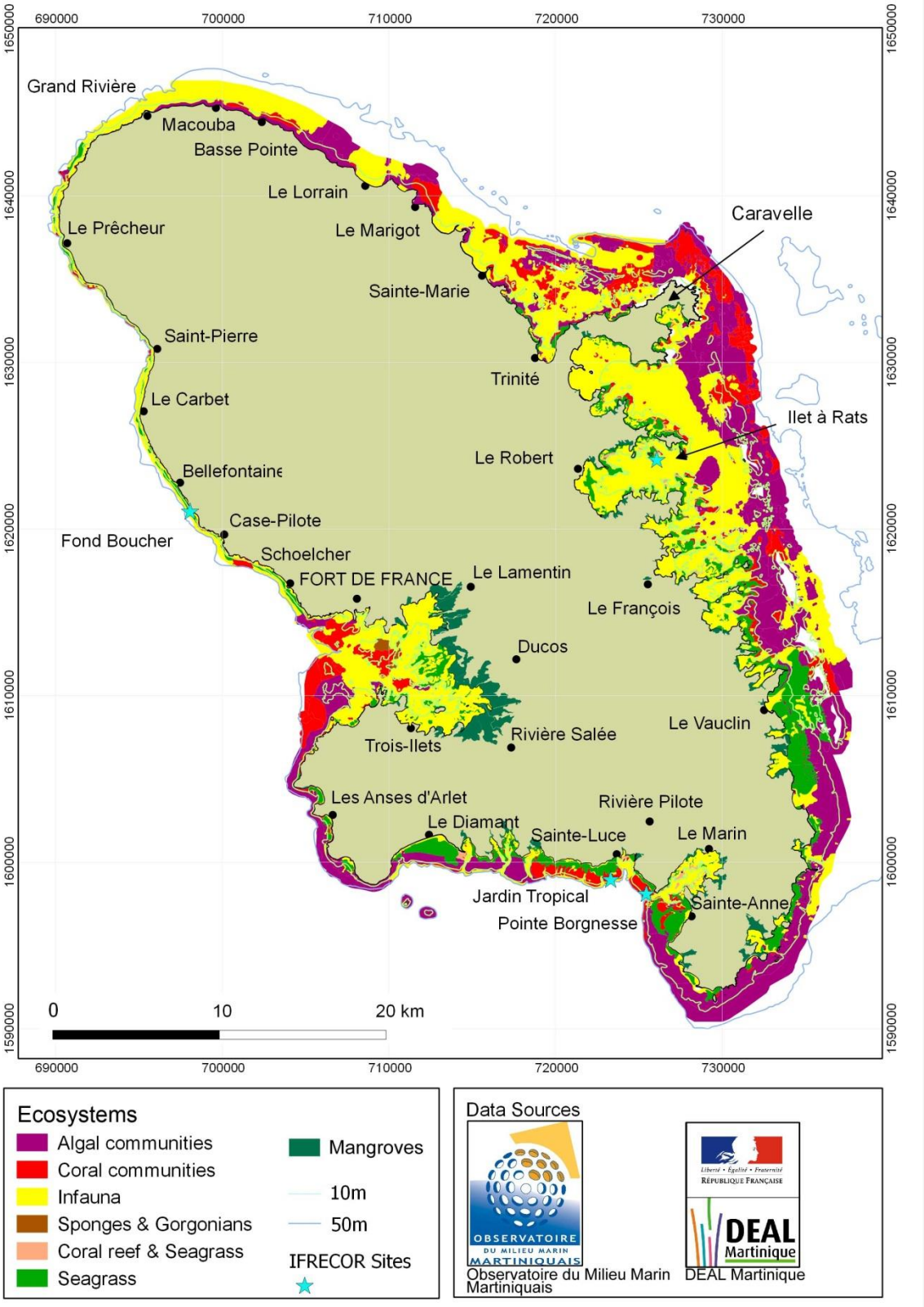

Figure 1: Marine habitat map of benthic communities along the coast of Martinique between 0-50m depth. (Source SIG-OMMM 2009)

Overall, the health of the marine ecosystems is alarming. More than 45% are regarded as degraded and 23% very degraded (cf. Figure 1 in SMP). Less than one third of the ecosystems are considered to be in good ecological health and only 1% can be regarded as being in a very good state. With regard to the mangroves, no data relating to their health exists except an evaluation of the damage generated by the passage of Hurricane Dean, which states that the losses undergone by the settlements of the mangrove are rather variable, ranging from 13 to more than 90% of density (compared to data of 1997). In 2009, another major event lead to the closure of river fisheries and fishing activity in bays, whose watersheds are polluted - the chlordecone pollution resulting from the use of this pesticide on banana plantations for decades. Despite its use being forbidden in 1993, harmful effects on the environment are still present.

The reefs undergo, in addition to environmental calamities, increasingly strong anthropic pressures. Pollution of agricultural, industrial and domestic origin, as well as physical degradation and hyper-sedimentation, weakens them a little more each day. Thus, more than 80% of the coral communities are regarded as degraded (including 44% that are classified as very degraded), primarily at a shallow depth. 20% are classified as in good health and only 1% meet the criteria of being in a very good ecological state (cf. Photograph 1 in the SMP for an illustration of the various health status of the coral communities).

Spatially, the coral ecosystems of the Atlantic coast in the south of the Caravel and those of the Bay of Fort de France are degraded, and have been observed as such since 1978 (Battistini, 1978). The southernmost reef in the south and the communities of the bay of Trinity present, also show signs of generalized degradation (see Photograph 2 in the SMP). The communities in good condition are today on the sea floor of the north-Caribbean littoral, to the south of Bay of Fort de France and on a few other sites (between Le Diamant and Saint-Anne and around the peninsula of La Caravelle). In recent years, the factors contributing most to the reduction of the coral cover are firstly the major episode of whitening of the second half of 2005 (having increased mortality by 15% in the coral communities of Martinique) and secondly, the propagation of coral diseases such as the “white plague” which resulted from the withering.

Sick reef communities were observed at the beginning of 2006. Mortality associated with the development of diseases was estimated at 15% on average in June 2006. The reefs of the south of the island suffered from the strong swells generated by the passage of hurricanes Dean in 2007 and Omar the following year. In a less visible and spectacular way, littoral pollution of anthropic origin (urban, industrial, agricultural wastes and pesticide residues such as chlordecone) is responsible for degradation of the coastal waters, and the clearing of land soils and urbanization as the origin of the excessive suspended particles (suspended elements and hyper-sedimentation), gradually reduce the physiological capacities of the corals enabling them to resist to natural aggressions (Rousseau, 2010). Thus, little by little, the dead coral is colonized by algae which benefit from the enrichment of the littoral waters and various nutrients to develop and proliferate (Legrand 2009; Trégarot, 2010).

As well as reefs, mangroves are prone to specific and recurring aggressions of natural and anthropic origins, which deteriorate their ecological functions and reduce their surface (see Photograph 3 in the SMP). They are degraded in 2 manners: firslt, by an accumulation of macro

waste between the roots of the mangroves trees that creates obstructions to the circulation of water and leads gradually to a draining of the marine part of the mangrove, limiting the development of young growth and; second, by urbanization, an encroachment and a clearing of the zones of the back mangrove.

Sea-grasses are less degraded than the coral communities. Only 12% are considered very degraded and 49% degraded (see Figure 1 in the SMP). They are overall in an acceptable ecological status, except for those present in bays and sheltered zones of the fringing reefs on the Atlantic coast (see Photographs 4 in the SMP). Their health improves when one moves away from the coast and towards the reef barrier. The sea-grasses, for which the health is the best, are localised in the southern point of Martinique (OMMM 2009).

Sea-grasses undergo the same anthropic pressures as the coral reefs. One of the factors limiting the development of the sea-grasses, in particular at depth, is the hyper-sedimentation (for instance in the Bay of Fort of France), and mechanical actions of anchors and chains of boats that tear off the roots of phanerogams. In the strongly eutrophicated sectors, the macro-algae develop quickly on the leaves of the phanerogams, which limits their growth.

2. Values and conceptual framework

The monetary value of an ecological service is measured by the tendency of a person to acquire it, decreased by its production cost. Thus, when nature provides ecological services, it is the willingness to pay of individuals which is likely to identify the value of the resources providing the service in question, whether there is real payment or not (Noël, 2006). In other words, the monetary value of the CRAE can be evaluated by the estimation of their contribution to commercial activities (which record costs and benefits) and to non-commercial activities (which record only benefits). If the estimation of the monetary value of the services related to commercial activities is undertaken by deducting the costs from the incomes in order to define the added value, then services related to non-commercial activities requires a more sophisticated approach in order to obtain the willingness to be paid of the potential recipient.

The concept of total economic value (TEV) offers a capable conceptual framework to take into account all the values enumerated previously and which can be allotted to the CRAE of Martinique. The advantage of such a framework is first that it allows a monetary valuation of the majority of the services provided by the CRAE, that they have an ecological or patrimonial non-commercial value or that they cover a commercial economic value. Due to its abundant use since the end of 1980, it moreover allows for comparison. The review of evaluations of the goods and services rendered by coral ecosystems, conducted by P. Blanquet (2008) and C. Amstrong (2010), shows the profusion of studies in this field and the interest in adopting such a framework.

The TEV can be divided into two categories: use values and non use values. The use values are associated with the direct use of the CRAE, e.g. leisure activities such as bathing and diving, or with commercial uses such as commercial fishing. The non use values are not related to any use but are linked to the sustainability of the CRAE (existing values) or more specifically to the need for keeping CRAE in a good healthy state for future generations (bequest value) and thus for preserving the intrinsic value of the CRAE. The non use values are thus linked with the current or future values (potential) associated to the CRAE and simply rely on their permanent existence,

independently of the use made. They constitute, to some extent, values of safeguarding. Figure 2 in the SMP presents the various components of the total economic value.

Within the use values, the direct, induced and indirect use values can be distinguished. In the first case, that of the direct use values, this consists of the most usual uses of the marine and coastal biodiversity to fishing, tourism, diving, etc. which consist of commercial and non-commercial activities. The induced use values represent the services provided by the CRAE as a factor of production for commercial services, such as the aquaculture. In that case, it is the natural environment as a factor of production of a commercial activity that is examined. With regard to the indirect use values, they are initially made up by regulating ecological functions (natural regulation services) of the CRAE. They can also come from the support that they give to economic activities with a directly measurable value like tourism. The indirect use value of an ecological function is related to the change in the value of production or consumption of the activity (or the property) that it protects or supports. However, this contribution, neither being marketed nor financially remunerated, and being only indirectly related to economic activities, such indirect use values must be the subject of estimates by methods like those of the replacement costs. The indirect uses relate also to the services provided by the CRAE, indirectly allowing for everyday production and consumption such as, postcards, films, documentaries and others media which use the CRAE as principal support.

The non use values include various values non-related to the direct or indirect use of the CRAE. Under this heading, several types of values can be identified. For example, the option value which represents a value that intervenes in the presence of uncertainty on the future availability of the CRAE. This can be defined as an insurance premium which one is ready to pay in situations of uncertainty to ensure oneself of the future availability of the CRAE. This future potential value can be of various types, ranging from the direct or indirect use to all the other non uses. With a strong uncertainty of the future value of the CRAE but of a potentially high estimate of the possible uses, a value of quasi-option can be estimated. This value relates to the conservation of certain components of the CRAE for future use whose interest is not yet shown (for example, the safeguarding of algae for still unknown uses). In such circumstances, the precautionary principle applies and stipulates the need for more information to undertaking an action that may potentially have irreversible impacts. Thus, by extension, the value of quasi-option is the discounted value of information that one will obtain because of postponing today the exploitation and the transformation of the CRAE. It relies on the fact that the passage of time increases information available like, for example, scientific knowledge on the marine ecosystems.

Among the existing values, one distinguishes the sub-group of bequest values and the one of intrinsic values. The bequest values correspond to the values which a generation allots to the legacy that it makes with future generations (such as the conservation of marine biodiversity). In Martinique, bequest values seem to have a particular importance for fisheing communities using the CRAE and wishing to see their way of life transmitted to their heirs and future generations (Failler, 1994 and 2002). The intrinsic value defines the CRAE as having a value higher than that associated with their current use. As Barbier *et al.* (1997) point out “one does not know yet with certainty up to what point biological diversity is important for the man but the idea is generally accepted that the more diversity is high the most stable is the ecosystem. Many are those who

appreciate the existence pure and simple of biological diversity and who grant it a high value". The protection of the CRAE becomes in consequence more a question of morals that the one of optimal or even equitable allocation of the resources.

Lastly, certain people in Martinique, who are resident or tourists, and who, although they do not use the CRAE, wish to see them preserved for themselves. This value granted to the existence of the reefs, independently of a current or future use, is known as "value of disinterested availability ". It is a difficult to measure non use value because it involves an assessment that sets aside any proper or other uses both for now and in the future. Figure 2 below presents the TEV for tropical ecosystems, and table 1 presents the set of values and services selected for coral reefs, mangroves and sea-grasses of Martinique. Some services such as the production of sand by death coral reefs have not been taken into account in this study as it was limited on services that occur while the ecosystem is alive. Further studies can nevertheless take these services into account as it contributes to the formation and maintenance of beaches in tropical areas.

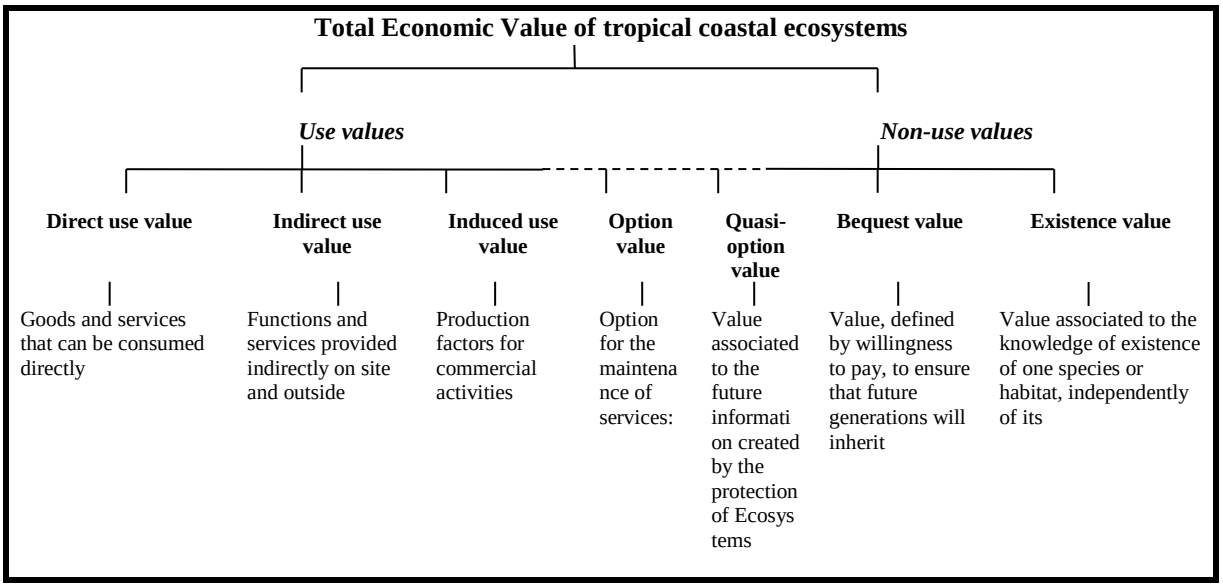

Figure 2: Decomposition of the Total Economic Value of tropical coastal ecosystems; adapted and modified from Jacobs (2004)

The dividing line between use and non use values of the CRAE of Martinique is, as shown above, the dotted lines in the diagram (above the values of option and quasi-option), more or less fuzzy according to the exactitude with which one can characterize option values and quasi-option values (and consequently to decide between the potentialities of the CRAE in non use or use values).

Table 1: Set of values and services selected for the IFRECOR study

<table>
<tr><th></th><th>Coral reef</th><th>Mangrove</th><th>Sea-grass</th></tr>
<tr><td rowspan="3">Direct use value</td><td colspan="3"><u>Common extractive use:</u>
- fishery uses
- pharmaceutical uses</td></tr>
<tr><td><u>Specific extractive use:</u>
- fisheries (reef fishes)
- ornamental uses
- other specific uses</td><td><u>Specific extractive use:</u>
- fisheries (crabs)
- wood cutting
- others specific uses</td><td><u>Specific extractive use:</u>
- fisheries (molluscs, sea urchins and fishes)
- others specific uses</td></tr>
<tr><td colspan="3"><u>Common non-extractive use:</u>
- recreational activities : diving, ecotourism, bathing, etc.,
- research
- education
- surveillance</td></tr>
<tr><td rowspan="2">Indirect use value</td><td colspan="3">- Biomass production
- Coastal protection and physical protection of other ecosystems</td></tr>
<tr><td>No specific indirect use</td><td colspan="2">- Carbon sequestration and storage
- Water and waste treatment</td></tr>
<tr><td>Induced use value</td><td colspan="3">Water and nutrient provisioning for fish farming</td></tr>
<tr><td>Option and Quasi-option values</td><td colspan="3">Biodiversity: habitat and critical species</td></tr>
<tr><td>Bequest and existence values</td><td colspan="3">- Marine habitats
- Marine species
-Marine biodiversity
- Social values, cultural values (including religious and spiritual)
- Way of living associated to coastal ecosystems</td></tr>
</table>

Various methods have been used to estimate the different values. Table 2 in the SMP shows for each of them the method utilised. The set of methods has been discussed and agreed by a group of economists from the French ministry of Ecology, IUCN and universities. A set of 3 guidelines has been produced by IFRECOR for the estimation of the direct use values, indirect use values and non-use values (Pascal, 2013; Marechal et al., 2013; de Battisti et al., 2013). Methods used for the socio-economic estimation of the use values of the CRAE of Martinique are standard valuation ones and are:

- Gross value added for the measurement of the value of commercial activities (fishing, diving, excursion, etc);
- Replacement value for the estimate of the coastal protection and water treatment functions of the CRAE;
- Market value for the carbon sequestration and biomass production using the current market unit price.
- Willingness to pay for the estimate of consumer's surplus for non-monetary activities: i.e. the monetary value that an individual would be ready to pay to be able to continue to practise an activity with the CRAE in their current state

For the non-use values, two standard methods were utilised:
- Choice Experiments for the estimate of the willingness to pay of individuals for a change of the ecological status of the CRAE. This method was chosen for its ability to capture in a synthetic way the various non-use values (option and quasi option, bequest and existence). Scenarios have been elaborated from three key elements of change in the health of ecosystems: terrestrial

activities and their coastal pollution (agriculture, coastal building, sewage pollution and coastal dump sites); coastal and marine activities and their potential of degradation or improvement of ecosystems (nautical excursion, anarchical mooring, fishing and diving without instructors) and the cost of restoration of damaged ecosystems (0, 20 or 50 € per household per year for the resident population and 0, 1 or 5 € per night per person for the tourist population).
- Public spending for the estimate of the expenditure related on teaching and research in relation to the CRAE.

A questionnaire with specific questions to tourists and residents was elaborated and passed on to 1200 people during interviews (details are presented in Failler et al. 2010). Nine scenarios were elaborated and presented to interviewees (see Table 2 in the SMP for 2 of them and Failler et al., 2010 for the whole set). Their selection has been used to define policy recommendations.

3. Total economic value

The economic and social value of coral reefs and associated ecosystems in Martinique is valued annually at 245 M €. The direct use value of non-extractive and extractive activities, are estimated at 142 M €. The indirect use value, associated with the ecological functions of the CRAE, represents nearly 94 M € (38% of the TEV) while non-use values represents less than 10 M € (or 4% of the TEV; cf. figure 3 in the SMP).

The main direct use values are those linked to leisure activities (27% of the direct use value) and to tourist accommodation (23%) whose activities have a proven link with the CRAE of Martinique. The value generated by commercial fishing is ranked thrid (15%). Subsistence fishing, which represents an annual value of almost 2,5 M € contributes only 1% of the value created but represents an activity of significant importance for those whose incomes are modest. The crew members are the first to benefit since a good share of their remuneration is done "in kind" during the low season, which makes it possible to maintain good fishing crews.

Among all the estimated values, the one associated with the protection of coasts is the most important since it accounts for 31% of the TEV (see Table 3 in the SMP for the ranking). The estimated value of the consumer's surplus relating to leisure activities and accommodation and subsistence of tourists whose stay is directly linked to the presence of the CRAE and their use, account for 50% of the TEV alone. The use value related to an extractive activity, e.g. commercial fishing, accounts for only 6% of the TEV. The four above mentioned values compose nearly 88% to the TEV. Among the nine categories of values which, cumulatively, account for the 12% remainder of the TEV, those of indirect use associated to the purification of water and of non use related to the restoration of the CRAE are the most important (7,5% of the TEV).

Overall, tourism contributes to 44% of the creation of the TEV (107 M €) compared to 18% for the activities of the residents (43 M €) (See figure 3 in the SMP). The ecological services of the CRAE (water purification, production of biomass, protection of the coasts and carbon sequestration), which cannot be directly attributed to any group (resident and tourism) in particular, account for 38% of the TEV (95 M €). Accommodation expenditure of tourists related to the CRAE and the consumers' surplus estimated for leisure activities form the main part of the TEV assigned to tourists (respectively 56 and 42 M €; see Table 4 in the SMP). The non use

value that they assign to the restoration of the CRAE represents a little less than 10% of their TEV. The residents, however, make the greater part of their TEV from the consumers' surplus from leisure activities (24 M €) and to a lesser extent from commercial fishing activities (15 M €).

Taking into consideration their contribution to the formation of the TEV, the three ecosystems do not contribute equally (Figure 5 in the SMP). The sea-grasses contribute the most, with a value of the services estimated at 107 M € (about 44% of the TEV), the contribution of the coral reefs follows with almost 100 M € (41%), while the contribution of the mangroves is limited to 38 M € (16%). However, when related to the surface area of each of the three CRAE (55.87 km^2 for the reefs, 49.74 for the sea-grasses and 20.63 for the mangroves), the distribution changes: the mangroves and reefs produce services of equal value (approximately 1.7 M €/km^2, about 31% of TEV /km^2 against 15 and 41% of the TEV); the services resulting from the sea-grasses remain the most important with an unit value of 2 M € (see Figure 6 in the SMP).

Therefore, from the services which they produce, being able to be directly or indirectly used by man or from their existence, each km^2 of each of the three ecosystems has a significant contribution to the formation of the TEV. The result is that the most important initial objective of the study was to measure the economical and social value of coral reefs and of the associated ecosystems. In other words, the reefs were to be at the centre of the study while the associated ecosystems could be satisfied with a less luminous lighting. In order to present an overall picture, table 2 presents the detailed results for the 14 studied values.

Table 2: Decomposition of the TEV per ecosystem, activity and population

Nature	Use type	Activities	Value per activity (M €)	TEV repartition %	Repartition of activities per ecosystem			Value (M €/year)			Value (M €/km²/year)			Value breakdown (M €/year) between:		
					CR*	S-G	M	CR	S-G	M	CR	S-G	M	Resi-dents	Tourists	Total
Use	Extractive direct	Professional fisheries	15,1	**6,2%**	94,6%	2,8%	2,6%	13,52	1,29	0,33	0,24	0,03	0,02	15,1	0,0	0,0
		Sport fishing	-9,6	**-3,9%**	71,0%	29,0%	0,0%	-6,86	-2,76	0,00	-0,12	-0,06	0,00	-6,9	-2,8	0,0
		Subsistence fisheries	2,4	**1,0%**	94,6%	2,8%	2,6%	2,31	0,07	0,06	0,04	0,00	0,00	2,4	0,0	0,0
	Non-extractive direct	Ecotourism (accommodation and catering)	55,8	**22,7%**	45,0%	45,0%	10,0%	25,11	25,11	5,58	0,45	0,50	0,27	0,0	55,8	0,0
		Diving (within clubs)	3,4	**1,4%**	19,9%	80,1%	0,0%	3,39	0,00	0,00	0,06	0,00	0,00	1,5	1,9	0,0
		Touring activities	7,8	**3,2%**	62,0%	3,0%	35,0%	4,79	0,23	2,77	0,09	0,00	0,13	5,0	2,8	0,0
		Consumer surplus for recreational activities	66,8	**27,2%**	49,2%	20,8%	30,0%	32,80	13,85	20,16	0,59	0,28	0,98	24,4	42,4	0,0
	Induced	Aquaculture	0,0	**0,0%**	0,0%	0,0%	0,0%	0,00	0,00	0,00	0,00	0,00	0,00	0,0	0,0	0,0
	Indirect	Coastal protection	77,0	**31,4%**	20,7%	77,8%	1,5%	15,91	59,98	1,16	0,28	1,21	0,06	0,0	0,0	77,0
		Fisheries biomass production	6,5	**2,6%**	75,0%	4,0%	21,0%	4,83	0,24	1,39	0,09	0,00	0,07	0,0	0,0	6,5
		Carbon sequestration	0,8	**0,3%**	21,7%	52,5%	25,8%	0,17	0,40	0,20	0,00	0,01	0,01	0,0	0,0	0,8
		Water and waste treatment	9,4	**3,8%**	2,3%	59,5%	38,2%	0,22	5,60	3,59	0,00	0,11	0,17	0,0	0,0	9,4
Non-use		Option, bequest, existence values	9,1	**3,7%**	33,3%	33,3%	33,3%	3,02	3,02	3,02	0,05	0,06	0,15	1,8	7,3	0,0
		Research and education	0,9	**0,4%**	46,0%	23,0%	31,0%	0,40	0,21	0,27	0,01	0,00	0,01	0,0	0,0	0,9
Total			**245,4**	**100,0%**	**40,6%**	**43,7%**	**15,7%**	**99,60**	**107,25**	**38,53**	**1,78**	**2,16**	**1,87**	**43,4**	**107,4**	**94,6**

*: CR : coral reefs ; S-G ; sea-grasses ; M : mangroves

4. Resident and tourist populations wishes regarding the improvement of health status of CRAE and management options

Among the 9 scenarios suggested to the people interviewed, the most respectful to the CRAE was the one for which terrestrial activities are decreased by 50% and marine activities prohibited (at least for a definite duration) (see Table 5 in the SMP). This scenario occupies the 6th rank in terms of willingness to pay (WTP) for the residents, the 4th rank for the tourists and the 5th rank in terms of budget represented by the WTP of the two populations. Residents are thus ready to pay 12.8 €/household/year and the tourists 1.4€ /night per capita for this scenario, which represents an annual WTP of almost 10 million € (403 520 households of 2.9 people on average and 500 000 tourists with an average stay of 10.4 days; see table 5 in the SMP). The preferences of the residents and the tourists with regard to the improvement of the health of the CRAE via management measures can be represented as follows:

By taking account the preferences of the individuals with regard wellbeing through satisfaction (economic utility) that they withdraw for each level of attribute; one can thus establish cartography of the attributes. By comparison, between the various levels of attribute and the status quo, the attributes can be classified according to preferences of the individuals:
- For terrestrial activities, the choice of residents is rather categorical, their preference for a reduction of 50% is strong; contrary to the tourists who direct themselves more favourably towards a simple reduction of 20% of these activities.
- With regard marine activities, the residents wish a change since they recommend a prohibition or a reduction of 50% of the activities rather than the status quo. On the other hand, for the tourists, if their choice also goes for the reduction of 50% of the marine activities, the status quo is preferred to total prohibition.
- Lastly, from the point of view of costs, residents as well as tourists wish to take part financially in the improvement of the CRAE but only to a certain extent because these two populations prefer to not pay anything (status quo) rather than to pay the most extreme suggested price (50€ /household/year for the residents and 5€/person/day for the tourists). They thus direct their preferences towards a moderate payment (20€ /household/year for the residents and 1€ /person/day for the tourists) rather than the status quo.

The “optimal” scenario would be the one for which economic, ecological and social interests meet. According to the observations made previously, no scenario entirely satisfies these three interests. Therefore, the choice of scenario to be adopted for the future will have to be a compromise. In this respect, the utility of the tourists and the residents converge with regard to the restriction of the detrimental marine activities by pushing for a reduction of 50%. This, however, does not satisfy the ecological requirements which need a complete stop of all diving activities that are not professionally supervised, fishing activities with passive gear put down on the reef, wild anchoring and mooring of boats and yachts and the use of jet-skis above sea-grasses and reefs. At the very least, it could be a first compromise.

With regard terrestrial activities, resident as well as tourists prefer a change to the status quo. From an environmental point of view, the best would be a maximum reduction of these activities, namely 50%. If such a change is in line with the utility of the residents, the tourists prefer a more modest reduction of terrestrial activities (20%). The difference in utility between a reduction of 50% and 20% is relatively weak (options 4 and 7 in Table 6 in the SMP), which suggests a second compromise, which consists of choosing a reduction of the terrestrial activities of 50%, is possible. The implementation of the two compromises leads to the formulation of an option of management which consists of decreasing terrestrial and marine activities by 50%. It is consequently advisable to evaluate, in a forthcoming work, the feasibility of the implementation of such a management option.

5. Cost of public inaction and sustainable policy of CREA

At the scale of Martinique, the disappearance of the totality of the coral reefs would represent an annual economic loss of about 100 M € (cf. Table 2 above, in the column Value (M €/year). The monitoring already carried out for 10 years, within the framework of the IFRECOR, out of 4 sites has accounted for the loss of reef coverage between 20% (îlet Ramier) to 54% (Fond Boucher; see Table 7 in the SMP). Such a reduction of reef coverage can be quantified economically as a result of the estimates made within the framework of this study:
- the value of one km^2 bio-built reef is equivalent to 1.78 M €/year (cf. Table 2 above);
- the reef that covers 14.75 km^2 is dispersed on a surface of 26.75 km^2, that is to say that its functional surface corresponds to 55% (14.75/26.75) of its geographical surface.

By considering, first of all, that the 4 sites are representative of the general evolution of the reefs in Martinique in recent years, and, that then, every percent less of reef coverage corresponds to a reduction of the functional surface of the bio-built reefs of 55%, one can deduce from this that the annual reduction of 9% of the reef coverage of the coast of Martinique (1.5 km^2 on average per year of the surface, taking 2009 as a starting point) corresponds to a deterioration of the economic value of about 1.5 M €/year (1.78 M€ X 1.5 X 55%). If a share of the degradation of the reefs is assignable to natural events like the hurricanes and with climatic change like the increase in temperature of the water which leads to the bleaching of the reefs, another, much more important is due to the public inaction and more particularly to: 1°, the political lack of consideration at the highest levels; 2° the laissez-faire way which characterizes the access to the coast; and 3°, the lack of interest in the knowledge of reef role and their ecological and economic functions. Therefore, this figure must be understood as the cost of public non-intervention as regards the management of the CRAE of Martinique.

If one extends this reasoning to the whole of the studied CRAE, one can estimate that each km^2 of missing CRAE generates an economic loss of almost 2 M € (average of the 3 ecosystem annual values per km^2, see table 2 above). The continuous degradation of a good part of the mangrove and sea-grass gives an idea of the extent of the annual economic loss (which it would be advisable to quantify in further research on this topic). Beyond the figures and results presented in this study to demonstrate the magnitude of the phenomenon which currently proceeds before our eyes, what should be noted it is that if nothing is done (or only little) it is not only tourism that will suffer but the whole of Martinique.

The economy of the CRAE however represents some 250 M €/year which is more than the value-added created by the transportation sector in Martinique (222 M €) or agriculture (166 M €). The political and economic investment in the CRAE is thus an answer to the difficult questions of employment (current rate of unemployment is about 30%) and of the economic emancipation of the island. It is thus difficult to make abstraction of it in any economic and social development plan. The Regional framework for the planning and development of Territory (SRADT), which is the major leverage tool, focused on employment and economic development such as catching up in terms of social advantages with respect to the Metropolis; the coastal and marine environment is missing from this framework. The Development Economic framework of Martinique (SMDE) which aims, since its development in 2005, to project the economy of the island by 2025, corrects this oversight by proposing "To implement tools for the valorisation of the biodiversity" (p. 53 of the SMDE). The SMDE represents a very simplistic vision of nature which is summarized as natural resources to exploit or to protect for the benefit of human kind. In 2009, the general assembly of the French overseas territories emphasised the major role played by biodiversity and in particular that of the coastal zone for the economic development and creation of jobs around the activities of valorisation of the ecosystems (eco-tourism, eco-certification of fish catches, research and education, pharmacopeia, etc). Focused on biodiversity *per se*, the conclusions of the general assembly occulted the ecological services of the ecosystems and in that respect a whole dimension of their value. It is, therefore, important that CRAE receive the attention which they deserve in the future.

6. Conclusion

The CRAE represent an important economic and social value estimated at some 250 M € per year. They constitute the basis of tourist and leisure activities and an important part of commercial and subsistence fishing activities. Moreover, they are responsible for the protection of the coast, the purification of water, the sequestration of part of the carbon emitted in Martinique and elsewhere and finally the production of a consequential marine biomass. The CRAE procure thus at the same time a quality of life for the inhabitants of Martinique and an insurance of safeguarding their natural environment. To the tourists, they offer an underwater biodiversity that enhances the pleasure of the neophyte divers or simply of bathers, without counting beautiful landscapes for the pleasure of hikers and excursionists. For this whole set of uses and non uses, the residents of Martinique and the tourists wish an improvement of the health of the CRAE by the introduction of restraint measures on terrestrial activities (various pollutions and encroachment on the coastal zone) and of the marine activities related to fishing, diving, jet-ski and wild anchoring and mooring.

The estimates carried out within this study are to be regarded as orders of magnitude intended to nourish on one hand the strategic dialogue on the conservation and valorisation of the CRAE of Martinique and on the other hand the budgetary arbitrations of the orientations of public policies. With regard to the first point, the maintenance of the biodiversity of the CRAE must be seen from the evolutionary point of view where one, at the same time, seeks to preserve what exists as a memory of the past and to preserve the potential of the future evolution of the living entities and the ecosystem functions. This consists of ensuring the maintenance of the capacity of the vital processes to change (Blandin, 2009). It is thus fundamental to adopt a concerted approach between all the stakeholders of the coastal zone. With regard to the second point, public policies must consider the protection of the CRAE and even more their valorisation from a point of view

which combines economic utilitarianism and selflessness. The CRAE seems indeed to be part of the identity of the coastal populations of Martinique and, for this reason, must be valorised. It is also an important potential source of employment and economic development and thus deserves more than the current inattentive neglect.

Finally, the current pressures exerted on the CRAE, in particular the destruction, the fragmentation and the deterioration of habitats, or the overexploitation of fish species, introduce the concept of cost of public inaction. Estimated at approximately 2 M € per annum for the whole of the CRAE, this cost shows that doing nothing has a price: the price of economic loss, for which it is advisable to add the price of the restoration of the damaged ecosystems (not estimated here). In that context, the recognition of the TEV of the CRAE is fundamental for the optimization of public actions, especially as the values which it comprises show the very strong bond between economic considerations and the living.

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