Journal of Environmental Management 116 (2013) 135–144

Contents lists available at SciVerse ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Economic valuation of ecosystem services from coral reefs in the South Pacific: Taking stock of recent experience

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ARTICLE INFO

Article history:
Received 20 October 2011
Received in revised form
12 November 2012
Accepted 28 November 2012
Available online

Keywords:
Coral reefs
Ecosystem services
Valuation
South Pacific
Decision-making

ABSTRACT

The economic valuation of coral reefs ecosystem services is currently seen as a promising approach to demonstrate the benefits of sustainable management of coral ecosystems to policymakers and to provide useful information for improved decisions. Most coral reefs economic studies have been conducted in the United States, Southeast Asia and the Caribbean, and only a few have covered the South Pacific region. In this region, coral reefs are essential assets for small island developing states as well as for developed countries. Accordingly, a series of ecosystem services valuations has been carried out recently in the South Pacific, to try and supply decision-makers with new information.

Applying ecosystem services valuation to the specific ecological, social, economic and cultural contexts of the South Pacific is however not straightforward. This paper analyses how extant valuations address the various management challenges of coral reef regions in general and more specifically for the South Pacific. Bearing in mind that economic valuation has to match policy-making contexts, we emphasize a series of specific considerations when conducting and applying ecosystem services valuation in South Pacific ecological and social contexts. Finally, the paper examines the decision-making situations in which extant valuations took place. We conclude that, although ecosystem valuations have been effectively used as a means to raise awareness with respect to coral reef conservation, methodologies will have to be further developed, with multidisciplinary inputs, if they are to provide valuable inputs in local and technical decision-making.

1. Introduction

Coral reef ecosystems represent a resource of primary importance for the economies of many South Pacific countries. Insular economies are particularly fragile, due to their relatively high dependence on natural resources, the risk of natural calamity, demographic pressure, poverty rates and low human capital capacity (Leisher et al., 2007; Pollnac et al., 2000). Despite the importance of coral reefs in the South Pacific countries, in general they remain threatened by various negative pressures: overfishing, coastal development, sedimentation and pollution from agriculture and logging, tourism overuse, climate change and acidification of the oceans (Mumby and Steneck, 2008).

Due to these characteristics, coral reefs are the subject of increasing attention from conservation organisations and scientists (Nyström et al., 2000; Bellwood et al., 2004). Recent studies suggest that, in many regions of the world, 50–70 % of reefs are likely or very likely to cease providing basic ecosystem services (Wilkinson, 2008; Bryant et al., 2011). The same studies show,

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http://dx.doi.org/10.1016/j.jenvman.2012.11.031

however, that coral reefs in the South Pacific appear healthier (on average) than in other regions such as the Indian Ocean and Caribbean.

Since the 1990s, Coral Reef Ecosystems Services (economic) Valuation (CRESV) has gained considerable interest. The concept of valuation, methods used and results obtained have been extensively discussed in earlier studies (Spurgeon, 1992; Dixon, 1998). Monographs and meta-analyses have been produced on the topic (Cesar, 2000; Ahmed et al., 2004; Brander et al., 2007). Costanza et al. (1997) and Cesar et al. (2003) both aimed at giving an estimate of the global value of coral reefs. The number of economic valuation studies on coral reefs has increased rapidly to exceed one hundred by the mid-2000s (Brander et al., 2007). These numerous studies have, however, mainly concentrated on the United States (Hawaii and Florida), Southeast Asia (Philippines, Indonesia, Thailand, etc.) and the Caribbean (Jamaica, Saint Lucia, Trinidad and Tobago, Martinique, etc.), while few valuations were carried out in South Pacific countries.

Since the mid-2000s a modest but growing number of CRESVs have been conducted in the South Pacific (Pascal and De Maziere, 2008). What do they tell us about the ecological services from South Pacific coral reefs? How do these results compare to those from other coral reef regions? How can these South Pacific CRESVs contribute to decision-making in such contexts where, as mentioned above, better management practices are urgently needed?

This article aims to provide a comprehensive overview of the knowledge base regarding coral reefs ecosystem services valuation (Section 2), to present and comment on the results of a series of South Pacific CRESVs (Section 3), to analyse the methodological details of this exercise when conducted in the South Pacific region (Section 4) and to specify the possible roles of South Pacific CRESVs in decision-making (Section 5). Finally, we conclude with a series of proposals to develop the practice and the use of sound-based CRESVs in the South Pacific.

2. Three complementary approaches for describing societal values of ecosystem services from coral reefs

2.1. Targeting decision-making through three complementary valuation approaches

CRESVs have been carried out as a means to foster conservation and support decision-making concerning the sustainable management of coral reefs. In the literature, the contribution of CRESV to decision-making may be categorized into three different economic approaches: the *economics of degradation*, the *economics of protection* and the *economics of welfare*.

The economics of degradation concentrates on the assessment of impacts of human activities on coral reefs. This approach was developed first at the end of the 1980s through three seminal papers: Hodgson and Dixon (1988), McAllistair (1988) and Hundloe et al. (1987). This category of economic valuation consists of comparing private benefits and social costs associated with human activities that impact coral reefs, so as to demonstrate the negative impact of those activities for society, when external (thus often hidden) costs are taken into account. "External costs" are costs borne by an economic agent, that are created by the activity of another agent, who does not consider and thus integrate them in her reasoning (Meade, 1979). For instance, when people practice blast fishing, they tend to destroy coral habitats upon which other important fish depend (including fish of commercial or tourism value) (Pet-Soede et al., 1999). Other typical external costs evaluated in coral reef regions come from cyanide fishing (Mous et al., 2000), coral mining (Berg et al., 1998; Ohman and Cesar, 2000; Cesar and Chong, 2004) and tourist overuse (van Beukering and Cesar, 2004. Another set of studies pertaining to this category, that investigates the costs of degradation from anthropogenic threats to the coral reefs at the global scale, includes the impacts of climate change and coral bleaching (Cesar and Chong, 2004; Westmacott et al., 2000), ocean acidification (Brander et al., 2009) or algae blooms (van Beukering and Cesar, 2004). The results of these studies have been used to advocate the introduction of bans on destructive practices, or for strengthening preventive policies by assessing the cost of policy inaction.

Some authors have also quantified the costs of policy inaction to prevent destructive practices. These costs include the economic and social cost that would result from not passing or enforcing adequate regulations, thus allowing the depletion of natural resources and of related economic activities, as well as loss of natural capital. For example, in Indonesia the economic costs of blast fishing to society have been estimated to be four times higher than the total net private benefits (Pet-Soede et al., 1999). Such economic estimates of the cost of degradation have been used to justify conservation measures, explicitly or implicitly.

The economics of protection and management of natural resources involves the valuation of benefits from marine biodiversity conservation and management. Studies have highlighted the benefits of conserving ecosystems by comparing costs of conservation with net benefits that accrue from conservation policy. For example, the coral reefs and mangroves of Olango Island in the Philippines generate annual net benefits of US$1.53 to 2.54 million, whereas the costs of conserving this environment are estimated to be less than US$100,000 a year, a more than ten-fold difference (White et al., 2000b). This provides a strong message in support of the conservation and management of such ecosystems. Other studies value the preferences of users for ecosystems in a good ecological state, which is often carried out through non-market valuation methods, such as contingent valuation (Spash, 2000). Contingent valuation is a means to simulate the absent market for coral reef ecosystem services by eliciting, through surveys, individuals' willingness to pay for the preservation of the given services, or willingness to accept for their loss. Another category of economic "valuation for conservation" focuses on the costs and benefits of specific conservation measures, such as the establishment of marine protected areas (Dixon et al., 1995; Subade, 2007). Finally, some authors have also examined the restoration of critical habitats. This approach aims to compare the costs and benefits of restoring degraded ecosystems (Spurgeon and Lindahl, 2000) or rehabilitating and creating habitats (*Ibid*). "Economics of conservation" analyses are thus intended to assess the economic opportunity created by protection measures, from a general societal perspective. They are symmetrical to the analysis of the "economics of degradation".

The economics of welfare stems from the recognition of the dependence of human beings on the provision of coral reef services and the contribution of coral reefs to coastal and national economies (Costanza et al., 1997; MEA, 2005; Haines-Young and Potschin, 2010). Studies with this perspective aim to provide an overall value of the coral reefs and generally frame valuations in terms of Total Economic Value (TEV, see below), which allows the identification of economic agents and sectors that are associated with the components of the TEV. However few valuations actually measure the *total* economic values, high sums of values are then used to make the case for considering coral reef conservation in the national decision-making process. Hence, the value of Martinique's coral reefs was estimated to be almost US$100 million a year (Failler et al., 2011), US$360 million a year for Hawaii (Cesar and van Beukering, 2004) and US$14,300 per km^2 in American Samoa (Spurgeon, 2004b). "Economics of welfare" analyses are thus

intended to demonstrate the economic importance of coral reefs to stakeholders, especially when their behaviour is likely to influence the reef's condition.

Having reviewed CRESVs in general, according to their policy and decision-making purposes, we now examine the ecosystem services provided by reefs that are assessed through these valuations.

2.2. Highlighting the societal value of coral reefs through ESVs

The initial CRESVs, in the 1990s, have largely concentrated on marketed ecosystem services, such as tourism and fisheries (Davis and Tisdell, 1996; Hodgson and Dixon, 1988) and, to a lesser extent, on research and education (Driml, 1994; Cesar and van Beukering, 2004). Tourism and recreation[1] values have remained the core topic of valuations through the 2000s, as shown by Brander and colleagues in their meta-analysis (Brander et al., 2007). As a result, in most cases the estimated value of reefs has been limited to these direct use values and has overlooked the non-marketed goods and ecosystem services.

Through the 1990s, the recognition of indirect use benefits provided by coral reefs marked a further step towards integration of coral reef protection in decision-making (UNEP-WCMC, 2006). Researchers have therefore investigated further the valuation of non-marketed goods, which requires different valuation approaches. The majority of such valuations assess indirect benefits, including storm protection and prevention of coastal erosion Riopelle, 1995; Ruitenbeek et al., 1999); biodiversity (Ruitenbeek and Cartier, 1999; Samonte-Tan et al., 2007); and flood prevention (Berg et al., 1998). Non-use values, including bequest values (based on an individual's desire to bequeath a given natural asset to future generations) and existence values (values that agents attribute to the mere existence of a natural asset with no reference to its utility at present nor in the future, (Barton, 1994)), have remained absent from many CRESVs. They have, however, been the focus of much anthropological and cultural geography research. These non-use values, although difficult to quantify, can potentially outweigh use values, since coral reefs regions inhabitants often place the former above the latter (Spurgeon, 2004a).

The results of CRESV exercises underline that the amounts estimated for both the sum of values and its various components vary widely (UNEP-WCMC, 2006). Indeed, economic values of coral reefs have ranged between US$100,000 and US$600,000 per km^2 (Cesar et al., 2003; Costanza et al., 1997). The main components of these partial TEV estimates are (annual values): (1) tourism and recreational activities, ranging from around US$1000 per km^2 in the Philippines (Samonte-Tan et al., 2007) and Sri Lanka (Berg et al., 1998), to several tens of thousands of US$ per km^2 in Jamaica (Cesar and Chong, 2004) and up to around US$50,000 per km^2 in the Caribbean islands of Trinidad and Tobago and Saint Lucia (Burke et al., 2008); (2) "indirect use values"(based on the positive external effects that ecosystem provide to agents), such as shoreline protection, from several tens of US$ per km^2 in Indonesia (Riopelle, 1995) to more than US$ 10,000 per km^2 in the Caribbean (Ruitenbeek et al., 1999; Burke et al., 2008); and (3) extractive activities such as fisheries, up to US$3700 per km^2 in Jamaica (Ruitenbeek and Cartier, 1999) and mining, with a maximum value of US$16,700 per km^2 in Sri Lanka (Berg et al., 1998).[2]

This variation in values is highly dependent on the socio-economic and ecological context in which assessments are performed, in addition to methodological heterogeneity between studies. Considering geomorphologically similar reefs, values generally increase with four factors: (1) the economic development of the coastal zone, which raises the value of assets protected by reefs, (2) the concentration of population, which increases the number of beneficiaries of coral reef services (and acts as the multiplier to which per capita estimates are extrapolated), (3) per capita national Gross Domestic Product, as a proxy for the budget availability or 'ability to pay' and (4) the rate of highly valued activities, such as tourism as opposed to agriculture and small-scale fisheries. As an illustration, the benefits from shoreline protection due to healthy coral reefs in Indonesia increases from US$829 per km in reefs adjacent to sparsely populated areas where agriculture is the main activity, to US$50,000 per km for reefs adjacent to areas of high densities of population, and US$ 1 million per km for reefs in areas where tourism is the main activity (Cesar, 1996; UNEP-WCMC, 2006).

This section has analysed the variety and complementarity of approaches to the use of CRESV for estimating the importance of coral reefs and the value of protecting them, and has described how researchers have valued different components of coral reef ecosystem services throughout the world. This survey has revealed the importance of some monetary figures, in specific cases, and their potential power to justify conservation policies. The analysis has also suggested, however, that ES values are subject to large variations according to locational and socio-ecological contexts; which leads to the conclusion that results are often best considered as site-specific.

The next section examines a series of CRESVs that have been carried out recently and specifically for South Pacific countries or areas, and that offer a means to illustrate both the specificity of the region and the similarities of ES from coral reefs across the world.

3. A review of estimates of coral reef economic values in the South Pacific: specificities and similarities

The results and contexts of a set of recent Economic Values studies in the South Pacific are briefly summarized in the form of an abstract and a recapitulation of their main quantitative results. These results are then discussed regarding the relative importance of the various ES across South Pacific contexts, and qualitatively compared with valuations of coral reef ecosystem services for other regions. It should be noted that the different valuation methods that have been employed in the reviewed studies estimate different measures of economic welfare (see Carson et al., 1996; Freeman, 2003), which means that the estimated values are not necessarily directly comparable (Brouwer, 2000; Smith and Pattanayak, 2002).

3.1. Summary of recent South Pacific CRESVs

3.1.1. Components of the total economic value (TEV) of a Fijian locally managed marine area (O'Garra, 2012)

The aim of this study was to estimate the total economic value (TEV) of the coastal ecosystems within the Navakavu Locally Managed Marine Area (LMMA). In addition, the study aimed to estimate the economic value of the LMMA management intervention, in order to assess ex-post the economic impact of establishing a protected area. Demand for this research came from the network of LMMAs and several local stakeholders. Using various valuation methodologies – a contingent valuation questionnaire, a catch survey and benefits transfer from secondary data – this study has produced estimates of the economic value of key services provided by the marine ecosystems within the Navakavu LMMA (i.e.,

[1] A clear distinction between tourism and recreation uses of coral reefs is often not made in the literature but generally tourism refers to the activities of non-local (mainly stayover) visitors and recreation refers to the activities of local residents.

[2] The values listed here are for illustrative purposes only and should not be compared directly with one another without correction for inflation, temporal and geographic scale, affected population, etc.

Table 1
Summary of results of O'Garra (2009, 2012) for Navakavu (Fiji). Original results are converted from Fijian dollars (2006) into international dollar (2009) based on average inflation rate of 3.6% y^{-1} and a PPP of 1.35 (Heston et al., 2011). Coastal area of coral reef is estimated in 18 km^2 and total population is 600 (aprox.). Subsistence fishing is the sum of the values of catches declared as household consumption and gifts.

	Subsistence fishing	Commercial fishery	Recreational fishery	Underwater and nautical tourism	Coastal protection	Research and education	Bequest value	Total
In int. Dollar Per hectare	257	336	Negligible	Non-existent	350	2	26	972
In int. Dollar Per capita	793	1037	Negligible	Non-existent	1081	7	79	2990

fisheries, coastal protection, bequest value and education). This valuation was one of the first made in a Small Island Development State and highlights the value of ecosystem services for local communities. Due to the absence of any regional references on which to base the value transfer, the results from the application of this method could arguably be improved (Table 1).

3.1.2. The economic value of coral reef ecosystem services of New Caledonia (Pascal, 2010)

A CRESV on the New Caledonian reef was commissioned in 2008 by the French initiative for coral reefs (IFRECOR) driven by demand from central and local governments. The objectives of the study were to: (i) estimate the value of coral reef ES in order to make the case for a better consideration of ecosystems in land and resource planning; and (ii) identify the key beneficiaries of these ES. The valuation has been conducted through different methods (production approach, market price, damage costs, and transport costs) to determine the annual benefits from more than 18 ES (covering all kinds of fisheries and aquaculture, several tourism sectors, coastal protection, bio-prospecting and education). The study has brought new insights regarding very specific ecosystem services (e.g. pelagic fisheries and coastal protection) and methodological developments. Improvements in the determination of potential values seem necessary to transmit a correct image of ES (Table 2).

3.1.3. Cost-benefit analysis of community managed MPA in Vanuatu (Pascal, 2011)

The AFD (Agence Française de Développement, the French Development Bank) was interested in assessing the impacts of community managed MPAs on local economic growth, poverty reduction and on world biodiversity as a public good. An ex-post appraisal of investment in MPAs through a cost-benefit analysis (CBA) and Return on Investment has been conducted in 5 selected villages in Vanuatu. The revenues from a selection of ecosystem services have been assessed (fisheries, tourism, social capital, coastal protection services and bequest value). As far as possible the values of selected ecosystem services were compared to villages without MPAs (control sites) to identify MPA impacts. It is one of the first valuations that provide economic values of impacts derived from the existence of coral reef MPAs. Knowledge gaps in the small-scale spatial distribution of ecological processes lead to underestimates in the valuation. The results presented in Table 3 are the values of the ES and not the value of the impacts of the MPA on them.

3.1.4. Components of the total economic value of Hawaiian coral reefs (Cesar and van Beukering, 2004)

The economic valuation of the coral reefs of Hawaii study was commissioned by the US National Oceanic and Atmospheric Administration (NOAA), Coastal Ocean Programme. The three objectives of the study were: (i) to estimate the total economic value of Hawaii's coral reefs, (ii) to assess the economic costs of coral reef degradation; (iii) to compare the costs and benefits of selected management options to protect Hawaiian coral reefs. The services valued (and valuation methods employed) are: support to commercial fisheries ("net factor income", i.e. gross fisheries revenues minus the costs of other inputs in production), tourism (net factor income), marine recreation (contingent valuation), amenity values (rough hedonic pricing, i.e. valuation derived from a differential in real estate prices, with and without the environmental benefits; see Ridker and Henning (1967)) and non-use values (based on a value transfer, i.e. transferring values from a pre-existing survey to the site under consideration; see Brouwer (2000)). This study addresses relatively few coral reef services. The value of coastal protection is notably absent and as observed in the other reviewed studies may be economically significant. The validity of some of the valuation methods employed is questionable (e.g. the rough hedonic price analysis) but subsequent studies have attempted to improve on these estimates for Hawaii (e.g. Brouwer et al., 2010) (Table 4).

3.1.5. Components of the total economic value of the coral reefs of Saipan in the Commonwealth of the Northern Mariana Islands (van Beukering et al., 2006)

This study was commissioned by the NOAA with the main objective to carry out an economic valuation of the six main services provided by selected coral reef areas on Saipan. The services valued (and the valuation methods employed) are: fishing (total revenue), recreational uses (value transfer), tourism uses (net factor income), shoreline protection (avoided damage cost, i.e. value of flood damage costs avoided due to the effects of maintaining a healthy reef), amenity values (value transfer), and information and education (gross expenditure, i.e. budget spent for education and research). In addition to the estimation of TEV of Saipan's coral reefs in general, two extensions of the study aim to demonstrate the practical use of economic valuation for: i) representing the spatial variation of ecosystem service values across reef locations using a Geographic Information System (GIS) in order to aid the prioritization of different management options at various locations; ii) designing financing measures that take into account the value of coral reefs to the CNMI. Again the validity of some of the valuation methods employed is questionable. In particular the use of gross revenues to value commercial fisheries and information/education is expected to produce over-estimates of the actual producer surplus derived from each service. The extensions of the study produce interesting results and can be taken as good practice for future studies (Table 5).

3.2. Discussion

3.2.1. Relative importance and weight of ES in the economies of South Pacific islands

In the five aforementioned CRESVs, three main ES explain over 80% of the sum of estimated value; these are tourism, coastal protection and coral reef fisheries in their different forms.[3] They

[3] We note that any general comparison of results is limited by the low sample size of studies and values for the South Pacific, which may not necessarily be representative of coral reefs and ecosystem services in the region due to research priority selection bias (Hoehn, 2006).

Table 2
Summary of results from Pascal (2010) for New Caledonia. Original results are converted from Euros (2009) into international Dollar (2009) based on a PPP of 0.86 (Heston et al., 2011). Coastal area of coral reef is estimated in 4923 km^2 and total population is 245,000 (approx.).

	Subsistence fishing	Commercial fishery	Recreational fishery	Underwater and nautical tourism	Associated tourism	Coastal protection	Research and education	Bequest value	Total
In int. Dollar Per hectare	46	45	55	20	42	394	8	–	609
In int. Dollar Per capita	92	90	111	39	81	792	15	–	1220

Table 3
Summary of results from Pascal (2011) for North Efate, Vanuatu. Original results are converted from vatu (VUD, 2009) into international Dollar (2009) based on a PPP of 41.38 (Heston et al., 2011). Coastal area of coral reef is estimated in 5.7 km^2 and total population is 740 (approx.).

	Subsistence fishing	Commercial fishery	Recreational fishery	Underwater and nautical tourism	Associated tourism	Coastal protection	Research and education	Bequest value	Total
In int. Dollar Per hectare	147	88	Non-existent	Negligible	179	38	–	207	658
In int. Dollar Per capita	113	68	Non-existent	Negligible	137	29	–	159	506

represent the key ecosystem services generated by these reefs in the Pacific, regardless of social and ecological contexts.

At the country scale, tourism and fisheries producer surplus (i.e. the difference between the amount that fishermen and tourism businesses receive from the sale of their goods and services, and the lowest amount that they would accept as a selling price) represent values equivalent to 5% of the GDP of the islands on average (SD ± 4). At the local scale for Vanuatu and Fiji, these two ES provide at least 25% of the monetary and non-monetary annual village incomes. In both cases, natural processes have produced added value to the economy in a non-negligible way. This highlights the high dependence of those economies on natural resources.

Across the five reviewed South Pacific CRESVs, value-added estimates in reef fisheries appear unrelated to the types of fishing activities and of reef geomorphology. This result is probably explained by the relatively low productivity of coral ecosystems and to a maximum fishing yield that is rapidly met or exceeded, which will be commented on further.

The value of reef related tourism appears to be quite variable across locations. In all cases, the values relate specifically to tourism that depends on reefs with fairly similar ecological attributes (at least those attributes that are relevant for tourism business). Subsequently, the socio-cultural and developmental context of the tourism industry appears to provide a much better explanation of variation in values than the ecological attributes of the reef.

3.2.2. The value of ES from South Pacific coral reefs, compared to other coral regions

When compared to values assessed in other coral reef regions (e.g. the Caribbean), South Pacific CRESVs produce lower estimates of ES values.[4] For instance, recreation and tourism values per hectare of coral cover are found to be an order of magnitude lower in the five studies mentioned for the South Pacific than in results from South East Asia and the Caribbean. This may be explained, albeit without being able to account for the possible bias introduced by the small number of studies, by relatively low rates of tourism in the places studied, in comparison to these regions. Likewise, the few valuations of commercial fisheries made in the South Pacific suggest that this service might be relatively modest in the region, particularly in comparison to South East Asia. This might reflect differences in types of fisheries across regions – South Pacific fisheries being of smaller scale and less reef dependent.

Also, regarding the value of reefs in providing coastal protection we again find that the South Pacific has the lowest values per hectare of coral cover. The values for this ES have been calculated based on the flood damage costs that are avoided due to the protection from the reef (avoided damage costs). Therefore, the more valuable the assets protected (in market terms), the higher is the monetary value of the service. Again in addition to the possible bias introduced by the little number of studies, the low value of flood protection benefits estimated for the South Pacific may therefore be explained by the low population density and modest development in the region, compared to other coral reef regions, such as the Caribbean.

The results of a sub-set of CRESVs made for South Pacific emphasise the contribution of location-specific socio-economic characteristics to coral reef valuation, and the values derived from such analyses. It provides some insight into the complex relationships among subsistence and commercial fishing, tourism, and the broader economy. This comparison highlights the need for a better understanding of the specifics of South Pacific contexts when dealing with CRESV.

4. Specificities of South Pacific contexts for applying ecosystem service valuation

The discussion of the recent CRESV results for South Pacific islands has shown, among other findings, that particular consideration is required regarding the valuation of reef related fisheries, the relative scales considered, and the technical choices made within economic valuation applications. This section will discuss these issues in greater depth.

4.1. Valuing "fisheries" services: usual proxies do not apply reliably

4.1.1. Valuing non-commercial fisheries

One of the first methodological difficulties encountered in monetization studies in the Pacific is the valuation of non-commercial fisheries, which includes two very different types: subsistence and recreational fishing. For each, the appropriate methodological approaches are substantially different and require the clear identification of their respective volumes and fishing efforts.

Valuation of non-commercial fisheries has to overcome a major obstacle. It should be based on estimates of fish stocks, catch and fishing efforts. Those variables are however generally unmonitored and highly inconstant, and yet their results are sometimes larger

[4] We compare coral ecosystem service values for the South Pacific to those for other regions that have been collected and standardised in the database developed for the TEEB Quantitative Assessment (Hussain et al., 2011). We acknowledge that any comparisons may be limited by the potential presence of research priority selection bias in the valuation literature, i.e. that we cannot be certain that valuation studies are necessarily representative of the regions in which they are conducted.

Table 4
Summary of results from Cesar and van Beukering (2004) for Hawaii. Original results are converted from US dollars in 2001 prices into international dollars in 2009 prices using purchasing power parity and GDP deflator factors from the World Bank World Development Indicators. Total values were converted to a per hectare basis using an area of coral cover of 165,990 ha.

	Commercial fishery	Underwater and nautical tourism	Associated tourism	Bequest value	Amenity	Total
Int. Dollar Per hectare	18	939	1889	20	282	3148
Int. Dollar Per capita	398	–	–	3	33	–

than for commercial reef fisheries. Some key aspects of subsistence fishing activity for the South Pacific populations are difficult to reflect in a monetary value. Some of these aspects include: the protein dependence for some vulnerable socio-demographic groups ("Engel law", see David, 1988), the non-substitutability of fishing activity due to its low level of initial investment and training (Hickey, 2008), the maintenance of a stable source of income independent of market uncertainty (Turner et al., 2007), and its importance as a factor of social cohesion (Bensa and Freyss, 1994; Boyer, 1997).

Several solutions to address these issues have been proposed by different authors in the context of the South Pacific: estimations of catch based on studies of household consumption to bypass the lack of direct monitoring of catches (Gillett and Lightfoot, 2001; Labrosse et al., 2000; Leopold, 2000), determination of the protein equivalent of fish and invertebrates catches to reflect partially the food security component (Bell et al., 2009; David and Cillaurren, 1992; Gillett, 2009; Kronen, 2007; Ramseyer, 2000) and segmentation of the population by lifestyle to increase the robustness of estimates (Guillemot et al., 2009; Jollit et al., 2010; Marty et al., 2005; Virly, 2001).

In our selected economic studies, valuation of subsistence and recreational fisheries was either based on secondary data without any further analysis (van Beukering et al., 2006; Cesar and van Beukering, 2004) or calculated from a mix of the previous approaches (Pascal, 2010; O'Garra, 2012).

4.1.2. Limits of the maximum sustainable yield for ecosystem services valuation

Reef fish populations are very sensitive to fishing effort and overfishing is rapidly reached in these ecosystems. Nonetheless, CRESVs rarely take into account the ecological sustainability of the fishery when calculating an ecosystem service based on fisheries. Defining the value based only on the total fish catches is inadequate since this would be equivalent to valuing the consumption and depletion of a capital stock as a revenue, instead of valuing the maximum revenue that can be obtained while preserving the capital and the future revenues ("sustainable revenue"). As for most of the renewable resources, it is thus necessary to define a maximum sustainable annual productivity in order to calculate the potential fishery ES or to project future ES flows. Concretely, this maximum level would be compared to the present level of catches to (i) reduce the observed values to the sustainable maximum when the former is currently above the latter, or (ii) reflect a potential value of the ES in the absence of reliable data regarding actual catches.

To do this, some of the CRESVs have proposed to reintroduce the use of the "Maximum Sustainable Yield" (MSY) coupled with expert judgements (David et al., 2007; Pascal, 2010). The MSY is described in many fishery management works (Dalzell and Adams, 1996; Labrosse et al., 2000; Newton et al., 2007) and theoretically corresponds to the maximum catch that would be considered stable over several generations, since it would not affect the rate of natural renewal of the resource (Armada et al., 2009). Nonetheless, two observations are worth noting, when applying this approach for ES valuation:

(i) Reef fisheries science shows that the calculations of MSY for these multi-species fisheries are highly uncertain and highly variable depending on ecological context (Munro, 1984). There is no consensus among experts on indicators to assess whether the quantities extracted by reef and lagoon fisheries can be considered sustainable or not (Dalzell and Adams, 1996). As a reference, the indicative levels of sustainable exploitation of fisheries and reefs in the Pacific vary from 3 to 20 t. per km^2 per year (Dalzell and Adams, 1996; Jennings and Polunin, 1995; Kuster et al., 2005; Labrosse et al., 2000; Munro, 1984; Newton et al., 2007);
(ii) As is the case in general for ES (Braat and Ten Brink, 2008; De Groot et al., 2010), the level of sustainable activity for one ES may not be compatible with the sustainable level of another ES. For example, conflicts have been observed between fishery catch of specific species and the scuba diving industry, dependant on their clients' encounter rate with these species (Rudd and Tupper, 2002).

4.2. Some aspects of the South Pacific culture are difficult to capture by common economic methodologies

In many Pacific islands, including Melanesia (Vanuatu, Solomons and PNG), the cash economy is still under-developed. Therefore, the value that local communities attribute to money, and its function in life, differs widely from common economic assumptions. Island societies assign value to things that lack exchange equivalents, or relative prices, and which therefore are difficult to include in a TEV. Three cultural aspects can be mentioned here:

- The degree of familiarity of islanders with the reef, which is measured by the density of place names per km^2 and the number of fishes named locally. These two metrics are a proxy

Table 5
Summary of results from van Beukering et al. (2006) for Northern Mariana Islands. Original results are converted from US dollars in 2004 prices into international dollars in 2009 prices using purchasing power parity and GDP deflator factors from the World Bank World Development Indicators. Total values were converted to a per hectare basis using an area of coral cover of 7159 ha.

	Commercial fishery	Recreational fishery	Underwater and nautical tourism	Associated tourism	Coastal protection	Research and education	Total
Int. Dollar Per hectare	106	72	1595	13,045	2782	273	17,873
Int. Dollar Per capita	15	23	9	1913	408	40	2409

for both the non-use value of the reef and its use value (Pacific islanders name only what they use).
- The role of the reef in the identity of the village community. The highest values are attached in the place where the canoe of the founding ancestor of the island population first landed.
- The role of the reef in the social and political positioning of the community towards other island communities. The highest values are found among reef fishing clans as in New Caledonia (Leblic, 1989) and among communities where the alliance relationships are built on sharing of fishery products, including turtles, as in Tanna island, Vanuatu (Bonnemaison, 1986).

To our knowledge, only one study has addressed the non-use values of coral reefs in the Pacific SIDS for local populations (O'Garra, 2009). All other assessments of non-use values, through contingent valuation or choice experiment, have been estimated for high-income groups from Australia or developed islands (Ahmed et al., 2004; Curtis, 2004; Whitten and Bennett, 2004; van Beukering et al., 2006). O'Garra's results highlight that local communities were willing to contribute 3 h of their time per week towards conservation, mainly for future generations (bequest value). In this study several challenging issues were raised such as time allocation conflict between communal and personal obligations, gender influence in decision-making and common property resource management by villagers.

Thus CRESV in the South Pacific has to cope with a series of limitations, since it does not work well in non-market economies nor does it capture non-economic social goals. The importance of non-market fisheries is therefore a major difficulty. Its relationship with the ecological status of the reef is not easily dealt with by using MSY, and this is often an unsatisfactory approach. Lastly, the status of money, in economies that are sometimes using currencies marginally can raise important difficulties when applying CRESVs to such contexts.

Beyond these methodological considerations, the analysis now turns to the intrinsic limits of using economic values for decision-making in this region. This will be discussed in the next and last section.

5. Using CRESVs for policy-making in the South Pacific

Section 4 has addressed some of the difficulties in conducting CRESVs in the context of SIDS of the South Pacific. Nevertheless, TEVs and other economic valuations are increasingly attracting attention in the region, as shown by the recent development of valuations described in Section 3. The question now arises about how these valuations can and should be used for decision-making in the South Pacific region, bearing in mind their specificities both in terms of typical results, as indicated in Section 3, and of methodological complexity, as described in Section 4.

Addressing this issue requires that the role of Ecosystem Services Valuations (ESVs) in the decision-making process is well specified. Laurans et al. (forthcoming) have reviewed the literature dealing with the use of ESV for decision-making worldwide, and found that three very different roles can be expected for them:(1) "decisive" utilisation of ESVs is when valuation is expected to allow an *ex-ante choice* over a given set of options by weighing the social and economic consequences of those options; (2) "technical" use is when ESVs are used to "fine tune" an economic instrument (such as setting payments for ecosystem services or environmental taxes); (3) some ESVs are used in an "informative" way, to advocate environmental conservation or to provide indicators of resources depletion; this use is the most frequently referred to in the ecosystem valuation literature. In this last category of use, no specific decision is explicitly targeted here, but implicitly all types of decisions that potentially affect the environment.

Indeed, most CRESVs have been produced in such a perspective, pertaining either to the "economics of degradation" or the "economics of welfare" types of Section 2 (Seidl and Pascal, 2011; Beukering et al., 2007; Pagiola, 2004). Their role has been to raise awareness of the importance of healthy coral reefs in supporting subsistence livelihoods and economic development in island economies, as well as their value as cultural heritage for the use and enjoyment of future generations (White et al., 2000a; Whittingham et al., 2003). Well-crafted valuation exercises are, however, needed to illuminate the trade-offs that decision-makers have to make, by calculating the costs and benefits from action or inaction in coral reef management (Pagiola, 2004).

In that perspective, South Pacific CRESVs have been used by a varied list of stakeholders:

a. Development banks, for which CRESVs intend to highlight "how conservation has helped the local or regional economy and the people who depend on the managed ecosystems" (e.g. the AFD cost-benefit analysis of community based marine managed areas in Vanuatu).
b. Environmental agencies and conservation NGOs that need to justify "why do we need conservation here?" when arguments regarding the pristine nature and uniqueness of ecosystems are considered insufficient (e.g. the valuation of mangroves to raise awareness of the role of these ecosystems in human well-being – Lal, 2003; or valuation of the costs of wild versus cultured live corals to inform public policy – Lal and Kinch, 2005).
c. Government planners to whom it is then suggested to incorporate "green" welfare accounting in their monitoring and planning activities, so as to change the compass, as is suggested by TEEB (2011), and just promoted, during Rio+20, in UNEP's "Inclusive Wealth Index" (UNU-IHDP and UNEP, 2012). An example of this application is the use of the World Bank natural capital accounting approach in New Caledonia – Brelaud et al., 2009).
d. Environmental government agencies that intend to assess and communicate the ecosystem services that their actions protect or improve. For instance, the results of the TEV in New Caledonia were used by the local environmental department to influence budget allocation.
e. Last, local stakeholders such as customary chiefs or MPA managers could use the results to highlight benefits for the local users and members of the community. For example, the Fiji and Vanuatu MMA valuation helped put forward benefits and equity distribution that, perhaps, were not perceived by the inhabitants. They were used also as a tool in the community for making trade-offs between the short and medium term.

Economic valuation has received attention in the case of large marine protected areas, for example during the creation process of an MPA in Kiribati or following the classification of the New Caledonian lagoon as a World Heritage Site (David et al., 2010; Pascal, 2010). This result was obtained thanks to the integration of a wide list of services, in order to obtain a better correspondence between the value of services and the health status of the ecosystem providing these services.

In sum, South Pacific CRESVs have been used in an "informative" way rather than in a "decisive" or "technical" perspective. The information they provide suggests that coral reefs ecosystem services will generally result from a site-specific careful management of uses, activities and of ecological conditions. Braat and Brink (2008) and Vigglizo and Franck (2006) have shown that the provision of ecosystem services are maximised where and when

a large variety of uses and activities are made possible in combination at the same site, which requires that the use of each service is kept to a moderate degree of intensity; otherwise the benefits obtained through one intensive exploitation of the ecosystem are potentially offset by the losses caused to the other uses. Analysing and comparing the South Pacific CRESVs tend to support this statement for these fragile and delicate contexts.

6. Conclusion and follow-ups

As we have shown, CRESVs have demonstrated both promising results and important limitations. This may explain why, up to now, CRESVs have mostly been used for "informative" purposes, and mostly been commissioned by public organisations. This configuration obviously creates a bias of some kind; CRESVs sites and subjects are chosen by organisations with a conservation agenda, where MPAs already exist and where information is available to investigate good practices and conditions for success. The reviewed figures presented in this paper do not provide economic consolidated accounts or any basis for an optimisation, at country or regional scale, of public policies. This is one more reason why CRESVs, even if they were to further develop in the future, should be considered as informative contributions to policy-making and political debates. A limited number of cases have been actually used to inform an ex-ante decision-making process and to support a specific choice. An example exception is the technical and economic study conducted in Kiribati to support the decision to substitute dredging for illegal aggregate mining (Greer Consulting Service, 2007). In general, ecosystem services are increasingly entering into general discussions on coral reef management and are likely to continue to expand their reach. From a conservation point of view, this is positive, in that it will help advocate a better management of coral reefs ecosystems.

These results suggest that the development of CRESVs in the South Pacific will depend on a combination of factors, each of them pointing to different research and policy programmes. Firstly, there is a need to improve the ecological knowledge base in relation to CRESVs, such as the need to address the "MSY" difficulty by better specifying the ecological-economic feedbacks in fisheries management. This orientation is congruent with recommendations from Fisher et al. (2008) to improve the use of ecosystem valuation. Secondly, it is requisite to develop the "advocacy" effectiveness of CRESVs in local communities and to better integrate the specificities of cultural relations to reefs, as was done in the work of O'Garra (2009). Thirdly, to increase the use of CRESVs by different kinds of stakeholders in different contexts, clarification and, above all, harmonisation of concepts used in coral reef assessments will be necessary. Lastly, it is necessary to enhance the mutual understanding of CRESV authors and decision-making actors, including a more thorough analysis of decision-making processes, with particular attention to their requirements in terms of economic data.

For researchers interested in improving ESVs, this paper hopes to make clear that progress should be based on improved collaboration with ecologists, geographers and anthropologists as well as management, policy and social scientists.

Role of the funding source

The review of the literature, drafting and coordination of the paper have been funded by the CRISP programme (Coral Reef InitiativeS of the Pacific, http://www.crisponline.net/). The CRISP programme is supported by the French Development Agency (AFD), the French Global Environmental Fund, the United Nations Foundation, The French Ministry of Foreign Affairs, Conservation International, the World Wildlife Fund, the Institut de Recherche pour le Développement and the IFRECOR.

Some materials, concluding remarks and orientations emerged out of a meeting, entitled "Investing in Coral Reefs: is it worth it?" held in Noumea, New Caledonia in November 2010 under the auspices of the CRISP programme.

Acknowledgements

This article is an outcome of the international meeting that took place in Noumea in November 2010 under the auspices of the CRISP programme (Coral Reef InitiativeS of the Pacific). This meeting entitled "Investing in Coral Reefs: is it worth it?" was organized by the Secretariat of the Pacific Community (SPC), in partnership with IUCN and the Secretariat of the Pacific Regional Environment Programme (SPREP), supported by a co-funding from the Agence Française de Développement (AFD) and the United Nations Foundation (UNF). More than 20 experts have attended the working sessions and their inputs are partly reflected in this paper: Luke Brander, Mahe Charles, Thierry Clement, Eric Clua, Nicholas Conner, Gilbert David, Thomas Binet, Emily Gaskin, Paula Holland, Yann Laurans, Padma Lal, Florence Mouton, Nicolas Pascal, Linwood Pendleton, Andrew Seidl, Sue Taei, Olivier Thebaud, Caroline Vieux, Ram Vina, Jean-Yves Weigel and Clive Wilkinson.

The paper has been vigilantly reviewed by Linwood Pendleton, Acting Chief Economist of the US National Oceanic and Atmospheric Administration, and by another anonymous reviewer. It has been improved in many occasions thanks to their precious advises.

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