

Reaping the reef: Provisioning services from coral reefs in Solomon Islands



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ABSTRACT

The marine biodiversity in the Coral Triangle sustains the livelihoods of roughly 100 million coastal people, yet this region is under threat from numerous local and global stressors. Regional actions underway to address coastal and marine degradation and an improve understanding of the social-ecological links between people and their environment. Economic assessments of coral reef provisioning services afforded to rural communities in Solomon Islands identified a diverse range of fisheries-based (fish, seaweed, clam, trochus, crayfish and shells) and coral-based (sand, rubble, stone, and corals for lime, aquarium and curio trades) products. Fisheries products (in particular reef fish) were important for both village subsistence and cash economies, providing the equivalent of US \$5173 (± 515) annually per respondent. In contrast, coral products contributed the equivalent of US \$2213 (± 396) annually per respondent, primarily to cash economies, particularly in study villages located in close proximity to national markets. Extractive coral activities have the potential to reduce reef resilience, diminish the viability of fisheries and so compromise the livelihoods of dependent communities. Improved management, legislative review and livelihood diversification strategies are likely to be required to manage coral reefs and the ecosystem services they provide across the Coral Triangle region.

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1. Introduction

Coral reefs are recognized as globally important ecosystems, for their fisheries, tourism and biodiversity values in particular, with an estimated annual contribution of \$30 billion to the global economy [1]. The benefits that coral reef ecosystems provide through their provisioning, regulating, cultural and supporting services are critical for human wellbeing [2,3]. The Coral Triangle region (which includes the waters of Indonesia, Malaysia, Papua New Guinea (PNG), the Philippines, Solomon Islands and Timor Leste) supports the highest coral and reef fish species diversity in the world [4,5]. This biodiversity contributes to the food security of an estimated 100 million people who depend on coastal ecosystems [4,6].

The Coral Triangle Initiative (CTI), an inter-governmental

agreement between the six Coral Triangle countries, was established in 2009 to address the degradation of marine and coastal environments in the region [7]. The CTI recognizes the value of coral reefs for the ecosystem services that they provide, along with associated habitats (e.g. seagrass and mangroves), to sustaining the livelihoods of millions of people living in the region [7]. Over 85% of coral reefs in the Coral Triangle region are at risk from global climate driven threats like coral bleaching and ocean acidification as well as local stressors including overharvesting, destructive fishing, land runoff and coastal development [4,6,8,9]. The extraction of corals for the aquarium and curio trades and mining for construction materials and lime are an important localized issue on many reefs in the region [1,10–14].

Spurgeon [15] described as some of the “root causes” of a cycle of coral reef degradation; development issues such as population growth, poverty, and food security; governance issues such as enforcement; and market failures and externalities. In the Pacific region, these issues have been summarized as the absence of formal markets, government failures and livelihood failures [16]. Economic valuation of coral reefs, contribute to the decision

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making process and guide their management [17]. Owing to its importance to decision making, Brander et al. [18] note a “flood of numbers” from valuation studies. Despite the high number of economic valuation studies of coral reefs, to date few have been undertaken in the Pacific region. In a recent assessment that examined economic valuations of ecosystem services from case studies in the Pacific (including Fiji, New Caledonia, Vanuatu, Hawaii and Northern Marianas) three main ecosystem services (fisheries, tourism and coastal protection) constitute 80% of the estimated values [19]. In the Pacific region in general, subsistence fisheries remain largely unmonitored and highly variable, may return larger economic values than commercial fisheries [19], and may require an upward adjustment in GDP estimates [20]. Cartier and Ruitenbeek [21] observed that most valuation studies involving coral reefs are concerned with their recreational and tourism use value despite fisheries being the most commonly valued harvested product of coral reefs.

In Solomon Islands, the majority (80%) of the population live in rural subsistence communities [22], where customary marine tenure accords the access and use of more than 90% of inshore coastal areas. Coral reef related fisheries are important for both subsistence and economic needs [20,23–25], with fish providing almost all animal-source protein to diets, particularly in rural areas [26]. Coral reefs and their associated fisheries are managed through the Solomon Islands Fisheries Act (1998, and revision 2015). Within the Fisheries Act regulation (1998), the harvest of coral (live and dead) is only prohibited in designated areas. There are no prohibitions on live coral harvested for the traditional making of lime to be chewed with betel nut. The collection of coral sands/gravel using excavation machinery is prohibited. A national coral management plan has been initiated; however at the time of writing there was no such plan or policy in place. The export of CITES listed corals is managed through the Wildlife Protection Act (1998) which is under review.

Understanding the socio-economic and cultural use of coral reefs is an essential step to design and support locally relevant management initiatives [27]. Yet, limited data on fisheries catches has made it difficult to determine the economic value and importance of reef fisheries to rural coastal people, and to accurately assess the effectiveness of fisheries management [20].

Nevertheless, a few studies in Solomon Islands have demonstrated that human population density and market access increase fishing pressure, which in turn, is a major driver of threats to fisheries stocks and diversity [28,29]. Socio-demographic and ecological attributes of communities reliant on coral reefs, might therefore be posited to relate to how reefs are used for provisioning services other than fishing.

This study was part of a Coral Triangle Initiative project on sustainable financing and payments for ecosystem services (PES) [30] and a response to the Solomon Islands Government's interest in rationalizing existing policy on export of corals [31]. Understanding ecosystem services values derived from coral reefs as natural capital stock [32,33] was identified as a necessary first step. This research was designed to fill an identified gap in understanding the economic value of provisioning ecosystem services that coral reefs provide to rural coastal people. The study focused on four case study communities selected because of contrasting socio-demographic and ecological attributes; two communities were distant and two proximate to the national market in the capital Honiara (the Honiara central market). A key question explored, was whether there was variation in the value and use of coral reef provisioning services among communities, and if that could be explained by socio-demographic (respondents age, gender, primary livelihood activity, population) and/or ecological attributes (reef area, reef area per person, distance to markets). The contribution of different fisheries- and coral-based products to subsistence and cash needs was quantified and potential issues with current harvesting practices identified in context to mechanisms for improved management decisions and policy development.

2. Material and methods

2.1. Assessing the economic value of coral reef provisioning services

In November 2011, 149 coral reef users were interviewed in four rural coastal communities in Solomon Islands to investigate the economic value of reefs provisioning services to rural communities. The two communities selected in Western Province

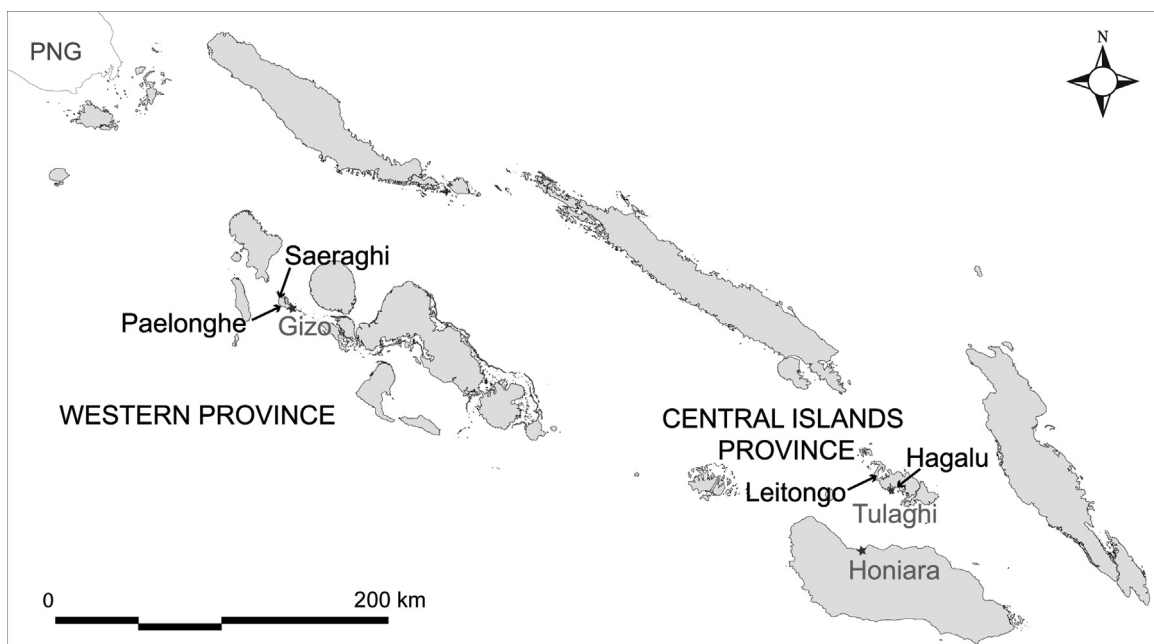


Fig. 1. Map showing the Western Province and Central Islands Province study sites in reference to the closest provincial (Gizo and Tulaghi) and national (Honiara) markets.

Table 1
Socio-demographic and ecological attributes derived from respondents and secondary data sources.

	TOTAL	Western Province		Central Islands Province	
		Saeraghi	Paelonghe	Leitongo	Hagalu
Number of people interviewed ^a	149	36	23	59	28
Mean age ^a	32	33	33	33	27
Sex (% males) ^a	62.4	66.6	65.2	64.4	57.1
Primary fisheries-based subsistence (%) ^a		42	11	23	23
Primary fisheries-based cash income (%) ^a		32	13	36	18
Population (> 14 years) ^b		744	274	393	237
Reef area (km ²) ^a		13.1	1.2	1.3	4.8
Reef availability (km ² population ⁻¹)		0.018	0.004	0.003	0.02
Distance to provincial market (km) ^a		14.8	7.8	19.5	3.1
Distance to national market (km) ^a		415	408	48	45

^a Derived from interviews or focus group discussions.

^b Derived from Solomon Island National Statistics Office.

(Saeraghi and Paelonghe) were distant to national markets (Hon-iara), while the two communities in the Central Islands Province (Leitongo and Hagalu) were close to national markets (Fig. 1). All four communities were coastal dwelling, rural and subsistence based.

The sampling strategy involved systematic random sampling of households, where men or women (aged 14–80 years) in every second household were interviewed on a day pre-arranged with the village leader (to ensure people were not engaged in usual daily activities). In total, 62% of the respondents were male and 38% female, all interviews were conducted in Solomon Islands pijin by trained Solomon Islands nationals.

Through structured interviews respondents were asked to free-list all of the provisioning services (products) from their reefs for use or sale by the household. For the purpose of this study, coral reefs were defined as the coral reef biome extending from the coast to the deep sea. As such, reef products extracted were not exclusively collected within coral habitats and included other habitats (shallow sand/rubble, seagrass meadows and nearshore open ocean), but excluded mangroves. The list provided by the respondents through free-listing was supplemented with a generic list of reef provisioning services, obtained from the Millennium Assessment [34] and Moberg [3] to derive usage and economic values.

For each of the provisioning services listed, respondents were asked to rank the relative importance of each of the coral reef products for their subsistence and/or cash needs by giving a ranking of zero (not important) to four (extremely important). The relative rankings provided by respondents were used in the analysis to estimate the value of goods harvested for cash and for subsistence use (the cash equivalent). This approach was used to ensure the economic value were not overestimated by separately asking the quantity of goods harvested for cash and subsistence use.

Respondents were questioned on the frequency of collection (daily, weekly, monthly or yearly), the number of harvest times within the collection period and the times they would did harvest these products (relating to seasons and events). Respondents were further questioned on the average quantity of product harvested each time they went collecting. For example, if a respondent collected reef fish, they were asked how often they went fishing, if the respondent stated weekly, they were further asked how many times they would go fishing each week, if this was regular throughout the year, if there were any times of the year they would not go fishing (e.g during rough weather, when sick) and how many fish they usually caught on an average fishing trip. Care was taken to use locally appropriate quantity measures (e.g. a

'market basket of seaweed' or 'a 20 kg rice bag of shells'). The measures indicated by respondents were observed at the time of interviews and the products were either weighed or counted. Market prices for reef products (based on local quantities) were determined for each community at the time of interviews through focus group discussions with village leaders. This approach was employed to ensure accurate market prices were assigned to the measure of quantity described by village respondents. Where possible, prices obtained during focus group discussions were compared with values observed in the provincial market place at respective locations. The differences observed between village and provincial market prices were negligible, so village obtained prices were used in following analyses.

The economic value for each product listed by respondents was determined by multiplying the quantity of product collected per year by the price, enabling an estimate of cash income and the cash value of fishery and coral reef products not sold in the market but retained by the household or shared with other community members. The economic values were converted to USD using the conversion rate of SBD \$7.28=US \$1 (exchange rate for November 2011).

2.2. Socio-demographic and ecological attributes

In Solomon Islands, gender roles and social norms are important factors that can influence the way that men and women participate in resource use and extraction [35,36]. Socio-demographic attributes (respondents age, gender, primary livelihood activity) were obtained from respondents during the interviews (Table 1). Population figures were obtained from the Solomon Islands National Statistics Office and are based on the 2011 population projection data from the 2009 census [22].

Customary tenure accords the rights to use and access marine and terrestrial resources in Solomon Islands, although the delineation of customary boundaries can sometimes be unclear [37]. The total reef area utilized by each of the study communities, as defined by their customary boundaries and user rights, was derived from focus group discussions with village leaders. Distances to provincial and national markets were calculated using the approximate route that boats take from village to market.

2.3. Data analysis

2.3.1. Testing the value of reef provisioning services for subsistence and cash

A correlation analysis, using general linear models was used to examine the relative value apportioned to cash or subsistence use

for fisheries-based and coral-based provisioning services. Lines of best fit are based on significant ($P < 0.05$) using general linear models. Fisheries-based products included: fish, clam (*Tridacna* spp.), seaweed (*Caulerpa* spp.), trochus and other shells (mostly *Lambis lambis* and *Strombus* spp.), and crayfish. Coral-based product extraction targeted the structure of the reefs themselves (live coral, dead coral and sand). Data were $\ln(x+1)$ transformed where necessary to meet the assumptions of homogeneity of variance for the GLM.

2.3.2. Assessing inter-village variation

Permutational multivariate analysis of variance (PERMANOVA) was used to examine variation in the value of reef provisioning services among villages. PERMANOVA is commonly used for the analysis of unbalanced multivariate data sets, such as this, because it lacks the formal assumptions of other non-parametric methods [38]. To quantify the potential impact of any response bias on the type of reef products harvested in each village, respondent details (i.e. age, gender and livelihood) were included in the analysis as covariates. Respondent details were significant terms in the model, but did not drive the variation among villages (Supplementary Table S.1). Data was $\log(x+1)$ transformed prior to analysis to improve multivariate heterogeneity. Canonical analysis of principal coordinates (CAP) was then used to graphically display significant factors following PERMANOVA and to identify reef products targeted at the different villages [39]. We then used BIO-ENV analysis to evaluate socio-demographic and ecological variables that may help explain variation in the reef products harvested by different villages [40]. Variables evaluated in this analysis were: reef area, population size, reef area per person, and distance to both provincial and national markets. All multivariate analyses were based on Euclidean distance similarity measures.

3. Results and discussion

3.1. Economic value of coral reef provisioning services

Coral reefs provided the four case study communities with a diverse array of provisioning services, yielding a mean cash

equivalent (\pm SE) of US \$ 7386 (\pm 796) yr^{-1} respondent $^{-1}$ for reef products harvested for both subsistence and cash needs (Table 2). Fish contributed the greatest amount to the total value of products derived from reefs (mean US \$ 1669 (\pm 195) yr^{-1} respondent $^{-1}$), with 91% of respondents involved in the harvest of fish. The high contribution of fish to the economic value of reef products for these rural communities is consistent with the importance of fish to the diet of Solomon Islands [4,26].

In addition to fish, other fisheries-based products (seaweed (mostly *Caulerpa* spp.), clam (*Tridacna* spp.), crayfish (*Panulirus* spp.), trochus (*Trochus niloticus*) and shells (mainly *Lambis lambis* and *Strombus* spp.)) were collected by more than 40% of respondents; while remaining fisheries-based products (turtle, shark, shark fin and shell money (traditional form of currency used in cultural practices and exchanges) were harvested by less than 13% of respondents. In total, fisheries-based products contributed an equivalent of US \$ 5173 (\pm 515) yr^{-1} respondent $^{-1}$, approximately 70% of the total mean value of reef provisioning services. The harvest of coral-based products (including sand, rubble, stone, coral for lime) was undertaken by 30–40% of reef users while the collections of corals for the aquarium and curio trade was undertaken by < 11% of respondents. Collectively, coral-based products contributed an equivalent of US \$2213 (\pm 396) yr^{-1} respondent $^{-1}$, 30% of the total mean value of coral reef provisioning services.

The calculated economic value (subsistence value and cash equivalent) for the majority of coral reef provisioning services was driven by the quantity of product harvested rather than market price. To evaluate the accuracy of the economic values, we compared the quantities of fish harvested reported in this study with literature values available. Market-based data collected for reef fish in Gizo and Tulaghi (the main provincial market venues for Saeraghi/Paelonghe and Leitongo/Hagalu respectively) reported fish catch and sale volumes from less than 1000 kg per year to > 10 metric tonnes per year per fisher at Gizo market and 100–10,000 kg at Tulaghi market [41]. The mean quantity of fish harvests in this study was 1426 (\pm 164) kg per year per fisher, which is within the lower-mid range of fish caught and sold by market vendors as reported by Brewer [41]. Similarly the market price for fish obtained through the current study (SBD \$8–9/kg) was within the range reported by Brewer [41]. Considering the data collected

Table 2

Annual economic value (USD) of reef provisioning services (mean (\pm SE)) showing the quantity harvested, product price range (across villages), percentage of respondents that harvested each product and the relative importance for subsistence and cash (% of total value).

		Economic value	Quantity (kg/pcs)	Price range	Harvest (%)	Relative importance		
						Subsistence (%)	Cash (%)	
FISHERIES	Fish	\$ 1668 (\pm 195)	1426 (\pm 164) kg	\$1.10–\$1.24	91	48	52	
	Seaweed	\$ 998 (\pm 174)	949 (\pm 150) kg	\$0.25–1.17	68	52	48	
	Clam	\$ 678 (\pm 114)	760 (\pm 112) pcs	\$0.69–\$1.37	66	59	41	
	Trochus	\$ 291 (\pm 50)	131 (\pm 22) kg	\$2.10–\$2.48	48	48	51	
	Crayfish	\$ 411 (\pm 81)	267 (\pm 65) pcs	\$0.96–\$2.75	40	54	45	
	Shell	\$ 371 (\pm 42)	453 (\pm 55) pcs	\$0.82	59	73	26	
	Turtle	\$ 140 (67)	3.8 (\pm 2) pcs	\$27.50–\$54.90	13	47	53	
	Shark	\$ 145 (\pm 63)	5.3 (\pm 2) pcs	\$27.47	6.2	46	54	
	Sharkfin	\$ 456 (\pm 204)	13.3 (\pm 6) pcs	\$34.34	11	0	100	
	Shellmoney	\$ 12 (\pm 9)	7.8 (\pm 6) pcs	^a NA–\$2.06	2.1	0	100	
	Fisheries total	\$ 5173 (\pm 515)						
	CORAL	Sand	\$ 448 (\pm 122)	4714 (\pm 1190) kg	\$0.04–\$0.21	36	48	52
		Rubble	\$ 393 (\pm 120)	2116 (\pm 620) kg	\$0.04–\$0.21	30	41	59
Stone		\$ 220 (\pm 70)	1287 (\pm 350) kg	\$0.14–\$0.21	35	44	54	
Lime		\$ 462 (\pm 109)	154 (\pm 40) kg	\$2.61–\$5.49	40	41	59	
Curio		\$ 444 (\pm 174)	215 (\pm 84) pcs	^a NA–\$2.06	10	0	100	
Aquarium		\$ 245 (\pm 97)	713 (\pm 284) pcs	^a NA–\$0.34	11	0	100	
Coral total		\$ 2213 (\pm 396)						
Total economic value		\$ 7386 (\pm 796)						

^a NA=not applicable denoting villages where no respondent harvested these particular reef provisioning services.

in this study includes both fish that are harvested for sale and for consumption by the household, it tends to suggest that respondents have not overestimated their catch. Similar comparisons cannot be undertaken for other products due to limitations in available data.

To contextualize the value of coral reef provisioning services to households, the contribution of reef-derived products to rural household income was calculated from the mean annual economic value data presented above (using the assumption that most rural households have (at least) one member who fishes [20] and national data on annual rural household expenditure (US \$3200 per year), as a proxy for cash income [42]. Comparatively, the value of coral reef provisioning services are on average 61% higher than rural household incomes when considering fisheries values alone and 130% higher when including coral-based products. Similarly, Warren-Rhodes et al. [43] reported a high contribution of mangrove-derived products (including firewood, propagules, building materials, fish and shell fish) to rural Solomon Island household incomes. Jointly, these two studies highlight the importance of coastal ecosystems for the provisioning services that they provide to rural subsistence-based communities.

3.2. Value of reef provisioning services for subsistence and cash

The cash equivalent value of reef provisioning services for all communities, based on all responses, was positively correlated to the total economic value calculated for both fisheries-based ($r^2=0.49$, $p < 0.001$) and coral-based ($r^2=0.52$, $p < 0.001$) products (Fig. 2). The value apportioned to subsistence use by the respondents, was also correlated positively with the value derived

from fisheries products ($r^2=0.80$, $p < 0.001$), but there was no significant correlation with the total value of coral-based products (Fig. 2).

These results show that in the four rural Solomon Island case study communities, fisheries products are important for both subsistence and cash needs, with > 90% of respondents harvesting fisheries products. Coral extraction primarily contributed to cash needs, with comparably fewer people (< 40% of respondents) harvesting these products. Although coral-based products have been used historically in Solomon Island rural households (e.g. sand, rubble and stone used for construction and lime for betel nut), there is evidence that the frequency and quantity of corals extracted for these purposes is increasing. Village respondents noted that local businesses have been increasingly requesting to purchase their coral sand, rubble and stone for the purpose of land reclamation and this was a topic of contention in some study villages (Albert pers obs). In addition, the export of corals from Solomon Islands for the curio and aquarium trades has steadily increased over the last decade, with trade peaking in 2006 [44]. Unlike many other Coral Triangle countries where there has been a shift away from the more ‘damaging’ trade of curio corals [14], in Solomon Islands there has been a relative increase over time in curio coral, both in total volume and as a proportion of total coral exports [44]. In addition, there has also been an increase in the chewing of betel nut [45], which has presumably led to a parallel increase in the harvest of corals for lime. Nevertheless, a relatively low proportion of respondents harvested coral products (< 40%) and is likely being driven by two factors: 1) most respondents recognized the negative impacts that harvesting corals can have on the coral reef ecosystem, although respondents also accepted

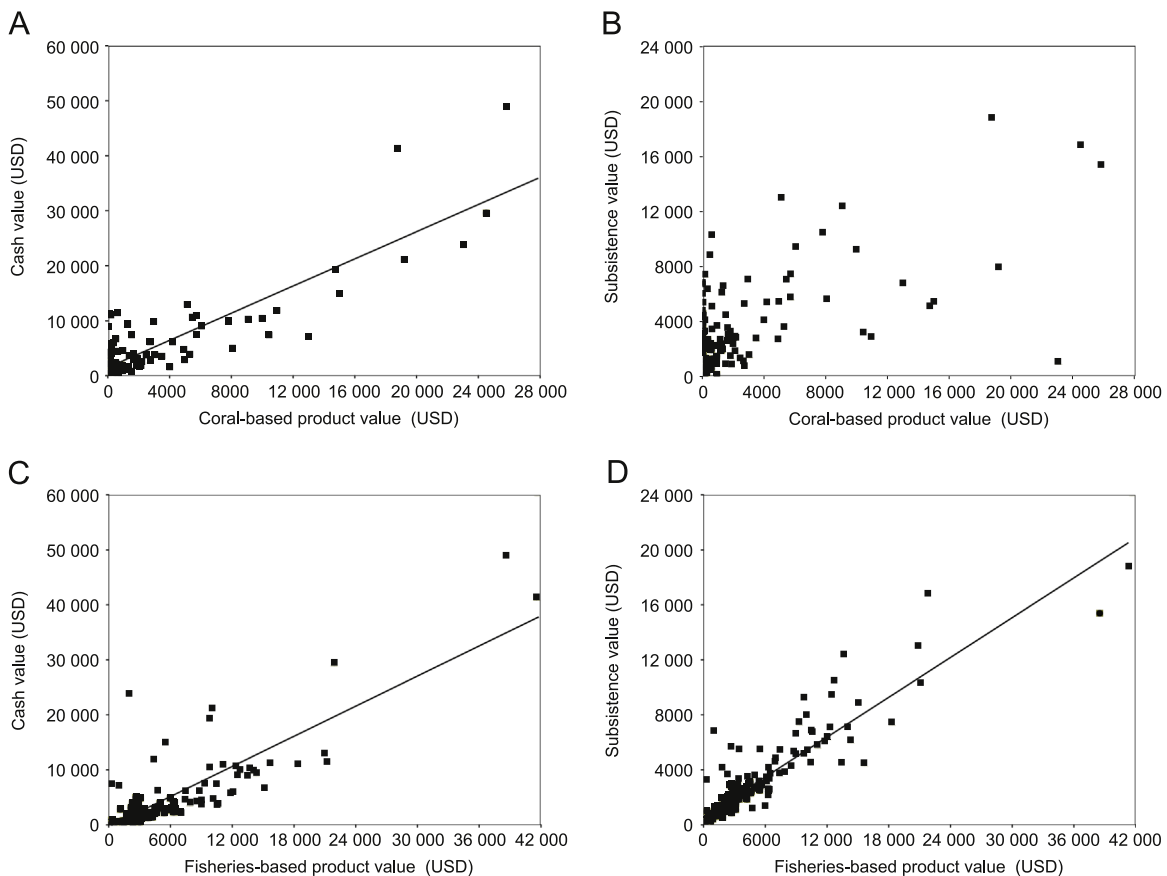


Fig. 2. Correlations between the economic value of coral-based products and all reef provisioning services for (A) cash and (B) subsistence, and between the economic value of fisheries-based products and all reef provisioning services for (C) cash and (D) subsistence for all respondents across all villages. Lines of best fit are based on significant ($P < 0.05$) general linear models.

that some people collect these products as they have few other income generating opportunities and 2) harvesting corals for betel nut lime, curio and aquarium trade requires specialist knowledge and equipment.

These findings may have implications for the distribution of wealth within communities and the broader benefits to rural communities. The integration of Solomon Islands into the global economy has resulted in rising prices for basic household needs, such as rice and fuel [46]. Given the limited access in rural communities to wage-based income, the need for cash has increased pressure on natural resources [47]. When considered in the context of the ecosystem services that coral reefs provide now and into the future, coral extraction has the potential to result in economic gain for a few community members, at the expense of reef and community resilience. It has been suggested that disturbances to reef substrate (like coral extraction) can reduce the ability of reefs to return from a degraded to healthy state e.g. [48] which has implications for reef fisheries [49]. The total biomass of reef fishes targeted in Solomon Islands is correlated with hard coral cover [29]. Therefore, if the levels of harvesting of coral-based products become unsustainable, the resilience of local reefs and the livelihoods of dependent communities may be undermined.

3.3. Inter-village variation in coral reef provisioning services

There were clear differences in the products that the four rural communities harvested from their coral reefs (Fig. 3, Supplementary Table S.1). Hagalu was typified by greater extraction of clams and coral (for stone, sand, rubble, aquarium and curio trades); Leitongo by the harvesting of trochus and coral (for lime and stone); Paelonghe by the collection of fish and crayfish; and Saeraghi by harvesting more fish, seaweed, shells and crayfish. The harvest of coral-based products was therefore greatest at Hagalu, lower in Leitongo and lowest in Paelonghe and Saeraghi (i.e. the level of coral extraction was inversely related to the x -axis on Fig. 3).

Variation in the type of reef products harvested was correlated with the proximity of villages to the national and provincial markets and the area of reef over which communities held tenure and user rights (BIO-ENV R value=0.246, $p=0.01$). Saeraghi had

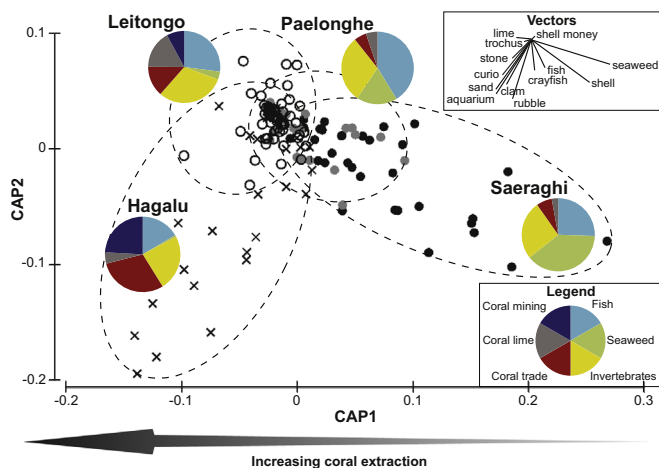


Fig. 3. (Color Online) Canonical analysis of principal coordinates (CAP) displaying variation in reef provisioning values among villages. Vectors illustrate the correlation of reef products with the canonical axis. Pie charts display the proportional value of fisheries-based (fish, seaweed and invertebrates (shells, crayfish, clam)) and coral-based (lime (for betel nut), coral trade (aquarium and curio) and coral mining (sand, stone, rubble)) products for each village (Hagalu=crosses, Leitongo=white dots; Paelonghe=gray dots, Saeraghi=black dots).

the greatest reef area and population and was relatively isolated from markets (Table 1). By contrast, Hagalu was closest to both national and provincial markets and had a larger area of reef per person than either Leitongo or Paelonghe (Table 1). These socio-demographic and ecological attributes were correlated with a higher reliance on coral extraction (i.e. mining for construction, betel nut lime and international coral trade) at villages closer to the national market (see pie charts on Fig. 3). Similar observations have been made for reef fisheries in Solomon Islands, where fishing pressure was driven by both market proximity and local population density [28].

Human population densities are relatively low across Solomon Islands ranging from 5 to 42 people km^{-2} across the country's nine provinces [22]. Yet they are growing rapidly, with an annual growth rate of 2.07% in 2014 [50], which is projected to threaten the sustainability of subsistence fisheries and food security over the coming decades [26]. The importance of market proximity in driving patterns of resource extraction infers that increased competition for reef resources (with improved market access, population growth, or diminishing reef productivity) might be expected to result in greater coral extraction. Excessive coral extraction would negatively impact on other reef organisms, decrease reef condition and thereby further reduce the productivity (and economic value) of dependent fisheries e.g. [11,51–53].

4. Management responses

Addressing the degradation of marine and coastal environments to maintain the ecosystem services that sustain the livelihoods of dependent people is a regional management priority for the Coral Triangle [7]. This study illustrates the economic importance of fisheries-based provisioning services that coral reefs provide, yet also illustrates the potential for these fisheries-based provisioning services to be undermined by the economic value of coral-based products and presents a case for improved management at local, national and regional levels.

The findings from this study highlight areas that could be addressed in the review of existing legislation and should contribute to the development of the national coral management plan for Solomon Islands and the revised Fisheries Act (2015) regulations. Improving the availability of alternative (and cheaper) construction materials close to urban centers may help reduce the demand for sand, rubble and coral stone for this purpose. Mariculture of corals for the aquarium, curio and betel nut lime trades have been proposed as a sustainable way to reduce harvesting pressure on coral reefs, by removing the harvest of wild coral stocks, while maintaining livelihood opportunities for rural communities [31,54,55]. The likelihood of success may, however, be low because of poor financial performance for small-scale local investments [56], restricted market opportunities and limitations in national government capacity for implementing management strategies and compliance monitoring [57]. To ensure the viability of mariculture technologies, investments in transport, marketing, training and economic incentives will be required [31,58].

Community-based management of marine resources is gaining momentum across the Pacific region [59,60]. In Solomon Islands community-based approaches build on customary marine tenure and use rights [61] and in this regard it is important to recognize the socio-economic and cultural connection between people and the environment [27]. To support governments and local communities in their endeavors, information on the economic value of the provisioning services their coral reefs provide to them, combined with information and awareness about the impacts of harvesting corals can better enable communities to assess the economic benefits and trade-offs and make informed decisions about

the management of their resources.

5. Conclusion

The results from this study highlight the high economic cash value afforded by coral reef provisioning services in rural villages close to national markets. To negate potential issues that come as Solomon Islands is further integrated into the global economy, there is a need for sustainable livelihood diversification strategies. Nearshore fish aggregating devices [62], seaweed farming [63], aquaculture [64], agroforestry [65] and sustainable forestry [66] have, among others, shown potential in rural Solomon Islands. Economic valuations can provide communities with assistance in choosing these activities [16], yet it is imperative that these opportunities are considered in wider development planning of communities and national governments to recognize benefits and tradeoffs, including those which disproportionately affect some members of society, such as the coral harvesters referred to in this study, and to be able to plan for these accordingly.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.marpol.2015.09.023>.

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