What matters to whom and why? Understanding the importance of coastal ecosystem services in developing coastal communities

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Abstract

Coastal ecosystems support the livelihoods and wellbeing of millions of people worldwide. However, the marine and terrestrial ecosystem services that coastal ecosystems provide are particularly vulnerable to global environmental change, as are the coastal communities who directly depend on them. To navigate these changes and ensure the wellbeing of coastal communities, policy-makers must know which coastal ecosystem services matter to whom, and why. Yet, capturing people's perceptions of the importance of ecosystem services in developing coastal settings is challenging for several reasons. Firstly, coastal ecosystem services encompass both terrestrial and marine services across multiple categories (i.e. provisioning, supporting and cultural), that are difficult to value together. Secondly, widely used monetary valuation techniques are often inappropriate, because of culturally specific attributions of value, and the intangible nature of key cultural ecosystem services. Thirdly, people within communities may hold different ecosystem services values. In this paper, we examine how people ascribe and explain the importance of a range of marine and terrestrial ecosystem services in three coastal communities in Papua New Guinea. We use a mixed-methods approach that combines a non-monetary, ranking and rating assessment of multiple ecosystem services, with a socio-economic survey (N=139) and qualitative explanations of why ecosystem services matter. We find that people uniformly ascribe the most importance to marine and terrestrial provisioning services that directly support their livelihoods and material wellbeing. However, within communities, gender, wealth, and years of formal schooling do shape some differences in how people rate ecosystem services. In addition, although cultural ecosystem services were often rated lower, people emphasized that part of the reason they ranked provisioning services highly was because of their contribution to, for instance, bequest. People also expressed concern about more extractive ecosystem services, like coral materials and fuelwood, which tended to be used and rated slightly more important by women. We contend that integrated ecosystem services assessments that include narratives can capture the broad importance of a range of ecosystem services, alongside relational values and normative judgements. This exploratory approach is a useful step towards understanding the complexities of ecosystem services in coastal settings.

Key words

gender, Papua New Guinea, non-monetary valuation, plural values, social differentiation

Words: 7,488

1. Introduction

Humans have changed the climate, lands and seas, forests and coasts, in ways that may destabilize earth's key systems (Steffen et al., 2018, 2015). Marine and coastal ecosystems are already highly exploited and rapidly depleting. Already, half of all the world's salt marches, and approximately one third of mangroves, coral reefs, and sea-grasses have been lost or degraded (Barbier, 2017). Yet, responsibility for and vulnerability to these global changes are not equal (Mattoo and Subramanian, 2012). Many of the burdens created by changed marine ecosystems will fall on the world's least developed countries (Blasiak et al., 2017) and communities who most directly depend on marine resources (Cinner et al., 2012).

Although ecosystem services approaches are uniquely poised to inform management by eliciting the diverse values people hold for vulnerable coastal ecosystems, further research is warranted. The bulk of empirical marine ecosystem services assessments are in Western, developed countries[1] - mostly in Northern Europe and Northern America (Liquete et al., 2013; Schaafsma and Turner, 2015) - rather than the low-income coastal and island countries most vulnerable to environmental change. Work in the Pacific, in particular, is nascent (Folkersen, 2018; Laurans et al., 2013; Liquete et al., 2013). To date, research in the Pacific has highlighted the importance of a range of ecosystem services for developing coastal communities, particularly for livelihoods. For instance, in Navakavu, Fiji, a locally managed marine protected area benefitted people through fisheries (commercial and subsistence), coastal protection, bequest value and education to an estimated total value of $1,795,000 (USD) per year (O'Garra, 2012). In four coastal villages in the Solomon Islands, fisheries products supported both subsistence and cash for over 90 percent of the population (Albert et al., 2015). Most marine ecosystem services assessments to date have focused on fisheries (often assessed at market value), recreation and tourism (Liquete et al., 2013). In the Pacific, specifically, studies of coral reef ecosystem services have focused predominantly on fisheries, tourism and coastal protection, but have struggled to include and value subsistence fisheries (Laurans et al., 2013). Although these studies emphasize that a range of ecosystem services matter monetarily to coastal developing communities, people value ecosystem services in multiple ways (Arias-Arévalo et al., 2018).

Although provisioning services are and will remain crucial in the Pacific (and globally, see Lillebø et al., 2017), there is need to capture the variety of ecosystem services that developing coastal communities value, including cultural ecosystem services across the land and sea-scape (i.e. marine and terrestrial, and cross-overs between these). Like ecosystem services more broadly, most studies of cultural marine ecosystem services have been in developed, Western countries and have examined tangible cultural ecosystem services such as leisure and recreation (Garcia Rodrigues et al., 2017). In developing countries, less tangible cultural ecosystem services, like bequest, may not only be more important (O'Garra, 2009; Oleson et al., 2015), but recreation and tourism benefits may be negligible or non-existent (Laurans et al., 2013; Pascal et al., 2012). In Fiji, people were willing to pay a significant proportion of household income to protect the bequest values of coral reef fisheries (measured through contingent valuation), whereas they were unwilling to accept loss of fishing grounds to future tourism ventures (O'Garra 2009).

[1] This geographical skew is also evident in ecosystem services research more broadly (Cruz-Garcia et al., 2017).

Capturing the importance of a range of marine and terrestrial ecosystem services across provisioning, cultural and supporting (hereafter referred to as an integrated assessment) requires a non-monetary methodology. Common economic methodologies fail to capture key cultural considerations (Laurans et al., 2013). For instance, many parts of the Pacific do not operate or value things solely as part of a cash economy, and 'the value that local communities attribute to money, and its function in life, differs widely from common economic assumptions' (Laurans et al., 2013, p. 140). Thus, there is a need to develop valuation that incorporates the needs of low-income countries and places that do not operate solely in a cash economy (van den Belt and Stevens, 2016). Non-monetary valuations can more inclusively reflect the cultural values and social norms of low-income countries (Folkersen, 2018), can better capture plural values (Arias-Arévalo et al., 2018) and are thus more appropriate in developing coastal communities. However, studies using such non-monetary ranking and rating techniques are rare (but see Hicks et al., 2015 for a regional study of developing coastal communities in the western Indian Ocean).

Alongside an integrated assessment of coastal ecosystem services, there is a well-established need to disaggregate ecosystem services valuations by demographic or other relevant social characteristics. Aggregated assessments may obscure the interests of different groups within a society or community. Within coastal communities people use, value, and access ecosystem services differently, often based on socio-economic identities like gender, class, and ethnicity (Daw et al., 2011), and the entitlements these characteristics support (Fisher et al., 2014). For example, a rural fisherwoman will use and value the coast differently to a visiting tourist, who differs again from a cash crop farmer, who occasionally buys reef fish to feed his family. For terrestrial ecosystem services, individual differences might even accrue within the same livelihoods (e.g. smallholder farmers) based on generational and education differences (Gomen-Baggethun et al. 2018). Different benefits likewise accrue at different scales. For instance, the economic value of tourism at a national level is often far greater than local level contributions to wellbeing (Hicks et al., 2009). However, disciplines that traditionally inform policy and management on coasts, tend to be blind to the heterogeneity of communities. Fisheries research treats communities (rather than groups within communities) as subjects of resource management and tends to offer technocratic solutions to resource degradation, without attention to power imbalances or competing values (Campling et al., 2012). Fisheries management itself often misses the role that gender and age relationships play in shaping small-scale fisheries (Bavington et al., 2004; Neis et al., 2013). These relationships, and relationships related to class and ethnicity, are likely to come under increasing pressure, in the context of global environmental and social change (Coulthard, 2011). For instance, in the Solomon Islands, increasing ties to the global economy have driven up the cost of basic household items like rice. This cost increase has in turn, pressures on coral reefs as one of the only livelihood opportunities. In this context, new markets for coral extraction (e.g. the aquarium and curio trade) have the potential to exacerbate inequities, by enabling a few community members to make economic gains at the expense of community and reef resilience (Albert et al., 2015). Capturing the different values people place on coastal services (and likewise capturing where values are shared e.g. Kenter et al., 2015), can help decision and policy-makers understand where costs and benefits brought about by changed ecosystems and/or changed management might fall. This knowledge is key for making informed and equitable decisions that do not harm people.

Ecosystem services approaches are making progress in identifying and incorporating the diverse and plural values people hold towards ecosystems. Recent ecosystem services programmes and organizations recognize and emphasize the 'multiple ways in which

ecosystems and ecosystem services are important for people and how these multiples ways of importance are related' (Arias-Arévalo et al., 2017, p. 43). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) explicitly recognizes people's plural knowledges, values, and worldviews as key to equitable management and assessment (Berbés-Blázquez et al., 2016; Díaz et al., 2018; Pascual et al., 2017). Eliciting plural values for ecosystem services is a necessary step towards the recognition of different worldviews and perspectives (Kenter et al., 2015). Ecosystem services are important and valued for one or a combination of instrumental (as a means to an end), intrinsic (as an end in itself) and relational (relations and responsibilities among people, and between people and nature) values (Arias-Arévalo et al., 2017; Chan et al., 2016). A recent study in Columbia emphasized that rather than a dichotomy between instrumental and intrinsic values, people often draw on multiple values, suggesting that integrating value pluralism will be important as environmental valuation progresses (Arias-Arévalo et al., 2017). Exploratory qualitative and narrative work is useful to capture why people ascribe importance to specific ecosystem services or relationships with ecosystems (Satterfield et al., 2013).

In this paper, we aim to provide an integrated, socially differentiated approach to understanding the importance of provisioning, supporting and cultural ecosystem services from both sea- and landscapes (i.e. marine and terrestrial) to coastal communities in Papua New Guinea. We also aim to capture the plural values underpinning people's perceptions of ecosystem service importance. Specifically, we ask which ecosystem services do people in coastal communities deem important and why, and is this importance socially differentiated? We use a mixed-methods approach, combining quantitative and qualitative methods in three communities in Papua New Guinea. These methods include key informant interviews, a ranking and ranking exercise combined with qualitative explanations, and informal interviews and observations in each community. The paper proceeds as follows, we first introduce our study sites, then outline our methodology, including our quantitative and qualitative approaches, and analysis. We then present our key results, beginning with aggregated ecosystem service importance, and then examining whether socially differentiation shapes how importance is ascribed, and how people explain ecosystem services matter to them. Finally, we tie these results into findings in the Pacific more broadly, and discuss implications for policy and practice in Papua New Guinea. We then discuss broadly how integrated assessments can assist policy-making in the region, and whether qualitative explanations may in fact be useful to elicit values that, in other methods, may be subsumed under cultural ecosystem services.

2. Background and study sites

We conducted fieldwork in three coastal communities in Papua New Guinea; Muluk, Wadau and Ahus (Fig. 1, Table 1). Muluk and Wadau are neighbouring villages on the eastern side of Karkar Island, Madang Province. Karkar is a highly fertile volcanic island with a population of around 70,000 people. People in Muluk and Wadau pursue a mix of livelihoods, predominantly cash-crop farming (copra, cocoa) and growing subsistence vegetables. Ahus, in contrast, is a low-lying atoll in Manus Province, with very little fertile ground, and a population of around 700 people. Ahus and the two Karkar villages are similar sizes but with different ecosystems, livelihoods, wealth, and persistence of customary systems for managing reefs. Ahus Island has been identified as highly vulnerable to climate change, particularly sea-level rise. Although the people of Ahus are predominantly fisher-

folk, there are many highly-educated Ahus islanders who have migrated to pursue careers in cities, and send remittances home.

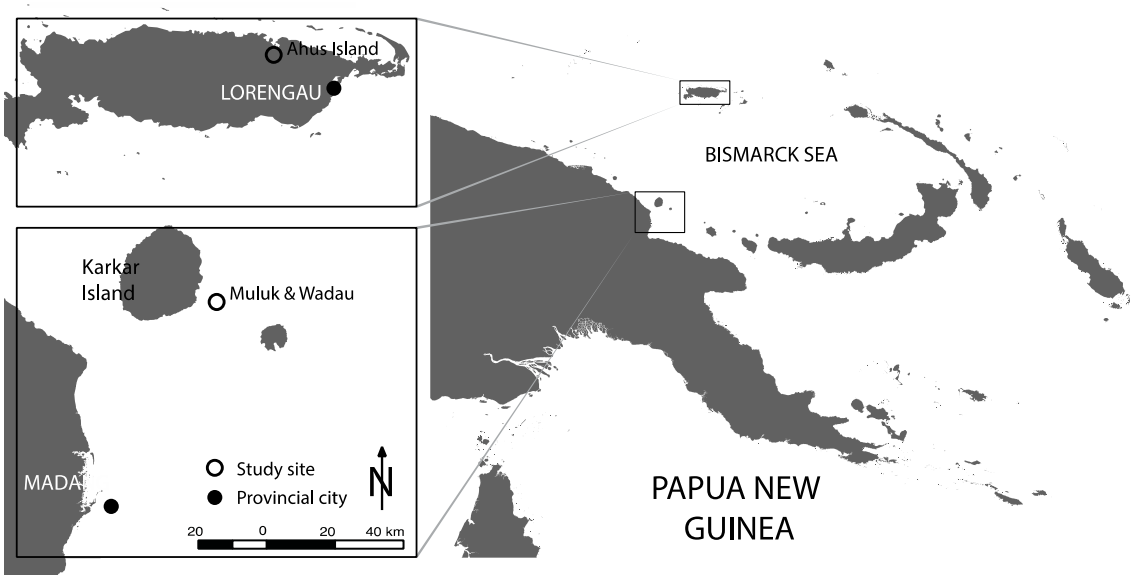

Figure 1. Location of study sites in Papua New Guinea.

Historically, all three sites managed their reefs through customary systems passed down through generations (Cinner, 2005). In Muluk and Wadau, clan leaders close the reefs to all gleaning and fishing when fish have become too 'flighty' and thus difficult to catch , and re-open it when there are more fish, and they are less easily scared (Cinner, 2007). Closures can sometimes last up to two or more years. Ahus had a similar customary system whereby clan leaders and individuals with sea tenure rights, closed certain small areas of the reef at their discretion. Individuals and clans owned rights to certain fishing practices (e.g. bait fishing with special nets), and times (e.g. night time), and others needed to seek permission. In Muluk and Wadau the practice of customary rotational closures remains strong; the reef in front of Muluk was closed during the first round of fieldwork. In contrast, Ahus' customary system has eroded over the past decade or more. Very few people obey taboos or ask permission to use specific gears or fishing space, although knowledge of the rules remains.

The sites are also ecologically distinct. A global study of over 1400 reefs identified that the reefs off Muluk and Wadau villages have above average fish biomass given key social and environmental conditions, including population density, and proximity to market (Cinner et al., 2016). In contrast, Ahus' reefs are depleted (MacNeil et al., 2015). We explore whether these ecological and socio-institutional differences affect the way people designate importance to ecosystem services.

a.	**Wadau**	**Muluk**	**Ahus**
Population	447	621	703
Households	72	96	143
Distance to nearest provincial market	68km	70km	24km
Dependence on marine resources	low	low	high

Customary marine management			
Type	Rotating reef closures	Rotating reef closures	Clan owned areas with gear restrictions
Strength	Strong	Strong	Weak

b. Sampling	**Wadau**	**Muluk**	**Ahus**	**Total**
Women	15	16	36	67
Men	14	19	39	72
Total	**29**	**35**	**75**	**139**

Table 1. Summary of a) socioeconomic, ecological conditions of study sties and b) sampling distribution at Muluk, Wadau, and Ahus.

3. Methods

3.1 Sampling

We surveyed a total of 139 community members (67 women and 72 men), from households in Ahus, Muluk, and Wadau (see Table 1). In each site, we systematically sampled every third household, starting in the South of Wadau and moving North into Muluk, and starting on the Eastern side of Ahus island. We surveyed the household head, asked individual level questions to both wife and husband (where applicable), and carried out the rating, ranking and explanation exercise with each individually, away from their partner to avoid bias. Within this sample, we asked three out of every four couples to provide qualitative explanations of the ranking exercise.

3.2 Socio-economic characteristics

We included eight socio-economic characteristics that might affect the sorts of ecosystem services that people deemed important. This selection was based on a review of literature in ecosystem services and political ecology (see Table 2), and on one authors' detailed knowledge of the sites from more than a decade of fieldwork there. We take an exploratory approach using pre-defined social differences, rather than a targeted approach that first identifies key differences through a situated case study at a given site (Daw et al., 2011). We examined age, gender, livelihoods (including main source of livelihood and livelihood multiplicity), migrant status, two measures of wealth (material style of life and fortnightly expenditure), and years of formal education (see Table 2). Age and years of formal education were measured in years. Gender and migrant status were binary. We measured both people's main livelihood source and livelihood multiplicity. Livelihood multiplicity was measured as the total number of different livelihoods within a household (see Table 2). The main source of livelihood was the livelihood respondents ranked most important out of fishing, gleaning, cash crops, farming, informal activities (e.g. a small store), tourism, salaried employment, and other (which we asked respondents to specify). We categorized these into one categorical variable with three categories including marine (fishing and gleaning), terrestrial (cash crops, farming) and other (informal activities, tourism, salaried employment and other). Alongside livelihood, we used two indicators of wealth, to better capture the multidimensional nature of poverty. The first indicator was a material style of life indicator (hereafter wealth), based on the presence or absence of household possessions and structures; e.g. thatched roofing, electricity, poultry (Pollnac and Crawford, 2000). We used a principal component analysis

(PCA) to calculate a single indicator from these variables, which explained 59% of variance (see table 1 in supplementary material for factor loadings). The second wealth indicator was an estimate of all household expenditure in the previous fortnight, in Papua New Guinean Kina.

Socio-economic characteristic Measurement	Mechanism and examples
Age Years	People in different life stages and cohorts hold different priorities, levels of family responsibility, and legitimacy around resource governance (Colfer, 2011). These age-related differences influence people's entitlements to ecosystem services (Daw et al., 2011; Fisher et al., 2014) and thus their perceived importance. **E.g.** Age has been shown to correlate with acceptance of certain conservation tactics (e.g. increased taxes) (Blasiak et al., 2015).
Gender woman or man (binary)	Gendered identities, norms, responsibilities, and opportunities shape how women and men use, perceive, prioritize and value different ecosystem services. **E.g.** In Zanzibar, women and men use different ecosystem services across the seascape, and these ecosystem services contribute differently to subsistence and income (de la Torre-Castro et al., 2017). In the USA, women and men hold different readiness to act on conservation issues (Blasiak et al., 2015).
Livelihoods Main source of livelihood: Marine, Terrestrial and Other (categorical) Livelihood multiplicity: number of different livelihoods pursued per household	Social actors pursuing different livelihoods, and with differing levels of livelihood diversity, have different interests in and emphasis placed on the importance of ecosystem services (Caceres et al., 2015). **E.g.** In four sites in rural Asia, a participatory valuation of aquatic resources found that fishers and farmers valued freshwater ecosystem services very differently to government officials and business owners. (Brooks et al., 2014)
Migrant status* Migrant or non-migrant (binary)	The context and timing of migration and how migrants assimilate into their host community, is important in explaining associations between migration and environmental impacts (Cassels et al., 2005). **E.g.** In Papua New Guinea, strong user rights mean that outsiders usually excluded from fishing coral reefs (Cinner, 2009).
Wealth Material style of life measure based on material possessions (see Table X in supplementary material) Fortnightly expenditure (in PNG Kina)	Often, but not always, people living in poverty are more directly dependent on ecosystem services (Fisher et al., 2014). Even within livelihood groups, wealth influences how people will respond to environmental change (Cinner et al., 2011). **E.g.** In Kenya, fishers with higher expenditures and high amenities scores (i.e. those who with greater economic wealth) expressed that they would fish harder and change gear in response to declines in the fishery (Cinner et al., 2011).
Years of formal education Years of school completed	Formal schooling plays an important role in education for sustainable development (Hopkins and McKeown, 2002), and thus may influence the sorts of ecosystem services people deem important. **E.g.** In South east Asia people with a higher level of education valued parks for their regulating services (Sodhi et al., 2010).

Table 2. Socioeconomic characteristics (bold), how they were measurement, and a summary of how people with these different characteristics may ascribe to ecosystem services differently, with examples. *In our sites, migrants are usually women who have married into the villages from outside, and thus marry into clan rights to reef resources.

3.3 Ecosystem services

We define ecosystem services as the benefits people gain from nature (Costanza et al., 2017), encompassing both direct and indirect services, and services where ecosystems support benefits (e.g. sanitation). We selected ecosystem services through a combination of a literature review (Hicks et al., 2015; drawing particularly on Hicks and Cinner, 2014), key informant interviews, and detailed observations in each community. We then used key informant interviews to pilot photographs and descriptions of each service (tailored to each community). Photographs were either selected from previous trips to each village (taken by JEC), or taken during the pilot (by JDL). The subject of each photo was selected if it was locally relevant and recognizable, and simple enough to depict a specific ecosystem service, without needing extensive explanation. In all villages, our first key informants were clan leaders, who then identified one or two others informants from their clan to interview. We specifically asked leaders to identify people with different socio-economic characteristics to ensure a more balanced representation of gender, age and wealth in these initial interviews. Initial key informant interviews were conducted in English by the first author and translated into Papua New Guinean Tok Pisin and back by research assistants. Subsequent interviews were conducted in Tok Pisin by the first author, assisted by language assistants who clarified meaning and translated to English if needed.

We piloted the ranking and rating exercises that have been used in the western Indian Ocean (Hicks and Cinner, 2014) but not in Papua New Guinea (see Section 3.4). Although we initially focused on reef-related ecosystem services, interviews and observations quickly highlighted the importance of terrestrial ecosystem services to both coastal communities. We therefore included terrestrial services in our final list. Unfortunately, we did not include forest habitat, forest edible foods, or forest bush meat in the list. While this was partly due to our initial focus on reefs, more importantly we wanted to keep the list of ecosystem services succinct so that the ranking and rating exercise did not become overly complicated. The eleven ecosystem services identified were crops (including both cash and subsistence garden crops), forest materials, reef materials, fishery (including fish, molluscs etc.), education/ knowledge, bequest, tradition, recreation, habitat, coastal protection, and sanitation (Fig. 2). We chose to keep fishery and reef materials separate because in Papua New Guinea, burning coral to produce lime is a common practice. We also observed coral rubble being used to build semi-permanent houses in Ahus.

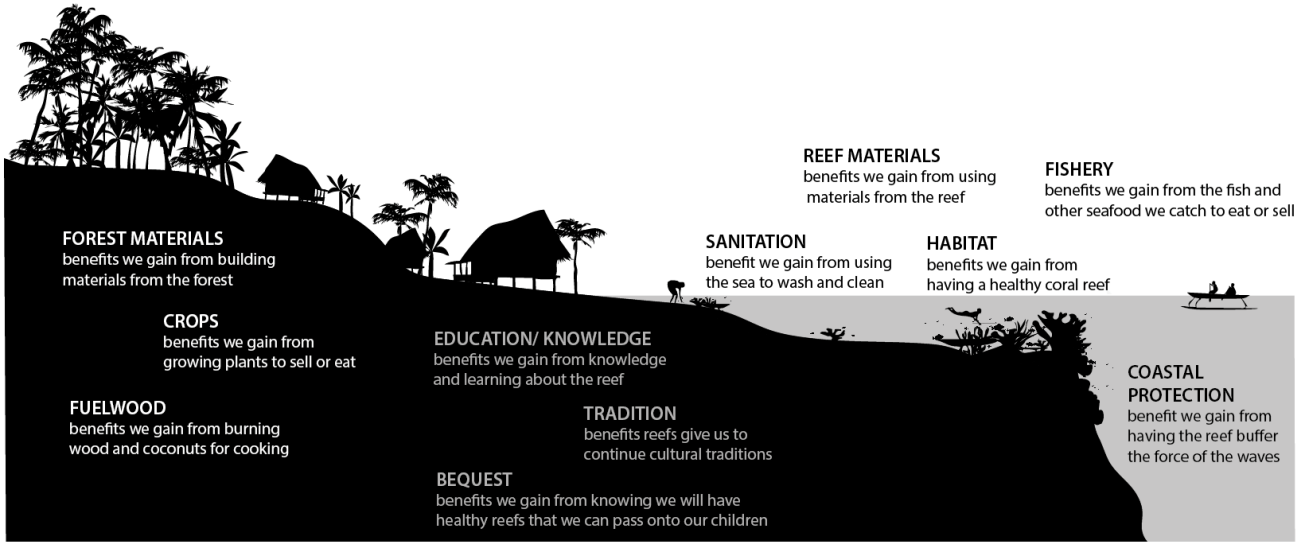

Figure 2. Coastal ecosystem services and descriptions identified in key informant interviews and used in ranking and rating exercise. Ecosystem services are arranged left to right from terrestrial (white text), to cultural (grey text) and marine (black text).

3.4 Rating and ranking exercise

We used the ecosystem services photographs with descriptions to elicit the importance people place on marine and terrestrial ecosystem services. We first introduced each ecosystem service by showing respondents the photograph, and briefly describing what the photograph represented. We then asked respondents to rank the ecosystem services in order of importance to their lives. To capture multiple reasons people may value ecosystem services, we left the specific definition of importance open to interpretation (Díaz et al., 2015). For instance, fish could be important for food and income, social relations through sharing, and/or to a persons' identity as a fisher. When the photographs were lined up in order of importance, we asked people to explain their ranking. These explanations also helped to ensure respondents had understood the point of the ranking and rating exercise. When respondents' explanations suggested they had deviated from ranking in order of importance, we then re-explained the aim of the exercise, and used their subsequent scores in our analysis. Explanations were written down in Tok Pisin and English and checked for accuracy by research assistants.

We then spread the photographs out randomly and asked respondents to place counters on the photographs to indicate which were most important to their lives. Unlike the ranking exercise, respondents could place multiple counters on the same photograph, could spread them equally between more than one, or could place several on one ecosystem service and one or two on another. We handed respondents five counters at a time, waiting for them to place all five before handing them another five. This approach gave respondents more time to consider their placement. In total respondents received 20 counters, over four rounds. Each round was then weighted; round one given the most weight and round four the least (see Hicks et al., 2015). We normalized these weighted scores to create continuous data.

3.5 Analysis

To test for differences between how people with socio-economic characteristics ascribed importance to ecosystem services we ran general linear mixed-models, with the weighted rate score for each ecosystem service as the outcome variable and socio-economic characteristics as the predictor variables. Significant variables indicated a difference in how people rate services. For each model, a priori we specified community and household as random effects to account for the nested structure of the data (i.e. individuals nested in households, nested in community). None of the socio-economic characteristics used in the models suffered co-linearity, with variance inflation factors all below 5 (see Appendix 1, Table 2 in supplementary material).

We performed a principle component analysis (PCA) to visualize the relationships between socio-economic characteristics and the importance of key ecosystem services across communities. We included only the ecosystem services and socio-economic characteristics and with significant relationships in our models.

As well as including gender as a binary variable in our models, we also explored intra-household gender differences by calculating the difference between ranks and rating for pairs of respondents. Specifically, we subtracted the woman's rank score from the man's rank score to calculated the difference in ranking, and the women's rate score from the man's rate score to calculate the difference in rating (i.e. a difference score). This approach allowed us to control for differences in livelihoods and wealth because men and women from the same household had the same suite of livelihoods performed within the household, and the same household wealth. We performed one-sample t-tests on the differences in ranking and rating to determine whether there were significant differences between women and men (see Appendix 3).

We coded the qualitative explanations of the importance of ecosystem services thematically around key contributions to wellbeing (material, subjective, and relational) and (where possible) value domains (instrumental, intrinsic and relational) in NVivo (see Appendix 2 for detailed explanation of coding). We also looked to any patterns of explanation that emerged from the data that seemed to fall outside these themes. We compared these explanations across different social groups (i.e. by age, clan, gender). In the following section, we triangulate between the results from our rating and ranking exercise and respondents' qualitative explanations.

4. Results

Across all sites, people ascribed most importance to the provisioning marine and terrestrial ecosystem services that directly contributed to their livelihoods (Fig. 3). Most people ascribed importance to ecosystem services that directly contributed to material wellbeing, and especially to basic needs, through food, income, and shelter (i.e. forest materials). For instance, in Karkar, one woman emphasized that "*Crops*[2] are important, we benefit from them and can look after our kids. That's the only way we get money to buy things". In Ahus, there was emphasis on fish as the only form of food and livelihood; "*Fishing* and work to do with the sea is our only living" (Woman, Ahus). People with different livelihoods ascribed importance to the provisioning services that supported those livelihoods (Fig. 4, Table 2), although the main source of livelihood was only associated with ascribing importance to

[2] Italicized words emphasize when a respondent was referring to a specific ecosystem service (i.e. photo).

crops. Fig. 4). This result reflects the different livelihood portfolios of people in Karkar and Ahus (Table 1, Fig. 4).

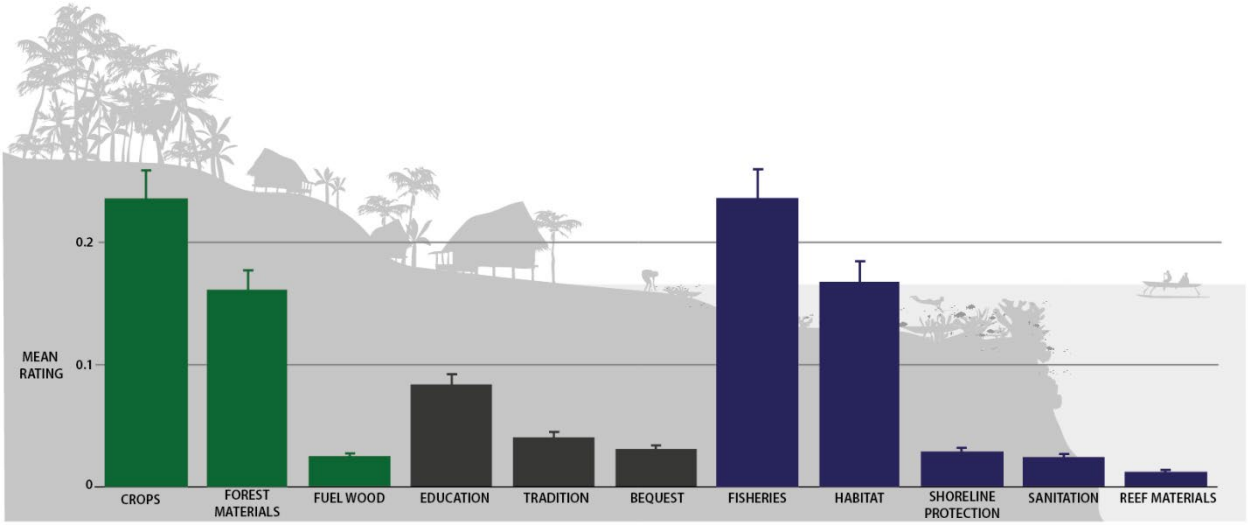

Figure. 3 Mean weighted rating value for the ecosystem services across all sites. Colours represent terrestrial (green), cultural (grey), and marine (blue) ecosystem services. The five ecosystem services rated most important encompassed provisioning, supporting, and cultural categories. Note that there are provisioning and supporting services within marine services.

People also ascribed importance to indirect ecosystem services that they perceived supported direct-benefits (e.g. habitat and fisheries). Often, those who perceived that in-direct services contributed to direct services had more years of schooling and were wealthier (Table 2). For instance, those who had completed more years of formal schooling ascribed higher importance to education and knowledge ecosystem services and habitat, and less to fisheries (Table 2). However, many explained that they had ranked and rated these services in this way because they directly contributed to other services. For instance, one man in Ahus explained that "*Education/ knowledge* leads to good *habitat* and good *fish*, which are good for catching and going to market, and helping family (*bequest*)". These perceptions were also socially differentiated by gender. Men tended to rate education and knowledge ecosystem services higher than women (Fig 3, Table 4, Appendix 3).

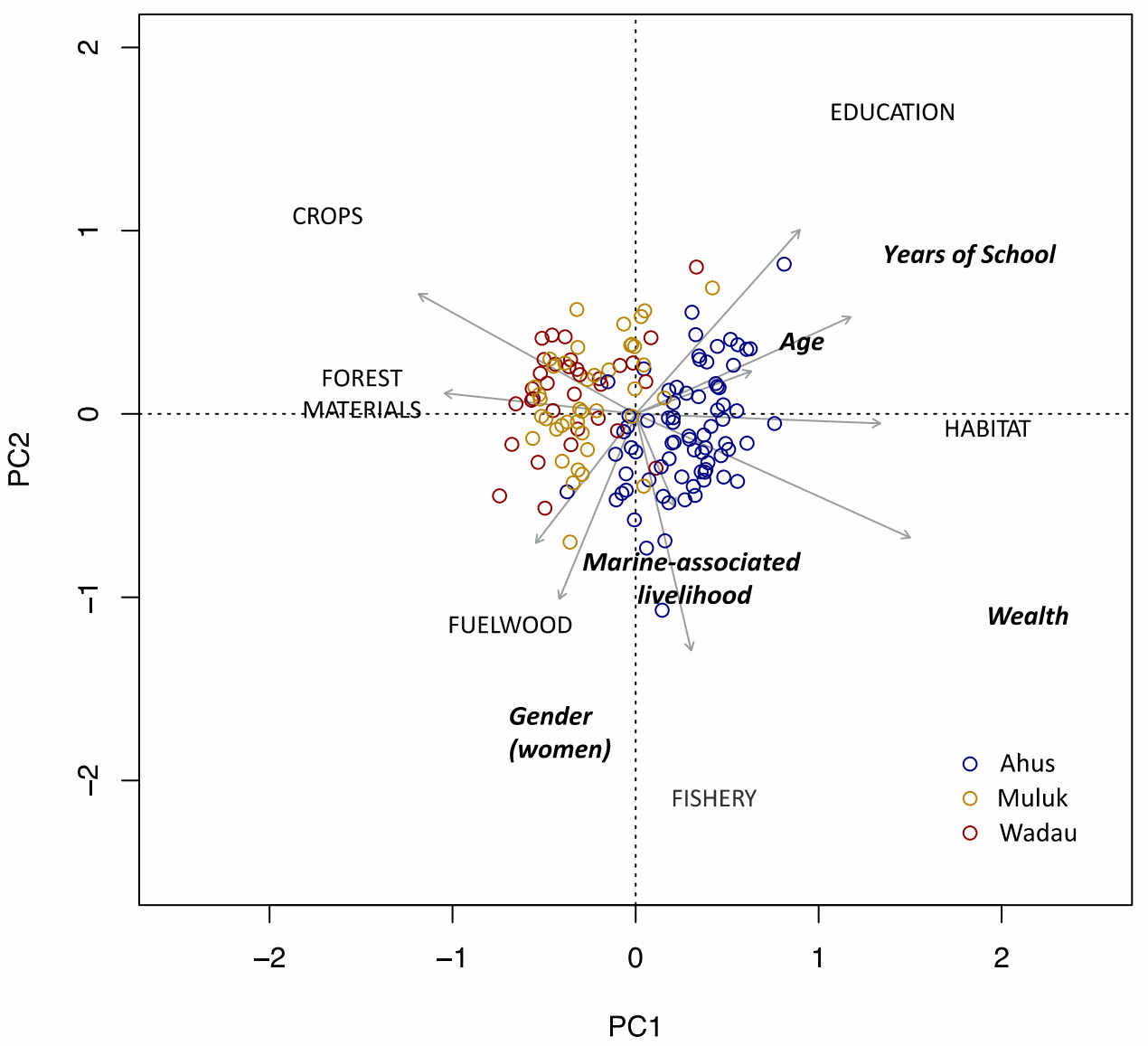

Figure 4. Principle component analysis (PCA) showing the relationship between socio-economic characteristics (bold, italicized) significant in our models and the importance ascribed to ecosystem services (capitalized) across all sites. PC1 and PC2 explain 44.74 percent of variance.

Ecosystem service	Significant variables		
	Variable	**Value**	**P value**
Terrestrial			
Crops	Main source of livelihood	0.072	0.0269*
Forest Materials	Wealth (MSL)	-0.052	0.0001***
Fuelwood	Age	-0.001	0.0369*
	Gender (women)	0.026	0.0463*
Cultural			
Education and knowledge	Gender (women)	-0.064	0.0141*
	Years of formal schooling	0.015	0.0046**
Tradition	None		
Bequest	None		
Marine			
Fishery	Years of formal schooling	-0.018	0.0193*
	Wealth (MSL)	0.041	0.0118*
Habitat	Wealth (MSL)	0.0599	0.0000***
Shoreline protection	None		
Sanitation	None		
Reef materials	None		

Table 3. Significant differences how people with different socio-economic characteristics rated ecosystem services in General Linear Models. See Table 3 in supplementary material for full models.

In addition, although cultural ecosystem services were usually ascribed low importance (Fig. 4), many people expressed that it was only through provisioning services that cultural services could be realised. For example, in Ahus, one woman emphasized that "when *habitat* is good then there are plenty of *fish*, which we can use for celebrations (*tradition*)". In this explanation, the habitat service ultimately supports fisheries benefits, which in turn supports the cultural service of tradition. People explained that cultural ecosystem services contributed to subjective wellbeing, through a sense of identity and relationships of care towards specific ecosystem services. They were also considered important to maintaining relationships with others in the community. For example, "It's custom (*tradition*) to give *fish* away and share, this custom is necessary to be happy" (Man, Karkar). Thus, when rating and ranking, people considered the relationships between ecosystem services, rather than viewing them as separate, stand-alone benefits.

People also expressed judgements about what was correct and responsible use of ecosystem services. For example, often people who explained part of their identity as being linked to the sea, also expressed the need for stewardship. For instance, in Ahus one woman said, "We are people of the sea, so we must have a good, clean reef [*habitat*], and we must look after it well. The sea is first… It's the place for growing life. All other things depend on conserving the sea. If we look out for the environment, it will look out for us. If not, the environment

won't look out for us". Some articulated a sense of stewardship and care that was necessary in order to enjoy other benefits. For instance, one women in Ahus emphasized that "[We] can have *traditions* if we respect the fish." The emphasis on traditions being possible only when people are respectful, suggests that some people perceive ecosystem quality (or quantity) as a result of good stewardship or correct behaviour or, in other words, hold normative judgements about the correct behaviour towards ecosystem services.

All people (including women and men) expressed aversion to ecosystem services that might damage the environment. However, these 'bad' ecosystem services, tended to be used and valued more by women. Fuelwood, shoreline protection, sanitation, and reef materials were consistently rated low (Fig. 3). People (in both Ahus and Karkar) perceived that using and benefitting from these more 'destructive' services, especially coral reef materials and sanitation will ruin the environment. One man in Ahus explained that, "*coral materials* come last [in ranking] because it will ruin everything else". In Karkar, one woman said 'I don't think *sanitation* is good; it's bad for the reef. I'm not happy with cutting *fuelwood*, or using *coral materials,* we'll ruin the environment". Others, who ascribed importance to firewood or reef materials, still offered caveats about how these services should be used. Specifically, many emphasized that people should only use dead fuelwood or dead coral materials. For instance in Ahus, a woman emphasized that with "*Fuelwood*, you should only cook with dead firewood, not live". One man in Ahus emphasized that with "*reef materials*… you can collect dead ones, the live ones should be left. Lime: that's live so that's bad. Only the dead stones should be used".

Although consistently lowly rated, compared to men, women often ascribed slightly more importance to these 'destructive' services. Specifically, we found that women ascribed more importance to fuelwood (Fig. 4, Table 3). These gender differences held (for both ranking and rating) when we tested at an intra-household level (see Appendix 3). In addition to fuelwood, when we tested for intra-household differences in ecosystem services rankings and ratings using a one sample t-test, we also found that, compared to men, women tended to rank forest materials ($p = 0.0006$), sanitation ($p = 0.03$), and reef materials ($p < 0.001$) higher (see Appendix 3).

5. Discussion

In the context of global environmental change, identifying and safeguarding the coastal ecosystem services most important to developing coastal communities in the Pacific, will be a crucial task for policy-makers, conservationists and development professionals alike. In developing coastal communities in Papua New Guinea, people ascribe most importance to the provisioning services that support their livelihoods. However, people also emphasize instrumental and relational values in narratives of why ecosystem services matter to them (Arias-Arévalo et al., 2017), and identify that ecosystem services contribute to all aspects of wellbeing (Coulthard et al., 2011). We discuss these key findings in turn, before exploring their wider implications for conservation and development in coastal communities in Papua New Guinea and the Pacific more broadly.

The direct, provisioning services that support coastal livelihoods, are crucially important to developing coastal communities. Similar to existing studies of ecosystem services in the Pacific (Albert et al., 2015; O'Garra, 2012), we found that people attributed most importance to provisioning services that directly contributed to their livelihoods: whether terrestrial or

marine. In the Solomon Islands, and in other regions, provisioning services provide crucial basic needs developing coastal communities (Albert et al., 2015; Chaigneau et al., 2018). Likewise, in China, people whose livelihoods depend directly on wetland ecosystem services, value ecosystem services very differently to those who were in decision-making roles, who did not derive their livelihoods directly from wetlands (e.g. government officials and business leaders) (Brooks et al., 2014). Work on terrestrial ecosystem services in developed countries, has likewise found that people's livelihoods are key to how they perceive ecosystem services (Caceres et al., 2015). Interestingly, livelihood multiplicity (i.e. how many livelihoods people pursued) did not differentiate the importance ascribed to ecosystem services.

Many have argued against combining intangible cultural ecosystem services with other categories in integrated ecosystem service assessment, because they are incommensurable with more tangible services (Chan et al., 2012) and can be nebulous (Fish and Church, 2014). Although we pursued an integrated assessment of different types of ecosystem services, we also found that in our sites, cultural ecosystem services tended to be lowly ranked. However, our qualitative results emphasized key aspects of cultural ecosystem services and relational values that were not apparent in the rating and ranking exercise. For instance, in our sites people did not tend to ascribe high value to bequest in the rating exercise. This result contrasts with studies of bequest values in the Asia-Pacific (O'Garra, 2009) and the western Indian Ocean (Oleson et al., 2015), which found bequest to be highly valued. However, rather than not valuing bequest, our respondents tended to see provisioning services as important means to ensuring bequest values, rather than ascribing importance to bequest as a value in itself. They expressed a sense of stewardship and care in their qualitative responses that reflects concerns for bequest values. Hence, we are more tentative about integrated assessments that include cultural ecosystems services. The somewhat blurry line between cultural ecosystem services and relational values seem better elicited in narrative form (see below).

Although people in both sites ascribed most importance to provisioning services, they nonetheless alluded to all aspects of wellbeing (material, subjective and relational) when they explained why ecosystem services mattered to them. These qualitative explanations also elicited a number of relational values and suggest that people drew on local environmental knowledge in their ranking. For instance, people often articulated links between ecosystem services like reef habitat and fisheries, and ranked them accordingly. Thus, local environmental knowledge likely played a role in the importance ascribed to ecosystem services because people drew on this knowledge to posit causal pathways between benefits from different services. As in developed countries, in developing communities, plural values (especially relational) are embedded in people's narratives about why ecosystem services matter to them (Arias-Arévalo et al., 2017). This narrative form of eliciting values better captures the sorts of intangible cultural values, like bequest and tradition, that are underpinned by relational values of respect and reciprocity.

Our findings emphasize that a sole focus on the ecosystem services considered important, without attention to why, might hide forms of environmental concern or stewardship that may be an important part of cultural identity. Our results support the argument that people judge the utility of an ecosystem service in relation to their identities, place, and pro-social beliefs, alongside economic and instrumental benefits (Kumar and Kumar, 2008; Singh, 2015). In our sites, there were culturally specific ways of perceiving ecosystem services. Specifically, customary marine tenure means that people have a sense of ownership, and thus stewardship over resources, that seems disconnected to how important ecosystem services were in relation

549 to livelihoods. For instance, in Muluk, reliance on reefs for livelihoods is low, but support for
550 and adherence to customary systems of management is strong (Table 1). In Ahus, even
551 though customary management systems had eroded, there was still the strong sense of being
552 'people of the sea' with an accompanying responsibility, to look after the environment.
553 Recent work contends that the expression of relational values is in fact a useful way to
554 identify cultural ecosystem services. Fish et al. argue for defining cultural ecosystem services
555 'as relational processes and entities that people actively create and express through
556 interactions with ecosystems' (2014, p. 211). In all our sites, people expressed concern about
557 the 'correct' or 'appropriate' way of co-producing ecosystem services, particularly services
558 like fuelwood and coral reef materials that were considered extractive and damaging. Many
559 people articulated that only dead coral or dead firewood should be used. People's relationship
560 of concern (including care and responsibility) towards ecosystem services is a ripe arena for
561 empirical work on ecosystem services (Singh, 2015), including whether accompanying
562 normative judgements are gendered (or otherwise socially differentiated), as we found.
563
564 Gender is a key blind spot in ecosystem services studies (Brown and Fortnam, 2018). We
565 found several differences in how women and men ascribed value to ecosystem services, and
566 more when we looked specifically at intra-household differences. Unsurprisingly, the
567 ecosystem services that women ascribed slightly higher value to, were both those that
568 traditionally fall to women. In Ahus, rights to burning coral to create lime (which is chewed
569 with betel nut) are matrilineal, and in Muluk when the reef is open, women also make lime to
570 gain a little extra income (although this practice was banned in 2017 when the reef closure
571 was lifted). In both places, fuelwood was almost the only source of fuel for cooking
572 (women's responsibility), although one or two houses in Ahus had access to gas.
573 Responsibility for sanitation practices, including washing pots, pans and clothes, also falls
574 mainly to women.
575
576 Our results aligned with gendered preferences for fuelwood as an ecosystem service in Kenya
577 and Mozambique, where women also placed more importance on fuelwood (Chaigneau et al.,
578 2018). This results emphasizes that people's perceptions may not accurately capture
579 contribution of certain ecosystem services to a household. Men also eat the food prepared
580 using fuelwood, yet did not rank it highly. Intriguingly, this findings suggest that not only is
581 women's contribution often overlooked in fisheries research and management (Kleiber et al.,
582 2014), but perhaps also at a household level by both men and women. Thus, not only at an
583 institutional, industrial or research level does women's work go unnoticed or undervalued.
584 Overlooking these contributions might have implications for both accurately assessing
585 ecosystem service pressure (Kleiber et al., 2014), and properly valuing women's contribution
586 to the wellbeing of their household. Indeed, the differences we found do not (and cannot)
587 reflect the gendered division of labour or other differences across an ecosystem service
588 cascade (as highlighted by Brown and Fortname, 2018). Feminist political ecology theory on
589 how everyday practices around resources reinforce gender identities, may be a useful avenue
590 for ecosystem services to being exploring how social identities (rather than simply the socio-
591 economic characteristics explored here) are implicated in the very practices that co-produce
592 ecosystem services, and thus sustain gender inequities (Nightingale, 2017).
593
594 Thus, assessing the importance of ecosystem services (and how this is socially differentiated)
595 cannot identify whether resource use is equitable or not. We agree with Kull et al. (2015),
596 with using ecosystem services assessments as evidence through which to assess issues of
597 equity, without assuming that equity is embedded in an ecosystem services assessment itself.
598 In other words, understanding the disaggregated importance of ecosystem services is an

599 important first step, but is ultimately insufficient for fostering or designing equitable
600 management. Instead, understanding participation in decision-making, and how needs and
601 desires are recognized and fulfilled is key to environmental justice (Agyeman et al., 2016;
602 Edwards et al., 2016).
603
604 **5.1 Limitations and caveats**
605
606 Our study has several limitations that point to avenues that would improve future work.
607 Firstly, we took an exploratory approach to defining socio-economic characteristics (Daw et
608 al. 2011), rather than a more grounded approach with in-depth ethnographic work to identify
609 key socio-cultural groups (e.g. Lakerveld et al., 2015). Exploratory analysis like this has
610 strength in making broader claims about socio-economic difference, while a grounded
611 approach provides more case-specific, practice relevant information. In addition, while
612 predefined socioeconomic characteristics are a useful exploratory tool, we agree with Fisher
613 et al., that framing differences this way 'may detract from the structural societal processes
614 perpetuating marginalization and poverty' (2014: 38). Had our study been linked with an
615 ecosystem service based conservation or management project then a grounded approach
616 would have been more appropriate and, indeed, necessary.
617
618 Secondly, the ecosystem services identified in our study were not elicited through
619 participatory, shared ecosystem service valuations (e.g. Kenter et al., 2011). Participatory
620 ecosystem services identification, followed by individual rating and ranking would have been
621 valuable, but was not possible in this case, and we wanted to ensure that we captured diverse
622 values across the community. Perhaps, in a more participatory environment, the slight
623 importance ascribed by women to more 'destructive' ecosystem services might not have
624 become apparent. How to best elicit ecosystem services and their importance while still
625 leaving space for different values and judgements within a community will be a key
626 challenge for future scholarship. In addition, we were unable to include a comprehensive list
627 of specific terrestrial ecosystem services for two reasons. Firstly, the rating and ranking
628 exercise is more successful and easier to conduct when there are a limited number of things
629 to rate and rank. Thus, we limited ourselves to 11 ecosystem services in total. Secondly,
630 additional terrestrial ecosystem services would not have been not relevant across all sites (i.e.
631 in Ahus, people rarely eat bush meat and forest habitat is limited).
632
633 Alongside our ecosystem services, the ways we measured some socio-economic variables
634 would not be appropriate in other settings. For instance, although migration is an important
635 feature of artisanal fisheries worldwide (Allison and Ellis, 2001), in Papua New Guinea,
636 strong marine tenure means that few fishers have the rights to fish in coral reefs that do not
637 belong to their clan. For instance, Ahus Island holds customary fishing rights both to waters
638 within its lagoon and between the island and the mainland. Thus, in our sample, most
639 migrants were women who had married into the village from outside. When someone married
640 in from the outside, they gain the clan rights of their husband's clan (in all our study sites it
641 was women who married into the village, rather than men, but this differs in other parts of
642 Papua New Guinea). Thus, in our sample, migrants are more integrated into their
643 communities than, for instance, temporary migrants. However, migration is often much more
644 dynamic, for instance, with local residents migrating to cities and back. Our binary variable
645 (migrant or non-migrant) did not capture this dynamism: people who are able to come and go
646 are likely relating differently to their home and host ecosystems. Future studies, particularly
647 in places with more movement, should try to capture the more fluid nature of migration.
648

5.2 Implications

Our study has several implications for natural resource management and conservation in Papua New Guinea and the Pacific more broadly. Firstly, our findings have highlighted that the provisioning services that support livelihoods are usually ascribed the most importance. Safe guarding fisheries and crops will thus be highly important as the global environment changes. The overwhelming importance placed on these provisioning services supports the argument that, to address poverty and conservation goals together, ecosystem services approaches might find it useful to assess and protect universal human needs (Chaigneau et al., 2018). Provisioning services likely support poverty alleviation in two ways; poverty reduction and prevention (Fisher et al. 2014). In semi-arid areas in Brazil, for instance, fisheries provide a less lucrative but more stable livelihood than aquaculture, and thus preventing poverty through supporting food and livelihood security (Lopes et al., 2018). In developing tropical contexts, transitions from fisheries to aquaculture, or other industries like tourism, must account for synergies and antagonism between ecosystem services use, especially the security that is lost when transitioning to higher risk, if more lucrative endeavours (Lopes et al., 2015). Thus, development and conservation projects should investigate not only what ecosystem services are important to which livelihoods, but whether they are important for reducing or preventing poverty. While tourism or aquaculture may seem like win-win options for conservation and development, how they interplay with more stable livelihoods, and who is able to benefit, will be key factors in whether they actually support people's wellbeing (Diedrich and Aswani, 2016).

Secondly, coastal communities differ from each other and from within. There are some gender and wealth differences in how people use and thus value ecosystem services. Disaggregated ecosystem services assessments can begin to identify where these differences lie, and may be useful for targeting specific conservation or management strategies. For instance, in our study, people with higher levels of formal schooling seem to perceive key links between in-direct and direct ecosystem services (in this study, between reef habitat and fisheries). Thus, enhancing education may not only improve people's wellbeing directly, but may have a flow on effect to environmental knowledge. As such, ecosystem-based management that, for example, targets reef habitat conservation, may gain more traction in places with more education and who are wealthier.

Thirdly, socially differentiated ecosystem services assessments need to take place over time, as peoples' needs and priorities, and reactions to ecosystem change, change themselves. The importance ascribed to ecosystem services will likely change over time as people's livelihoods and priorities shift. Although we found that coral materials were rated quite low in terms of importance, and people in Ahus emphasized that its best to only use dead coral, increasing affluence means that more and more people are constructing semi-permanent houses that require concrete, often made in part with dead corals. This new sort of use (different to the highly-regulated rights to cook coral for lime for chewing betel nut), may shift use of coral in the future, with impacts for reef fisheries.

Finally, people's own judgements about how their ecosystems should be used and governed are crucial for ensuring that management is fair. Assessments that include a qualitative aspect that asks people why things matter to them can capture the sorts of relational values that purely monetary, or quantitative techniques cannot. Alongside individual narratives,

participatory focus groups would be a valuable setting to explore these questions (Kenter et al., 2015).

Conclusion

Coastal ecosystem services provide multiple values to communities in developing countries, who directly depend on them. In Papua New Guinea, provisioning marine and terrestrial ecosystem services matter most to people because they support basic materials needs for food and livelihoods. Nonetheless, people also ascribed importance to ecosystem services because they supported material, subjective and relational aspects of wellbeing, and because they perceive links between direct and in-direct services (e.g. education/knowledge, habitat, and fisheries). Importantly, we found that people bring normative judgements to the ecosystem services that matter to them. Specifically, people expressed relational values of concern about how more extractive ecosystem services like coral materials and fuelwood are used. These more extractive ecosystem services tended to be used and rated slightly more important by women. In other words, we found that the ecosystems services about which people held particular normative judgements were gendered. In addition, here, as in other studies, we found that cultural ecosystem services tended to be ranked and rated lower that direct provisioning services. However, concerns about bequest, stewardship and identity, were elicited in people's narratives about why certain ecosystem services matter to them. Cultural ecosystem services fall on a separate plane, and are entwined with provisioning services. Thus, in contrast with other approaches, we contend that quantitative integrated ecosystem services assessments that include less tangible cultural services are likely to miss crucial relational values and normative judgements. Instead, asking people why ecosystem services matter to them helps to identify aspects of bequest values, care and the cultural aspects of ecosystems. In the context of global environmental change, identifying and safeguarding these important coastal ecosystem services will be crucial for ensuring peoples' wellbeing, particularly in developing country contexts where cultural ecosystem services extend beyond tourism and aesthetic values. To do this, policy-makers, conservationists and development professionals alike can draw on the relational values that people already express towards ecosystem services about what is appropriate use and management.

Acknowledgements

Many thanks to John Ben, Lawrence Gandong, Fiona Naron, Otto Selan, Rhonda Pominis, and Santina Memes for assistance in the field. A big thank-you to the people of Ahus, Muluk and Wadau for their time, patience, and knowledge. Thank you to the special issue editors and three anonymous reviewers for helpful comments that greatly improved the manuscript.

Funding

All authors acknowledge support from the Australian Research Council Centre of Excellence for Coral Reef Studies, James Cook University. C. Hicks acknowledges support from the Lancaster Environment Centre. J. Cinner acknowledges funding support from an ARC Future Fellowship.

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Supplementary Material

Appendix 1. General Linear Models

Table 1. Material Style of Life Principle Component Analysis (PCA) loadings

Variable	Factor loading
Roofing	-0.506
Flooring	-0.578
Wall	-0.473
Garden	-0.431

Table 2. Variance inflation factors for socio-economic variables

Variable	Variance inflation factor
Years_School	1.195535
Material style of life	1.359079
Last expenditure	1.115972
Migrant	1.067086
Gender	1.105806
Age	1.129096
Main source of livelihood	1.200537
Different occupations	1.052677

Table 3. Linear Mixed Models

Linear Mixed Models for importance of ecosystem service values including household and village as random effects. We ran a model for each ecosystem service with household and village specified as a priori random factors. We used the step function to select the most parsimonious model. We then used the Akaike information criteria values (AIC) to select the best model fit. In cases where the null model remained the best fit we discontinued analysis. These models are not included in this supplementary material. For the remaining models, we examined which socio-economic variables were significant in explaining ecosystem services rankings, taking this to mean that people with differences in these socio-economic characteristics ascribe importance to the ecosystem service in question, differently.

a) Fishery

Model: FISH ~ Yrs_School + MSL + log(LastExpend) + Migrant + important.livelihood + (1 | Household) + (1 | Village)

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.5789736	0.12103191	79	4.783644	0.0000
Yrs_School	-0.0199223	0.00825857	53	-2.412318	0.0193
MSL	0.0412983	0.01602981	79	2.576343	0.0118
log(LastExpend)	-0.0311442	0.01905521	79	-1.634418	0.1062
Migrant1	0.0646804	0.05951766	53	1.086743	0.2821
important.livelihood	-0.0561830	0.02977098	79	-1.887172	0.0628

b) Habitat

Model: HABITAT ~ Yrs_School + MSL + log(LastExpend) + Age + important.livelihood + (1 | Household) + (1 | Village)

	Value	Std.Error	DF	t-value	p-value
(Intercept)	-0.17360596	0.11281901	79	-1.538801	0.1278
Yrs_School	0.01146164	0.00591378	53	1.938123	0.0579
MSL	0.05992463	0.01319800	79	4.540434	0.0000
log(LastExpend)	0.02674564	0.01565133	79	1.708842	0.0914
Age	0.00190567	0.00156991	53	1.213876	0.2302
important.livelihood	0.03096638	0.02473458	79	1.251947	0.2143

c) Forest materials

MODEL: FOREST_MATERIALS ~ MSL + GENDER + Age + Different_occupation + (1 | Household) + (1 | Village)

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.29681411	0.10861625	80	2.732686	0.0077
MSL	-0.05205641	0.01260569	80	-4.129596	0.0001
GENDER	0.03808869	0.02673905	53	1.424459	0.1602
Age	-0.00202567	0.00163202	53	-1.241204	0.2200
Different_occupation	-0.01613554	0.01817615	80	-0.887732	0.3773

d) Education and knowledge

MODEL: EDU_M ~ Yrs_School + MSL + GENDER + important.livelihood + (1 | Household) + (1 | Village)

	Value	Std.Error	DF	t-value	p-value
(Intercept)	-0.03716837	0.05574045	80	-0.6668113	0.5068
Yrs_School	0.01613039	0.00545286	53	2.9581517	0.0046
MSL	0.02017984	0.01098696	80	1.8367079	0.0700
GENDER	-0.06520844	0.02568638	53	-2.5386390	0.0141
important.livelihood	0.02288237	0.02065782	80	1.1076858	0.2713

e) Fuelwood

MODEL: FUEL_M ~ Yrs_School + GENDER + Age + important.livelihood + (1 | Household) + (1 | Village)

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.08903729	0.03318499	81	2.6830591	0.0088
Yrs_School	-0.00244157	0.00229920	52	-1.0619215	0.2932
GENDER	0.02595144	0.01271109	52	2.0416382	0.0463
Age	-0.00123097	0.00057465	52	-2.1421296	0.0369
important.livelihood	-0.00441983	0.00797504	81	-0.5542072	0.5810

f) Crops

MODEL: CROP_M ~ important.livelihood + (1 | Household) + (1 | Village)

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.08594522	0.06107808	81	1.407137	0.1632
important.livelihood	0.07169284	0.03181760	81	2.253245	0.0269

Appendix 2. Qualitative coding

We coded the qualitative responses thematically, into three categories of wellbeing (i.e. material, subjective, and relational), and, where possible, into value domains (i.e. instrumental, intrinsic and relational). Mention of monetary, subsistence or livelihood was coded as material wellbeing. References of the importance of ecosystem services because of personal taste were coded as subjective. Relation wellbeing included references to the importance of ecosystem services for maintaining human-human and human-nature relationships, and included reference to a particular sense of identity. We did not find any intrinsic values expressed here, but that perhaps reflects the exploratory nature of this data, which was not aimed at capturing all aspects of value. The references that expressed material wellbeing were likewise coded as expressing instrumental values, while references to stewardship, care, identity, and normative judgements (i.e. how one should use and care for ecosystem services) were coded as relational values. The following table presents a subsection of quotes coded at each node. Note that most references indicate more than one aspect of wellbeing or value domain, particularly between material wellbeing and instrumental values, and relational wellbeing, and relational values. For example, we coded the quote "*Education/ knowledge* leads to good *habitat* and good *fish*, which are good for catching and going to market, and helping family (*bequest*)" (Man, Ahus) as both a contribution to material wellbeing (i.e through supporting livelihood), and an instrumental value (i.e. education etc. leading eventually to the instrumental value of directly benefiting from fish). The quote "We are people of the sea*,* so we must have a good, clean reef (*habitat*), and we must look after it well. The sea is first." **(**Woman, Ahus) was coded as both relational wellbeing, and relational value (i.e. identity, and stewardship).

Table 1. Examples of quotes coded at each wellbeing theme, and value domain.

Wellbeing	
Material basic needs, subsistence, livelihoods	*Crops* are important, we benefit and look after our kids with them. That's the only way we get money to buy things. ~ Woman, Karkar We survive on cocoa, copra and gardens (*crops*), [that's why its ranked first]. ~ Man, Karkar We like the reef (*habitat)* to be good so we can find things to eat…we catch *fish*, we eat it, we smoke it and sell it at market. ~ Woman, Ahus *Fishing* and work to do with the sea is our only living. ~ Woman, Ahus
Relational care, stewardship, identity, continuity of custom and tradition	We are people of the sea**,* so we must have a good, clean reef (*habitat*), and we must look after it well. The sea is first. ~ Woman, Ahus We only use *reef materials* and *fuel wood* if they die. ~ Man, Ahus [We] can have traditions if we respect the fish. ~ Woman, Ahus I'm not a *fisher*, I don't dive. I'm a bush man, I'm not interested in *fishing*. ~ Man, Karkar It's custom to give *fish* away and share, this custom is necessary to be happy. ~ Man, Karkar
Subjective taste, enjoyment	I don't want to finish drinking soup that has no *fish*, but with fish it tastes good. ~ Man, Karkar *Fish* is the best food; good taste. ~ Man, Ahus

Value domains	
Instrumental	*Habitat* is important because *fish* hide there, live there. With big events (*tradition*) we can catch fish and celebrate, that's important. ~ Woman, Karkar When *habitat* is good then there are plenty of *fish*, which we can use for celebrations (*tradition*). ~ Woman, Ahus *Education/ knowledge* leads to good *habitat* and good *fish*, which are good for catching and going to market, and helping family (*bequest*). ~ Man, Ahus
Relational	We are people of the sea*, so we must have a good, clean reef (*habitat*), and we must look after it well. The sea is first. ~ Woman, Ahus I don't think *sanitation* is good; it's bad for the reef. I'm not happy with cutting *firewood*, or using *coral materials,* we'll ruin the environment. ~ Woman, Karkar If you care (for the reef *habitat*), it will grow, if you break it, it will die. If you care for it you get plenty of *fish* and they're important for life. ~ Man, Karkar

Appendix 3. Intra-household gender differences

To calculate intra-house hols differences, within each partnership we subtracted each women's score from each man's score to get a variable for the gendered difference in ranking, and in rating. We then conducted one sample t-tests to test whether there were any patterns in gender differences for each ecosystem service.

One sample t-tests

Alternative hypothesis: true mean is not equal to 0, meaning there is a difference in how women and men rank or rate this ecosystem service.

Table 2. One sample t-tests results for ecosystem services where there was a significant gender difference in ranking and/or rating of ecosystem services.

Ecosystem service	t=	df	p-value	95% confidence interval	Mean of X
RANKING					
Fuelwood	-2.814	133	0.005629	-1.322 -0.231	-0.776
Education & knowledge	3.690	133	0.0003258	0.512 1.696	1.104
Shoreline protection	2.352	133	0.02014	0.078 0.907	0.493
Reef materials	-4.274	133	3.64e-05	-1.659 -0.609	-1.134
Sanitation	-2.138	133	0.03431	-1.121 -0.044	-0.582
RATING					
Forest Materials	-3.5048	133	0.0006232	-0.103 -0.029	-0.066
Fuelwood	-3.9042	133	0.0001496	-0.0520 -0.0170	-0.035
Education & knowledge	3.9278	133	0.0001371	0.039 0.117	0.078

Figure 1a. Boxplots of intra-household differences in ranking of ecosystem services

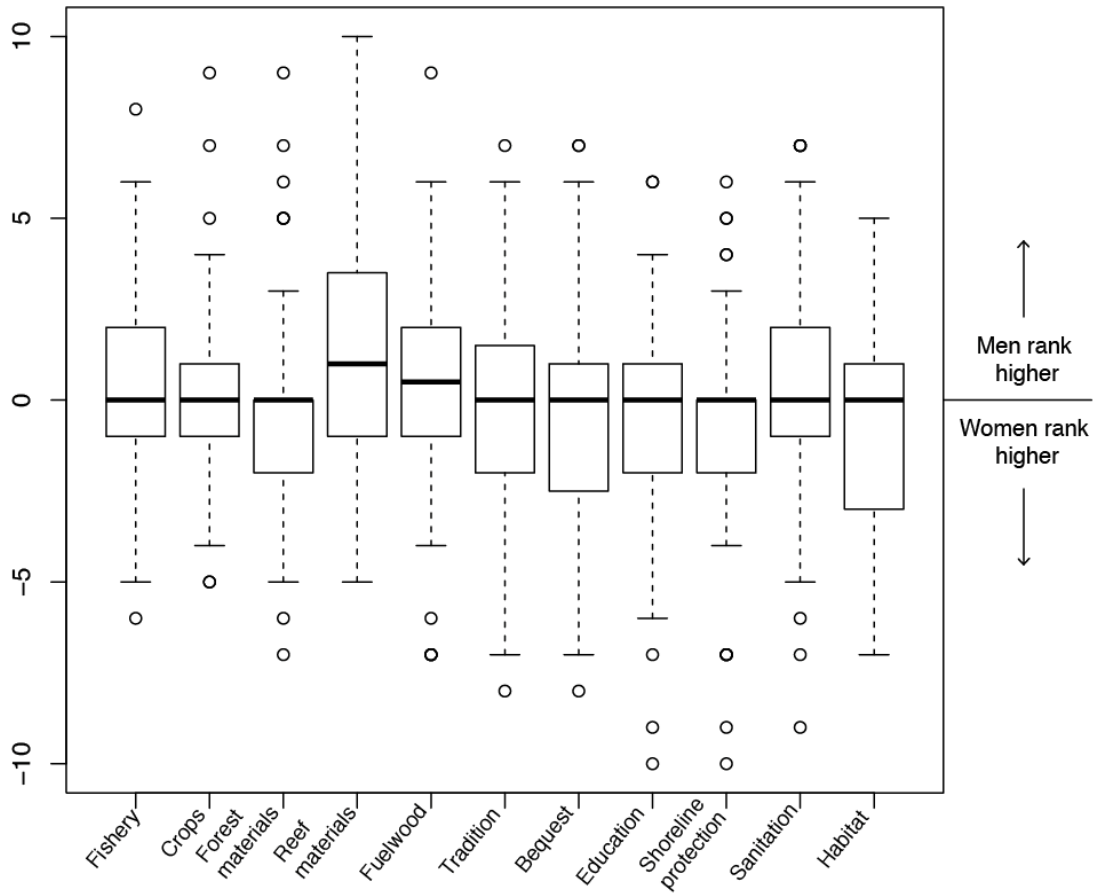
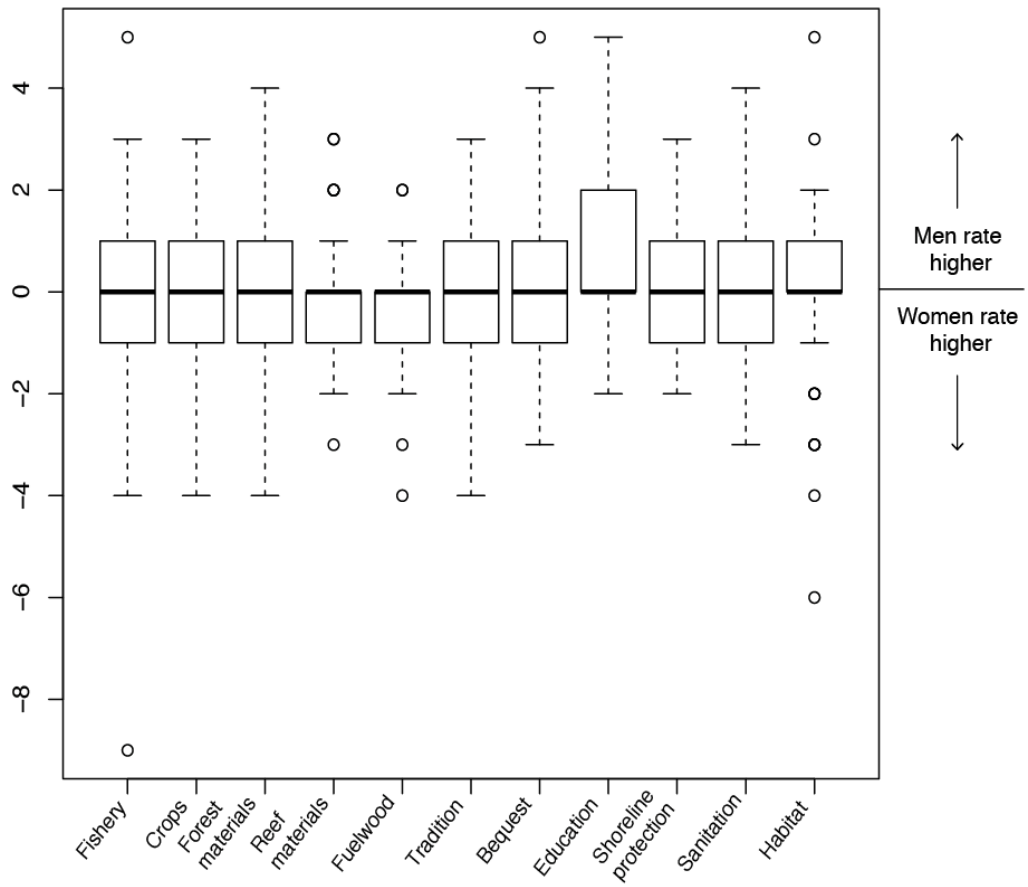


Figure 1b. Box plots of within household differences in rating of ecosystem services.


4
2
0
−2
−4
−6
−8
Fishery
Crops
Forest materials
Reef materials
Fuelwood
Tradition
Bequest
Education
Shoreline protection
Sanitation
Habitat
Men rate higher
Women rate higher

1170