Title: Social capital as an ecosystem service: Evidence from a locally managed marine area

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Abstract

Social capital is an important ecosystem service, yet we lack common understanding of how it fits, and can be operationalized, within the ecosystem services framework. We review the literature to clarify the role of social capital in this context, establishing it as a multidimensional concept and a fundamental constituent of human well-being that is both supported by, and affects, all categories of ecosystem services. We then draw on qualitative and quantitative data to assess and value social capital as an ecosystem service and explore its role in facilitating management goals in a Malagasy locally managed marine area. We find high levels of social capital, gauged by trust, community involvement, and social cohesion. Results of a choice experiment show positive utilities associated with high levels of social cohesion. Respondents also ranked social cohesion higher than some provisioning, regulating, and cultural ecosystem services. Qualitative data suggest social capital increased as a result of the community based management institution, and has facilitated the success of marine management measures. Our results offer insight into the ways in which social capital can both affect, and be affected by, the management of natural resources, and how it can be assessed and valued as an ecosystem service.

Keywords: social capital, cultural ecosystem services, ecosystem service valuation, environmental management, locally managed marine area, Madagascar

1. Introduction

The notion of social capital has historical roots, but the term's prevalence in academic discourse has greatly expanded since the 1990s. Social capital is multifaceted, broadly referring to the individual and collective benefits embedded in relationships between people and communities (Bourdieu, 1986; Coleman, 1988; Putnam, 2001). Though there is some debate over its use (or misuse) (Dasgupta and Serageldin, 2000; Durlauf, 2002), social capital is often defined by its function, which emphasizes the notion that social bonds and cohesion build trust, encourage reciprocity and exchanges, and enable the establishment of common rules, norms, and sanctions (Ostrom and Ahn, 2009; Pretty, 2003; Putnam, 1995).

Social capital and ecosystems are linked. Strong social bonds at the community level can enhance ecosystem service flows by facilitating collective action and sustainable natural resource governance (Gutiérrez et al., 2011; Ostrom, 1990; Pretty and Ward, 2001). Conversely, ecosystem change can impact networks of trust, reciprocity, and exchanges within and among communities by altering human-environment relationships (Burke, 2010; Chan et al., 2012b; Hicks et al., 2009). Recognizing this critical feedback, many articles in the ecosystem services literature cite social capital as an important ecosystem service. Yet few ecosystem service assessments and economic valuations include even basic analyses of social capital. This is likely due to its inherent complexity as a multidimensional and somewhat intangible concept, whose definition and place within the ecosystem services framework has not been clearly established. When considering trade-offs involved in environmental decision-making, potential impacts to social capital are thus likely overlooked in favor of more tangible, quantifiable factors.

We begin with a review of the literature to clarify the place of social capital within the ecosystem services framework. We then draw on qualitative and quantitative data to assess social capital and its role in facilitating marine management goals in a Malagasy locally managed marine area (LMMA). Finally, we provide the first economic valuation we are aware of that explicitly captures the value individuals place on social capital as an ecosystem service. Social capital values linked to natural ecosystems are likely particularly important for resource-dependent, indigenous communities involved in community-based

environmental management (Pretty, 2003). In the absence of effective institutional support for marine and coastal governance, LMMAs have been rapidly proliferating across the globe, and are particularly prevalent in developing economies (Govan et al., 2009; Johannes, 2002). Our results offer insight into the ways in which social capital can both affect, and be affected by, the management of marine and coastal resources in this context, and how it can be assessed and valued as an ecosystem service.

2. Social capital and ecosystem services

Social capital has long been recognized as an important contributor to human welfare due to its ability to foster collective action for mutual benefit. The idea can be traced back to Tocqueville ([1840] 2014), though the concept benefited from substantial theoretical development by Bourdieu (1986), Coleman (1988), and Putnam (2000), among others. Despite this rich history, social capital was generally overlooked by classical economics with its focus on self-interested individuals and a welfare model comprised solely of land, labor, and manufactured capital. In their seminal work, Daly and Cobb (1989) offered a rebuke of this oversight, arguing that individuals are inherently social beings embedded in communities of interrelations, and that the quality and thickness of these social relationships comprise important components of human well-being that both affect, and are affected by, all aspects of economic life. Their work, now cited over 4,700 times[1], had a profound influence on both development and environmental economics, where the connection between social capital, human well-being, and environmental sustainability has become an increasingly popular research focus (e.g., Costanza, 2000; Howarth and Farber, 2002; Lehtonen, 2004).

Though economic system models now consider social capital a key contributor to human well-being (see Costanza, 2000), to our knowledge the Millennium Ecosystem Assessment (MEA) (2005) was the first to

[1] Google Scholar as of October 7, 2014.

recognize an explicit connection between changes in natural capital (and ecosystem service flows) and changes in social capital. Throughout its five technical volumes and six synthesis reports, the MEA (2005) identifies several aspects of social capital as central dimensions of human well-being affected by ecosystem change (i.e., social relations, social cohesion, cultural ties, communal interaction, interactions between individuals, networks of relationships, alliances, mutual respect, and social networks). The MEA largely recognizes social capital as a nonmaterial ecosystem service under the umbrella category of *cultural ecosystem services* (MEA, 2005). An example is given in the very first chapter, where the authors note that the loss of important ecosystem service attributes linked to ceremonial or spiritual practices can weaken community bonds, which in turn affects human well-being (MEA, 2005, pg. 29). Despite its principal assignment to the cultural services category, the overarching MEA framework also identifies social capital (i.e., 'good social relations' comprised of social cohesion, mutual respect, and the ability to help others) as one of five primary constituents of human well-being supported *by all* categories of ecosystem services (supporting, provisioning, regulating, and cultural) (MEA, 2005; pg. 28).

Identifying the importance of social capital to human well-being and recognizing its explicit relationship to environmental services was one of many significant contributions made by the MEA (2005). Yet the report failed to provide a formal definition of social capital, a consistent description of how it fits within the framework, and an expansion of how it can be operationalized, quantified, and valued. This, in conjunction with social capital's complex and multidimensional nature, has likely contributed to sparse references to social capital in ecosystem service work. Some exceptions include recent advancements in the cultural ecosystem services literature, where social capital is identified as an important benefit (Chan et al., 2011; Chan et al., 2012a; Chan et al., 2012b; Daniel et al., 2012; Milcu et al., 2013). Yet even these examples lack clarity on social capital specifically. One exception is Chan et al. (2012b), who classify 'social capital and cohesion' as one of nine prominent cultural ecosystem services and dedicate a small section to its description. Per Chan, 'social capital and cohesion' have both intrinsic and instrumental value. The authors explain that activities enabled by ecosystems, such as hiking and traditional fishing,

95 are associated with interactions between individuals that contribute to rich, cultural networks of
96 relationships. These relationships facilitate trust, reciprocity, and cultural norms that are intrinsically
97 valuable to people (as social cohesion), while also providing instrumental (i.e., functional) 'social capital'
98 benefits. The authors acknowledge that both the instrumental and intrinsic benefits of social capital can be
99 impacted by ecological (or social) change (Chan et al., 2012b).

100 Outside the ecosystem services literature most of the work on social capital in relation to the natural
101 environment is largely in line with its functional conceptualization, focusing on the ways in which social
102 capital can enhance environmental health and integrity by facilitating cooperation toward sustainable
103 resource governance. For example, Pretty and Ward (2001) provide analyses of rural community groups
104 in diverse settings from Kenya to the U.S. who have leveraged local social capital to act collectively in
105 order to confront environmental problems and sustain key environmental services. Bodin and Crona
106 (2009) review empirical evidence highlighting the critical role of social networks in facilitating, and
107 sometimes constraining, successful natural resource governance. Several other studies describe social
108 capital as a key feature of successful collaborative environmental management (e.g., Gutiérrez et al.,
109 2011; Plummer and FitzGibbon, 2006; Pretty, 2003).

110 Though the contribution of social capital toward the effective management of resources is well
111 established, only a thin literature exists linking its intrinsic value to natural ecosystems. Yet this appears
112 to be changing, with several recent notable examples documenting how changes in ecosystem service
113 flows (even if not labeled as such) and the management of ecosystems can impact social capital. For
114 example, Burke (2010) showed that the virtual collapse of a first nation local fishery in British Columbia
115 negatively impacted community-level social capital in several distinct manners, e.g., by decreasing the
116 community's ability to access and exchange traditional resources, engage in social and kinship networks,
117 and perform acts of generalized reciprocity. Hicks (2009) found evidence suggesting government
118 management interventions on the Kenyan coast that maximized coral reef direct use values (primarily for
119 tourism) were associated with losses in social capital in resource-user communities. Conversely, Wagner

120 and Fernandez-Gimenez (2008) found that community-based collaborative resource management can
121 enhance social capital at the community level and foster outside links to formal agencies. Analyzing the
122 societal impacts of marine protected areas (MPAs) in four countries in the Asia-Pacific region, Van
123 Beukering et al. (2013) found that MPAs strengthened the social fabric of communities, while social
124 cohesion was also an important factor contributing to the success of the MPAs.

125 In synthesizing this previous work on social capital and the environment, we see a need to clarify the
126 definition and role of social capital within the ecosystem services framework. Our review exposes many
127 terms that directly and indirectly refer to social capital, and a lack of consensus about how social capital
128 relates to ecosystem services – is it a cultural ecosystem service (akin to spiritual, recreational, and
129 heritage benefits), or a primary constituent of human well-being derived from many ecosystem services
130 (similar to access to basic materials or health), or both? Because analyses of the relationship between
131 social capital and the environment are prevalent in the natural resource management and development
132 literature, we suggest aligning the ecosystem services literature with this foundation, defining social
133 capital as *a multidimensional concept comprised of trust, reciprocity and exchanges, and common rules,*
134 *norms, and sanctions embedded in networks of relationships* (see Plummer and FitzGibbon, 2006; Pretty,
135 2003; Wagner and Fernandez-Gimenez, 2008; among others). As recognized by the MEA (2005), social
136 capital is a product of social cohesion, mutual respect, and relationships of mutual support (i.e., 'the
137 ability to help others').

138 In terms of its role, social capital is clearly a fundamental component of human well-being that both
139 affects, and is affected by ecosystem change (see Fig. 1). In line with Chan et al.'s definition of social
140 capital as a cultural ecosystem service (2012b), ecosystems help to both build social capital that can foster
141 socially beneficial behavior, and facilitate social interactions that are intrinsically valuable to people.
142 Stocks of social capital can be augmented (or depleted) as a result of changes in natural capital and
143 ecosystem service flows, and social capital contributes to human well-being through multiple channels –
144 directly as a primary constituent of human well-being, and indirectly through better management of

145 resources and actions (Fig. 1). Following Chan et al.'s (2012b) argument that many benefits typically
146 linked exclusively to cultural ecosystem services are in fact produced by multiple categories of services,
147 social capital is perhaps best understood as a cultural ecosystem service and primary constituent of human
148 well-being often supported *by all* categories of ecosystem services (including other cultural services)
149 (MEA, 2005; pg. 28).

150 Applying this conceptualization of the feedback relationship between social capital and ecosystem
151 services, here we provide an initial example of how social capital can be assessed and valued as an
152 ecosystem service. We begin with a description of our study site, followed by our methodological
153 approach for operationalizing social capital in this context under the ecosystem services framework. Next
154 we discuss our empirical results and offer an interpretation of their significance. We conclude with a
155 discussion of the limitations of our study, followed by our recommendations for future research.

156

157 **3. The Velondriake locally managed marine area**

158 Velondriake (Fig. 2) was the first collaborative LMMA to be established in Madagascar, and is currently
159 the largest in the Western Indian Ocean (Harris, 2011). It consists of a complex array of islands, forests,
160 coral reefs, mud flats, seagrass beds, and mangroves spanning over 1,000km^2 on the southwest coast, and
161 is home to over 7,500 people of Vezo identity living in 24 villages. Average per capita income in the
162 LMMA is under the international poverty threshold at less than $2 a day (purchasing power parity, PPP),
163 and the Vezo depend almost solely on the exploitation of natural resources to support their livelihoods
164 and protein needs (Barnes-Mauthe et al., 2013).

165 The Vezo, known as the "fishing people" who "struggle with the sea and live by the coast" (Astuti, 1995;
166 pg. 5), have subsisted for generations from traditional fishing activities. Yet in recent years stressors from
167 climate change and local anthropogenic activities threaten their livelihoods, cultural identity, and
168 economic security. These stressors include chronic political instability, population growth, increased

migration to the coast, an escalation of extreme weather events, degradation of key habitats including mangrove forest and coral reefs, and a deterioration of marine fisheries catches (Ateweberhan and McClanahan, 2010; Cheung et al., 2012; Giri and Muhlhausen, 2008; Harris, 2011; Le Manach et al., 2012). In response to these pressures, in 2006 representatives from 24 villages acted with the support of Non-Governmental Organizations (NGOs) and the National Marine Science Institute to establish the LMMA, whose mandate is to protect marine and coastal biodiversity while improving livelihood sustainability in the Velondriake region. Governed by the democratically elected Velondriake Management Committee, the LMMA was ratified in 2009, and has since successfully instituted bans on destructive fishing practices, temporary octopus fisheries closures, and an integrated population-health-environment program (Andriamalala and Gardner, 2010; Harris, 2011). Though management of the LMMA is supported by NGOs (primarily Blue Ventures Conservation), community members hold regular meetings concerning management actions, the Velondriake Management Committee is made up of representatives from each village, and ultimately all management decisions are made solely by the community (Harris, 2007).

4. Methods

4.1 Assessing social capital

Akin to the deliberations over the definition and use of the social capital concept, much has been written concerning the challenges of explicitly measuring it (e.g., Sabatini, 2009; Van Deth, 2003; among others). Most agree that social capital is difficult, if not impossible to measure directly, and for empirical purposes the use of proxy indicators is necessary (Grootaert and Van Bastelaer, 2002; Leisher et al., 2013). Social capital is also highly contextual, and it is generally suggested that the choice of indicators be guided by local conditions and the breadth of the unit of observation (e.g., indicators that reflect community level social capital may be less relevant at the national level) (Grootaert and Van Bastelaer, 2002). Similar to

193 Chan et al.'s (2012b) recommendations for determining the different ways in which people value cultural
194 ecosystem services, Woolcock (2001) suggests that surveys to measure relevant components of social
195 capital should follow periods in the field where the most appropriate ways to ask the necessary questions
196 are uncovered.

197 With these recommendations in mind, in 2009 we began a research program aimed at identifying and
198 quantifying social capital and other ecosystem service values held by the Vezo in the Velondriake region.
199 Through key informant interviews (n = 26) and focus group meetings (n = 7) in 2009 and 2010, villagers
200 noted that aspects of social capital, such as inter-village cooperation, intra-village communication, trust,
201 and their personal involvement in decision-making and resource management, had all increased as a result
202 of the community-based management institution, which was facilitated by local ecosystem service flows.
203 They valued these changes, and expressed their belief that the success of the LMMA, and thus the
204 conservation and sustainability of key ecosystem services (such as fisheries), depended on them.

205 To quantify this qualitative information we designed a framework adapted to the local context to assess
206 social capital and understand the value individuals place on it as an ecosystem service (Table 1). The
207 social capital indicators that most accurately characterized the sentiments conveyed by focus group
208 participants and key informants, presented in Table 1, were selected after a review of the literature on
209 social capital measurement (e.g., Adger, 2003; Lochner et al., 1999; Narayan and Cassidy, 2001; Onyx
210 and Bullen, 2000; Ostrom and Ahn, 2009; Putnam, 2001; Woolcock, 2001) and in consultation with the
211 Western Indian Ocean monitoring protocol for coastal managers (Malleret-King et al., 2006). Final
212 indicators included trust, community involvement, and social cohesion, which characterize fundamental
213 aspects of social capital (see above-mentioned references). These characteristics were measured by
214 employing simple nominal or Likert-scale questions designed with input from key informants, focus
215 groups, and local experts. For example, when asked to specify the different ways that social cohesion
216 manifested itself, the number of people from each village attending inter-village meetings was suggested
217 by – and resonated with most – focus group participants. They explained that the number of people

attending the meetings reflected the level of respect and buy-in across villages, and that increased participation in the meetings helped to build trust and improved communication of decision-making and eventual enforcement. The number of people attending inter-village meetings was therefore chosen as one measure used to value social capital (described further in the following section), while the number of meetings each respondent had attended since the establishment of the LMMA was used as an indicator of community involvement. Though in our assessment we attempt to parse out trust, community involvement, and social cohesion as separate indicators of social capital to capture what emerged as important for the Vezo in interviews and focus groups, we acknowledge that they are often highly interconnected. For example, we used two factors to gauge social cohesion in our assessment that likely also capture aspects of trust in the community, i.e., feeling part of the Velondriake community, and knowing that you can rely on others in times of need (Table 1). This is a central feature of what Woolcock (2001; pg. 7) refers to as the inherently related "consequences" of social capital (i.e., trust, social cohesion, etc.).

4.2 Valuing social capital

Because social capital is not mediated through markets, its value as an ecosystem service is difficult to quantify using valuation methods traditionally applied in ecosystem service assessments. Here, we focus on the increase in social cohesion that focus group participants and key informants perceived as resulting from the community based management institution, and applied three different methods to gain an understanding of how the Vezo value these perceived social capital gains. First, we designed a simple Likert-scale question aimed at gauging the extent to which respondents agreed that the establishment of the Velondriake LMMA had increased social cohesion between villages (Table 1). We then employed two innovative methods to assess preferences and rankings of social cohesion in comparison to other ecosystem services that were also identified as important by focus group participants and key informants. These methods included a discrete choice experiment (DCE) and a rating and ranking game, described in turn.

243 *4.2.2 Discrete choice experiment*

244 DCEs are a method commonly used to elicit preferences for ecosystem services that aren't mediated
245 through markets (e.g. Adamowicz et al., 1998; Boxall et al., 1996; Hoyos, 2010). DCEs derive from a
246 well-tested theory of choice behavior (Thurstone, 1927), and can be used to model hypothetical scenarios
247 involving trade-offs that model real-world decision making. Specifically, the approach is based on the
248 idea that any good or environmental scenario can be described in terms of its *attributes*, or characteristics,
249 and the *levels* (representing hypothetical changes in quantity or quality) that these attributes take. In a
250 DCE, respondents are asked to choose between different bundles of these attributes and levels (i.e., make
251 trade-offs). Drawing on the characteristics theory of value (Lancaster, 1966) and random utility theory
252 (McFadden, 1974; Thurstone, 1927), which describes discrete choices in a utility maximizing framework,
253 marginal utility values for each attribute reflected in respondents choices can be analyzed using logit and
254 probit regression models.

255 In our DCE the hypothetical scenario was a general strengthening of rules governing the use of natural
256 resources within the LMMA, and specifically included management measures that were being considered
257 at the time of data collection.[2] Ecosystem services identified by key informants and focus group
258 participants as important for the community that were expected to be affected by the hypothetical scenario
259 were selected as the attributes included in the experiment (Table 2). In addition to social cohesion, these
260 services included bequest (a cultural ecosystem service), shoreline protection (a regulating ecosystem
261 service), and commercial fisheries (a provisioning ecosystem service). A payment vehicle was also
262 included to capture the trade-offs associated with stricter management, which was represented by a short-
263 term loss in commercial seafood income expected in the first year after implementation of the

[2] Measures included a strict enforcement of a ban on destructive fishing methods, expanding areas permanently closed to fishing, increasing the number of octopus fishing reserves, and limiting the destruction of mangroves and coral reefs.

hypothetical management scenario. The level to which these services might be affected by the hypothetical scenario (i.e., 'Levels', Table 2) reflected current conditions and experts' opinions on expected changes due to strengthened management. Attributes and levels were refined after several expert consultations with local collaborators and key informants, and after a pre-test in several villages. Additional information on the selection of attributes and attribute levels and the DCE experimental design is provided in the Supplementary Information (SI) and in Oleson et al. (2014). We used NLOGIT version 4.0 (Greene, 2007), a standard package for estimation of multinomial discrete choice models, to estimate a dummy coded multinomial logit regression on the main effects of respondent's choices in our DCE. Additional information on the analysis is provided in the SI.

4.2.3 Rating and ranking game

The rating and ranking game we employed assessed preferences and rankings for social cohesion using beans as weights to examine the priority order of social cohesion and eight other ecosystem services, which were illustrated using pictograms and described in an oral narrative (see Fig. S1 for an example of the pictograms). Other services included income from fisheries ('commercial fisheries'), food from fisheries ('subsistence fisheries'), ceremonial practices involving ecosystems ('ceremonies'), the ability of coral reefs and mangroves to act as storm barriers ('shoreline protection'), participation in decision-making ('agency'), bequest of the traditional Vezo fishing culture ('bequest'), traditional medicine ('medicine'), and waste disposal ('waste'). In the game, respondents first ranked these services in priority order, and were then given a total of 20 beans and asked to rate their importance by allocating beans to the services in four rounds of five beans each.

We analyzed subjects' ecosystem service ratings using hierarchical clustering to estimate potentially distinct groups holding different value sets within the sampled community using the R package *cluster* (Maechler et al., 2011). Using the R base function prcomp, we further displayed variation within and among these clusters using a Principal Component Analysis ordination that maximally spreads the

centroids of the identified clusters. Last, we examined mean ratings of each ecosystem service per clustered group with bootstrapped 95% confidence intervals. Though the game does not allow us to estimate the relative importance of the nine ecosystem services in specified units, the information it generates offers interesting insight into respondents' prioritization. Readers are referred to Oleson et al. (2014) for additional information on the rating and ranking game.

4.3 Sampling

To apply our framework, we conducted face-to-face interviews using a stratified random sampling technique accounting for differences in habitat surrounding the villages in Velondriake (coastal, mangrove, island) and their geographic location (north, central, south) (Fig. 1). Fieldwork was carried out in the villages between August and September 2010. To improve reliability, we extensively trained and supervised local survey teams fluent in Vezo and ran daily quality checks. We alternatively interviewed the male and female head of household. The response rate was high (>95%). The total sample containing the pre-test included 301 respondents. Information from the pre-test *(n* = 43) helped to refine attributes and levels for the DCE (Table 2) and our social capital assessment metrics (Table 1). Pre-test data was therefore not used in this analysis. We additionally removed 63 of the 258 remaining responses from our database due to respondents' disclosure that they did not understand the DCE.[3] Our final sample thus consisted of 195 respondents, which were found to be representative of Velondriake's population in terms of gender and habitat surrounding the villages (see Table S1 in the SI).

5. Results

[3] 77% of the total 258 respondents stated that they believed the DCE was either clear or very clear, while 22% felt that it was somewhat clear and the remaining 1% did not believe that it was clear. Only responses from those that believed it was clear or very clear were included in our analysis.

308 Shown in Fig. 3, our social capital assessment revealed that a majority of respondents felt they could trust
309 information from those closest to them, such as their family (94%) and fellow village members (85%).
310 The majority of respondents also trusted information from those directly involved in, or supporting the
311 management of the LMMA, such as the democratically elected Velondriake Management Committee
312 (95%), Blue Ventures NGO (64%), and local government officials (88%). In contrast, most respondents
313 claimed they did not typically trust information from fishers from other families (60%) (though they did
314 trust fellow village members) or the local university (100%)[4].

315 Results reflected a high level of community involvement, with the majority of respondents (75%)
316 attending at least one, but up to seven community meetings since 2004, when the initial fisheries
317 management initiative began (a precursor to the LMMA's formation). One-fifth reported attending up to
318 40 meetings, while only 5% reported attending none ($\mu = 5.59 \pm 5.21$).[5] Nearly all (95%) respondents
319 were involved in community decision-making. Nearly two thirds (63%) reported being passively involved
320 by attending meetings and staying informed, while 32% reported being actively involved by voicing their
321 opinion. Moreover, practically all (99%) respondents either agreed or strongly agreed that they were a
322 part of the Velondriake community and could turn to others within the community if they were in trouble,
323 reflecting a high level of social cohesion.

[4] The university initially helped to establish the LMMA, but since has primarily interacted with locals through Blue Ventures acting as an intermediary. The fact that no one viewed the university as a trusted source likely has to do with the lack of villagers' direct engagement with university representatives.

[5] The exact number of meetings since 2004 are unknown. However, field researchers estimate that from April 2005 through July 2010 (immediately preceding data collection) there were approximately 190 meetings, generally including one meeting in each village per month, one or two regional committee meetings per year, and two general assembly meetings per year. Regional committee meetings occur in each region (north, central, and south), while general assembly meetings bring all regions together.

When respondents were asked if they believed the Velondriake Management Committee increased the relationships and respect between villages, 86% of respondents agreed or strongly agreed, while 6% were unsure, and only 7% disagreed. Results from our DCE model show that the utilities associated with social cohesion are positive and non-linear (Table 3). Specifically, there is no statistically significant difference in preferences between low and medium levels of social cohesion, yet there is a statistically significant difference in preferences for high levels of social cohesion ($p < 0.001$), indicating increasing marginal utility associated with participation and cooperation in inter-village meetings. In comparison to other ecosystem services included in the model, the utility associated with the high level of social cohesion is second only to that for the high level of cultural bequest, and is equivalent to the high level of shoreline protection. Interestingly, the utilities associated with a short-term loss in income from commercial seafood sales are positive, and suggest decreasing marginal utility of income (Table 3).

In the initial priority order ecosystem service ranking, social cohesion was ranked after bequest, fisheries (commercial and subsistence), and ceremonies by a majority of respondents. In the rating game, ratings fell into three major clusters (Fig. 4A, B), which were classified as "Fishing First", "Bequest First", and "Diverse Values", according to the benefits defining the group. Members of the "Fishing First" cluster divided their ratings between commercial and subsistence fishing and excluded most other values (Fig. 4C). Members of the "Bequest First" cluster focused their ratings on cultural bequest, but left some value for fishing and other benefits (Fig. 4C). Members of the "Diverse Values" cluster divided rating values across all benefits (Fig. 4C). After the final round of rating, social cohesion was weighted as a priority benefit only second to bequest by the Diverse Values group, and after bequest and fishing (commercial and subsistence) by the Bequest First group (Fig. 4C). In contrast, the Fishing First group gave less weight to social cohesion, with it winning out only over agency and waste. Mean cumulative proportional ratings over each of the four rounds are presented in Fig. 5.

6. Discussion

To operationalize social capital we developed a context dependent framework driven by qualitative information on what social capital meant to the local community, and how they understood it to be related to ecosystem service flows. In this case, key informants and focus group participants understood social capital to represent relationships of trust, community involvement, and social cohesion (broadly stated), which they believed was augmented by ecosystem services through their involvement in managing them as a community, yet at the same time facilitated their success in this endeavor – thus capturing the feedback relationship highlighted in Fig 1. Quantitative data used to assess social capital (i.e., Table 1, "Assessment of Social Capital") indeed revealed high levels of community involvement and social cohesion throughout the LMMA. Though we did not have data on the temporal distribution of community meeting attendance since the establishment of the LMMA, which was used to evaluate community involvement, key informants suggest that involvement has remained relatively steady over time. Results on trust were more variable, indicating that some sources of information are more trusted than others (Fig. 3).

Taken together, these results suggest there exists a high level of *bonding* social capital in the LMMA, characterized by strong, localized ties and high levels of trust and cohesion within families and villages (Narayan, 1999; Woolcock, 2001). Yet *bridging* social capital, which comprises weaker social ties and trust across somewhat similar, but different groups of actors, and *linking* social capital, which refers to linkages and trust that span disparate groups (Grafton, 2005), is more tenuous. Specifically, our results suggest a high level of trust between respondents and the Velondriake Management Committee, which connects different villages, but a low level of trust across fishing families, two potential sources of bridging social capital (Fig. 3). It is unclear why fishers trust information from fellow villagers, but not fishers outside of their families; this is an area worthy of further research. Similarly, in regards to potential sources of linking social capital, we found that while government officials and Blue Ventures NGO are more or less trusted sources of information, no one reported trusting the local University. The

373 latter is a surprising result that should be explored further, but may be explained by the lack of sustained
374 involvement of the university in the region.

375 These results are important locally because they highlight potential imbalances in different types of social
376 capital, which previous research has shown can affect collaboration and natural resource governance
377 initiatives in diverse ways (Fig. 3). For example, dense networks and high levels of social cohesion in the
378 form of bonding social capital can be a key factor facilitating initial joint action to confront environmental
379 problems (Ostrom, 1990; Plummer and FitzGibbon, 2006). Yet deficiencies in bridging and linking social
380 capital can threaten the long-term sustainability of community-based and collaborative management
381 arrangements. For example, deficiencies in bridging social capital across social groups can result in the
382 emergence of disparate opinions and internal power struggles, and a lack of access to trusted sources of
383 information and resources spanning different hierarchical levels can negatively influence a community's
384 ability to cope with external shocks (Bodin et al., 2006; Bodin and Crona, 2008; Bodin and Crona, 2009).

385 Additional opportunities for cross-village interactions across the Velondriake region may help to bolster
386 trust across villages and fishing families, which would likely enable greater rule compliance and
387 adherence to norms, thereby having a positive net effect on local ecosystem service flows. Efforts to build
388 ties and trust between the community and the local university should also be a priority, as the university
389 represents a key source of scientific information and resources that can aid in enhancing the adaptive
390 capacity and resilience of the LMMA, particularly in the face of climate change. Similarly, the local
391 government is a trusted source, yet has not been involved in the LMMA management. Finding ways to
392 involve local government and increase interaction with the local university would be particularly
393 important for the long-term sustainability of the LMMA if NGO capacity in the region were to decline.

394 Turning now to social capital as an ecosystem service, our results show that the vast majority of
395 respondents felt the community based-management institution delivered valuable social capital gains.
396 Respondents prioritized high levels of social cohesion over both commercial fisheries and short-term

income from fishing (Table 3), suggesting they were willing to make trade-offs to support increases in social capital. Though some respondents strongly valued cultural bequest [see Oleson et al. (2014) for a more thorough discussion on bequest values in this study site] and some fishing in our ranking and rating game, the largest group of respondents prioritized social cohesion only second to bequest after the fourth and final round (Figs. 4 & 5). Taken together, the results of the DCE and ranking and rating game suggest that social capital is an essential ecosystem service that is valued by the local community and is being augmented by the community-based management institution. This represents an important finding, as it provides empirical evidence of the feedback relationship between ecosystem services and social capital and the value of social capital as an ecosystem service.

Our results, coupled with existing research on the manner in which environmental decision-making can impact social capital (Burke, 2010; Wagner and Fernandez-Gimenez, 2008), highlight the importance of assessing stocks and values of social capital and the manner in which they are tied to ecosystem service flows. Yet we acknowledge there is some difficultly in determining how this information can be used to support on-the-ground management, which we consider a critical step in its operationalization. One issue stems from the nature of social capital values being inherently tied to multiple ecosystem services, making it difficult to parse out and tie to specific ecological attributes that are ready targets for management. Though perhaps heightened due to the multidimensional nature of social capital, this challenge is associated with nearly all ecosystem services. Cultural services in particular are known to derive from multiple ecosystem functions and simultaneously provide varied, interrelated benefits (Satz et al., 2013) that themselves can have diverse values (Chan et al., 2011). Nevertheless, our results indicate that social capital values are critically important – in some cases perhaps even more so than other ecosystem service values. Information on potential impacts to social capital, social capital benefits, as well as social capital's role in successful outcomes could therefore be important inputs for negotiations and deliberative decision-making with relevant stakeholders (Satz et al., 2013).

7. Conclusion

In this paper we attempted to carve out the relationship between social capital and ecosystem services, and provided an initial example of how social capital can be assessed and valued as an ecosystem service. There is still much work to be done, both in further investigating the feedback relationship between natural and social capital, and in determining relevant strategies for operationalizing social capital. Operationalization of social capital in the ecosystem services framework involves agreeing upon common categories and metrics that can be flexibly applied across contexts, and strategies for using the results to guide adaptive natural resource management. Though our results provide some insight into the presence of the diverse types of social capital (i.e., bonding, bridging, and linking), we did not explicitly incorporate relevant indicators for these in our measurement framework, and were therefore unable to determine if they perhaps held diverse values. How people value bonding, bridging, and linking social capital facilitated by ecosystem services flows is an important area ripe for future research, as existing evidence indicates there may be trade-offs associated with them, i.e., an increase in one type, such as bridging, may occur at the expense of another, such as bonding (see Bodin and Crona, 2009). Such endeavors would help us to understand how environmental decisions may impact the flow of these diverse benefits.

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Figure Captions

Fig. 1. Feedback relationship between natural capital and social capital. Additions to social capital are conceptualized as an ecosystem service (top arrow); and social capital can in turn directly affect natural capital by facilitating collective action and effective ecosystem management (bottom arrow). This reciprocal relationship illustrates a degree of complementarity between natural and social capital, implying that they are not necessarily substitutes as might be formulated in a simple production functions.

Fig. 2. Map of Velondriake, Madagascar. Adapted from Barnes-Mauthe et al. (2013).

Fig. 3. Existence of trust among respondents toward different groups, expressed as a percentage of respondents.

Fig 4. Hierarchical clustering of ecosystem service ratings after the final round (round 4). A. Dendrogram of Euclidean distance among each subject's ecosystem service ratings, with three major clusters highlighted and named: "Fishing First", "Bequest First", "Diverse Values". B. Principal Components Analysis (PCA) biplot of cluster centroids, showing both subject ratings and service loadings along PC1 and PC2. C. Mean ecosystem service ratings by cluster, as proportion of total rating value for rating round 4 (i.e. given 20 beans, what average proportion of beans was scored for each ES, according to each cluster).

Fig 5. Mean cumulative proportional ratings of each ecosystem service in the ranking and rating game across four rounds. Each line represents a different round (1-4), with the final round emphasized in bold. Each subject was given 5 beans in each round to score against the nine listed services. Here we display the cumulative total score proportional to total beans scored. Adapted from Oleson et al. (2014).

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