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Insights from experimental economics on local cooperation in a small-scale fishery management system

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ABSTRACT

Cooperation is central to collective management of small-scale fisheries management, including marine protected areas. Thus an understanding of the factors influencing stakeholders' propensity to cooperate to achieve shared benefits is essential to accomplishing successful collective fisheries management. In this paper we study stakeholders' cooperative behavioral disposition and elucidate the role of various socio-economic factors in influencing it in the Roviana Lagoon, Western Solomon Islands. We employed a Public Goods Game from experimental economics tailored to mimic the problem of common pool fisheries management to elucidate peoples' cooperative behavior. Using Ostrom's framework for analyzing social-ecological systems to guide our analysis, we examined how individual-scale variables (e.g., age, education, family size, ethnicity, occupational status, personal norms), in the context of village-scale variables (e.g., village, governance institutions, group coercive action), influence cooperative behavior, as indexed by game contribution. Ostrom's framework provides an effective window for conceptually peeling back the various socio-economic and governance layers which influence cooperation within these communities. The results of our research show that the most important resource user characteristics influencing cooperative behavior were age, occupation and beliefs about giving access to others to fish for commercial gain. Through elucidating the factors affecting stakeholders' propensity to cooperate to achieve shared benefits, our analysis provides guidance in understanding cooperation in relation to collective management of marine resources.

1. Introduction

Researchers have stressed the importance of developing a standardized methodological approach for studying complex social and ecological systems (Basurto and Ostrom, 2009; Glaser et al., 2012), although they caution against using local panaceas for solving governance and resource use problems in resource management globally. Particularly, as emphasized in this volume, Ostrom (2007) developed a diagnostic multi-tier framework as a starting point in the analysis of social and ecological systems. This framework allows researchers to conceptually peel back the various socio-economic and governance layers existing within social and ecological systems and to identify the characteristics in social self-organization that lead these to sustainability or not. In her analysis, she identifies four core characteristics (or sub-systems) of social and ecological systems: a resource system (e.g., fishery, forest), the resource units (e.g., fish, trees), the users and stakeholders, and a governance structure. These sub-systems are embedded within social, economic, and political settings and associated ecosystems, and, in turn, produce a series of interactions and outcomes. Each of these sub-systems is composed of second-tier variables that can occur at multiple scales that may be used to address specific interactions affecting particular social and ecological systems. One such interaction is cooperative norms and behavior, and there are many demographic, socioeconomic and resource-related variables suggested to influence people's decisions to cooperate including the size and productivity of the resource system, resource unit mobility, collective-choice rules, leadership, monitoring and enforcement, and social capital.

Fundamental differences in the relationship between diverse users and natural resources can lead to significantly dissimilar behavior regarding resource exploitation or conservation. For instance, Atran et al. (1999) report that three distinct groups in northern Guatemala, which are dependent on a common resource, display very different resource use behavior and cognition, making any uniform conservation prescription very challenging. Even

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when groups are not ethnically or linguistically distinct, characteristics of users and the history of their interactions can impact social dynamics and collective action outcomes in important ways (Barr, 2003; Gurven et al., 2008). Given that conservation and natural resource management policies are largely contingent upon inducing changes in human activity and are thus intrinsically social phenomena, a key determinant of their efficacy is a grasp of the nature of human psychology, decision-making and behavior in the context of cultural institutions (Dimech et al., 2009; Suuronen et al., 2010). A comprehensive understanding of how and why different factors influence stakeholders' behavior in regards to natural resource management is therefore vital to designing and implementing effective management interventions.

Knowledge of the constraints and drivers on different elements of human behavior aids in predicting likely responses to new policy, and enables crafting of management activities to align with stakeholders' needs and aspirations, hence fostering positive attitudes toward conservation. However, the range and relative role of factors which influence human behavior in relation to natural resource management in general remains poorly understood (Anderies et al., 2011; Milner-Gulland, 2012; St John et al., 2010; Vollan and Ostrom, 2010). This is especially true in regards to stakeholder engagement in collective management of small-scale fisheries, including marine protected areas, and a number of authors (e.g., Christie, 2004; NOAA, 2005) have highlighted the issue as a critical area of research urgently requiring attention. In sum, central to stakeholders' behavior in regards to co-management or community-based approaches to managing small-scale fisheries is cooperation.

In this paper we study stakeholders' cooperative behavioral disposition and elucidate the role of various socio-economic factors in affecting it in the Roviana Lagoon, Western Solomon Islands (Fig. 1). We employed a Public Goods Game from experimental economics tailored to mimic the problem of common pool fisheries management, and survey data on demographic characteristics and perceptions of fishing access rights to examine how individual-scale variables (e.g., age, education, family size, ethnicity, occupational status, personal norms), in the context of village-scale variables (e.g., village, governance institutions, group coercive action), influence cooperative behavior, as indexed by game contribution. Individual-scale variables like wealth and education may affect the costs of public goods provisioning or the benefits of short-term defection, and so wealthier and more educated individuals who can obtain resources more readily can expect to be more generous. However, the educated and wealthy may represent a self-selected minority of striving, self-interested individuals, especially in developing countries where advancement opportunities are limited. In this case, education and wealth may associate with less willingness to contribute to the commons. Ethnicity and religion might influence cooperative behavior in villages where heterogeneity may impede coordination and increase transaction costs (Leigh, 2006; Letki, 2008). Other resource user characteristics, such as age, social status and family size, might also impact decision making due to effects on time preference, resource demand, perceived benefits of signaling behavior on reputation, and opportunity costs.

In addition to strategic behavior, as measured by individual-scale variables, village-scale variables should capture differences in norms and institutions that shape important features of people's choices in the context of social and ecological systems. These form the rules and playing field by which stakeholders interact and engage with each other, and shape expectations of others' behavior, potential sanctions and reputational dynamics. Villages may therefore differ in their willingness and ability to participate in pro-social behavior and conserve local resources (Barr, 2003; Gurven et al., 2008; Lamba and Mace, 2011). In sum, cooperation is central to collective action for the creation of marine protected areas in particular, and for small-scale fisheries management in general. Because the Public Goods Game mimics the kind of collective action problem typical of fisheries management, it may be a useful tool to provide insights into the conditions which may foster community-based and co-managed marine protected areas. Additionally, the Public Goods Game may be useful as a diagnostic tool to provide insights into obstacles to cooperation that are specific to certain villages or regions.

2. Methods

To gauge stakeholders' cooperative behavioral disposition and the factors which may affect it, we drew on Ostrom's (2007) diagnostic framework to inform our study design and used a simplified version of a voluntary contribution public goods game from experimental economics (Ledyard, 1995). The game is designed, in part, to understand prosocial behavior or voluntary actions such as sharing that can benefits others or groups (Gurven and Winking, 2008) and it examines people's behavior when individual and group interest conflict with each other (Andreoni, 1995).

2.1. Study sites and sampling

Roviana was selected for this research because of our long-term research and work in the region spent designing, establishing, and expanding marine conservation and fisheries management initiatives in partnership with local communities (see Aswani et al., 2007). This joint effort, therefore, makes the Roviana region ideal for studying decision making processes as they relate to the management of common pool fisheries resources. Human exploitation of marine resources is vital for both protein and income for coastal communities in the region and in recent decades marine resources have been increasingly overexploited. To assist local communities to manage their marine resources, we worked together with traditional authorities to establish a series of preventative-management measures across villages in the Roviana, Vonavona, and Marovo Lagoons starting in 1999. The management sites were selected through a combination of locally driven assessments and socio-ecological research of local habitats and associated management needs. Temporal and permanent closures were selected following a perceived decrease in fish and shell size and abundance driven by fishing pressure, site preferences, and village proximities (see Aswani et al., 2007). The social and ecological characteristics of this region in tandem with local conservation initiatives made this area an ideal candidate for experimental economics research.

Between 5 and 30% of men (depending on hamlet size) across seven villages and one regional town (Noro) between the ages of 40 and 70 years ($N = 171$) were asked to participate in the Public Goods Game and an associated questionnaire in July and August 2004 in the Roviana region. Only men were selected because they are in charge of most resource governance and management decisions and because of limited research time and resources. The sampled villages, all located within the Roviana and Vonavona Lagoons (Fig. 1), were selected due to their characteristics regarding levels of modernization, access to markets, land and sea tenure system, social and religious heterogeneity, and existence of marine protected areas (all have these barring Noro Town). Generally, Baraulu, Nusa Hope, Kozou, Olive, and Saika hamlets are the least modernized, are more socially homogenous, and have strong traditional governance. Dunde and Kekehe are more socially heterogeneous and have mid-level modernization and weak traditional governance. Noro town is semi-urban, socially diverse, and has no traditional governance area.

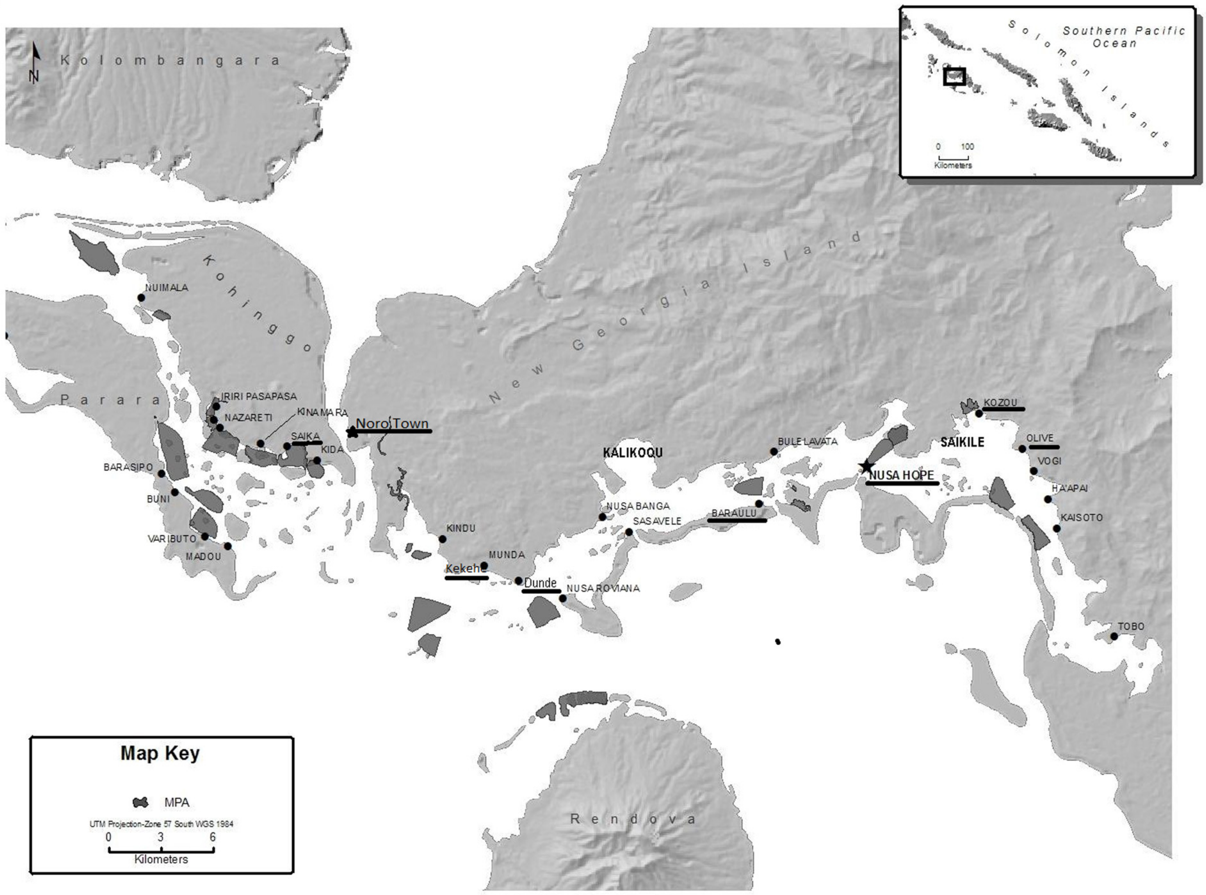

Fig. 1. Marine Protected Area network in Greater Roviana, Western Solomon Islands.

2.2. The public goods game

The Public Goods Game involved giving participants a sum of money which they could keep or put all or a fraction in a common pot (i.e., public good), with the payoff they receive at the end of the game depending on the actions of all players. Games were played in groups of four but players did not know the identity of others in their group. Participants from each hamlet were given $15 SBD (Solomon Dollars) (equivalent to around 2 US dollars, or ½ day wage labor) and they were told that they could anonymously contribute any portion of their donation to a village common pot (i.e., public good). The framing of the public good contribution was described in terms of preserving the marine commons, whereas no contribution was described as analogous to fishing only for private gain.

Participants were instructed that the contributed funds would be doubled and that the total in the common pot would be equally distributed to all participants regardless of their initial contribution. For example, if participants separately cooperated and contributed their $15 SBD, they were expected to receive a payoff of $30 each. However, individuals may free-ride and contribute little to the common pot; regardless of others' actions (especially if they expect that others will do the same). That is, free riders who contribute nothing to the common pot profit the most because each $1 put in the pot returns a marginal gain of 2×$1/(4 players) = $0.5. As $0.5 is less than the sure $1 a free-rider could keep for himself, it is expected that self-interested money maximizers will free ride and under contribute to the public good (Camerer and Thaler, 1995). A payoff structure of this type can result in a situation in which participants will sacrifice the public good in an attempt to maximize their return, especially in groups where there is mistrust. If everyone does the same this results in a tragedy of the commons, or a state of shared defection and economic paralysis. Each player had to answer four test questions correctly to insure understanding, and for their game behavior to count. Five SDB was given to each player for attending the game regardless of whether they correctly answered the test questions.

Then, players were gathered at schools or common assembly grounds where the instructions of the games were given and translated into the local language. A visual aid was presented when describing the different payoff scenarios to highlight the range of possible outcomes. During the briefs, the game was explained to participants using a framing that explicitly incorporated a fisheries (marine protected area) context. Players were told they would be given a fishing quota of 15 fish (i.e., per week) and by abstaining from part of their weekly fishing quota they could let the fishing population increase (by allowing those fish to grow and reproduce) at the end of the year thus increasing the individual fishing quota the next year. The profits of any increase in the fishing quota would be equally distributed to each participant in the group, regardless of individual contribution to the growth of the fish population. Participants were randomly and anonymously divided into groups of four to play the game. Each player was then called into a private room in a random order, where he was instructed to place his bid. Before the bid was placed a few questions were asked in order to ensure that the participant understood the instructions of the game. At the end of the game, individual payoff was calculated and cash distributed accordingly to all participants the same day.

2.3. Potential factors affecting cooperation

We collected information on nine resource user characteristics which fall under three of the second-tier categories of Ostrom's (2007) framework, namely socioeconomic attributes of users, norms and importance of resource (Table 1). We additionally collected data concerning the resource governance system, specifically the property rights system. The indicators used to operationalize this second-tier variable were perceptions about fishing access rights to members of neighboring groups: whether others should be allowed to fish in local territory only for personal consumption or for commercial gain (i.e. cash). These two perception questions provided insights into stakeholders' mental models regarding access rights to marine resources.

2.4. Data analysis

We assessed the ability of resource user characteristics (explanatory variables; Table 1) to predict the amount players contributed in the Public Goods Game (response variable) by fitting a generalized linear mixed model (GLMM; Zuur et al., 2009) with a Poisson distribution. Village was set a priori as a random factor due to the hierarchical nature of the data (respondent nested in village). The need to account for inter-village variation was confirmed by analysis of village-level residuals using a caterpillar plot, which indicated that the village-specific contribution amount for the majority of villages differed significantly from the global mean. We also included two interactions; between access for cash and ethnicity, and between access for subsistence and ethnicity, to explore whether ethnic group members with similar beliefs might behave differently in the Public Goods Game. Continuous variables were standardized by subtracting their mean and dividing by two times their standard deviation; variables thus take $a \pm 0.5$ value, and are on the same scale as binary variables, easing comparison of relative effects of variables bearing different units (Gelman and Hill, 2007). Explanatory variables were checked for multicollinearity by calculating Spearman's correlation coefficients (for numerical values) and variance inflation factors (VIF). If a pair of variables had a correlation coefficient of >0.6 we removed the variable which had the highest VIF. Subsequently we also removed variables which had a VIF of >5 (Logan, 2010).

We adopted an information-theoretic approach to model selection because it enables model uncertainty to be quantified and accounted for and inference can be based upon a number of models (multi-model inference) rather than one model that is estimated to be the best (Burnham and Anderson, 2002). Model selection under an information-theoretic approach is undertaken by simultaneously comparing and subsequently ranking models based on Akaike's information criterion (AIC; Akaike, 1974). Decreasing AIC values indicate increasing model parsimony relative to all other possible models in the set (Burnham et al., 2011; Johnson and Omland, 2004). Further, a measure of the likelihood of the model given the data is calculated (i.e., Akaike weight or ω), which provides an estimate of the relative weight of evidence for each model. If no model is overwhelmingly supported by the data (i.e., every model has a $\omega < 0.9$), it is suggested that model averaging be used (Burnham and Anderson, 2002; Grueber et al., 2011). Model averaging provides weighted parameter estimates based on the entire set of possible models or a subset of 'top' models which can be determined by various criteria.

Next, we used AIC adjusted for small sample size and over-dispersion (i.e., $QAIC_c$; Lebreton et al., 1992) to rank candidate models. Over-dispersion was detected for our global model (all variables except those removed due to multicollinearity); the variance inflation term was <4 and thus warranted the use of $QAIC_c$ (Burnham and Anderson, 2002; Zuur et al., 2009). Given that no model had a $\omega > 0.9$, we derived parameter estimates by averaging across a subset of candidate models with changes in $QAIC_c$ units <3 (i.e. $\Delta QAIC_c < 3$) of the model with the lowest $QAIC_c$. Explanatory variables were ranked according to their relative importance by summing the Akaike weight from all model combinations containing that variable. Further parameter estimates were given by a weighted average of the parameter estimates in the subset of models according to the ω of each model. Model averaging also provides estimates of uncertainty for parameters (i.e., unconditional standard errors), which account for model selection uncertainty and sampling variance (Burnham and Anderson, 2002). All analyses were conducted using R software (version 2.15.0).

3. Results

Solomon Islanders contributed between 0% and 100% of their endowment to the common pot or public good, and the average contribution for each village was between 33% and 67%. The contribution distributions were often bimodal, and varied among villages. Age and stated beliefs about whether neighboring villagers should have access to fishing resources for commercial gain (i.e., cash) were the most important predictors of Public Goods Game contribution, followed by occupation and ethnicity (Fig. 2). Despite the appearance of inter-village differences in Public Goods Game contributions, inter-village variation accounted for only

Table 1
Characteristics of resource users and resource governance system used as explanatory variables to model contribution in the public goods game. Indicators are organized according to Ostrom's (2007) diagnostic framework for examining social-ecological systems.

Ostrom's diagnostic framework components	Indicators	Description
Users (U)		
U2 Socioeconomic attributes of users	Age	Age of player
	Education	Junior or high school attendance
	Number of children	Number of children of player
	Marital status	Single or married
	Household income	Total household income for all members
	Personal income	Personal income of the player
U6 Norms/Social capital	Ethnicity	Roviana, mixed-Roviana and non-Roviana
	Religion	Traditionalist Roviana (CFC), mainstream-Roviana (United, Methodist, SDA) and other churches (new evangelical churches)
U8 Importance of resource	Occupation	Engaged in subsistence activities or employed by the government or private company
Governance system (GS)		
GS4 Property rights systems	Access rights-consumption	Whether players believe that people from neighboring tribes can fish for food in their village's territory
	Access rights- cash	Whether players believe that people from neighboring tribes can fish for cash in their village's territory

Table 2
The 12 candidate models selected to describe the relationship between resources user characteristics and contribution amount given in the public goods game.

Model rank	$QAIC_c$	ω	Age	Education	Marital status (married)	Ethnicity (non-Roviana)	Ethnicity (mix-Roviana)	Household income	Access for cash	Access for subsistence	Occupation
1	205.01	0.20	×						×		×
2	205.39	0.17	×						×		
3	207.01	0.07	×		×				×		×
4	207.10	0.07	×						×	×	×
5	207.18	0.07	×					×	×		×
6	207.18	0.07	×	×					×		×
7	207.23	0.07	×		×				×		
8	207.48	0.06	×			×	×		×		
9	207.50	0.06	×					×	×		
10	207.53	0.06	×						×	×	
11	207.54	0.06	×	×					×		
12	207.56	0.06	×			×	×		×		×
Relative importance			1.00	0.13	0.14	0.12	0.12	0.13	1.00	0.13	0.54
Model average			+0.27 ± 0.06	+0.01 ± 0.05	−0.08 ± 0.09	−0.16 ± 0.09	−0.24 ± 0.10	+0.01 ± 0.06	+0.20 ± 0.04	−0.02 ± 0.06	+0.25 ± 0.08

Models are ranked by quasi-Akaike's information criterion ($QAIC_c$), with all models within $\Delta QAIC_c < 3$ of the top ranked model. The relative weight of evidence for each model is indicated by Akaike weight (ω), and the variables present in each model is indicated by an ×. The parameter estimates and unconditional standard errors averaged over the 12 models are given along with the relative importance of each variable based on the sum of Akaike weights of the models in which the variable is present.

5.42% of the total variance, indicating that villages overlapped considerably in the distribution of Public Goods Game contributions; differences between villages did not have a large effect on the amount people contributed in the game.

In terms of the individual-scale predictors of Public Goods Game contributions, the modeling yielded 12 models within $\Delta QAIC_c < 3$ of the top model (Table 2), indicating some model uncertainty. The most parsimonious model ($\omega = 0.2$) contained age, access to cash, and occupation, and was 1.18 times more plausible than the next model ($\omega = 0.17$), which eliminated occupation. As stated above, the most important resource user characteristics influencing contribution amount were age and beliefs about whether neighboring villagers should be entitled to have access to fishing resources for cash; both variables were present in all of the top 12 models and were equally important with a relative importance value of 1 each (Table 2). The positive parameter estimates of these two variables (age = 0.27 ± 0.06 and access for cash = 0.20 ± 0.04) indicate that a belief in sharing access to fisheries resources with neighboring villagers for the purpose of selling, and older age are associated with greater commons contributions in the game.

The effect size of occupation was large, with those players employed by the government or a private company contributing more (on average 15% more) than those employed solely in subsistence activities. However, the confidence intervals for occupation were a lot wider than those for age and access for cash, and this was reflected in its relative importance score (i.e., 54%) compared to the other two variables. Ethnicity had a relatively weak effect on contribution amount (relative importance of 0.12), with those with mixed-Roviana heritage giving less than those solely from Roviana. There was little difference between the contributions of non-Roviana and Roviana players, as indicated by the confidence intervals overlapping zero. While education, marital status, household income and access for subsistence were present in the top 12 models (Table 2), their confidence intervals overlapped zero (Fig. 2), indicating that they have little effect on contribution amount. Personal income and household income were highly correlated ($r_s = 0.79$), as were age and number of children ($r_s = 0.68$); we removed personal income and number of children because they both had the highest VIF of the respective pairs, VIF = 3.92 and VIF = 2.52, respectively. Religion and the two interactions examined (i.e., access for cash × ethnicity and access for subsistence × ethnicity) were not significant in the global model and were not present in the top ranked models.

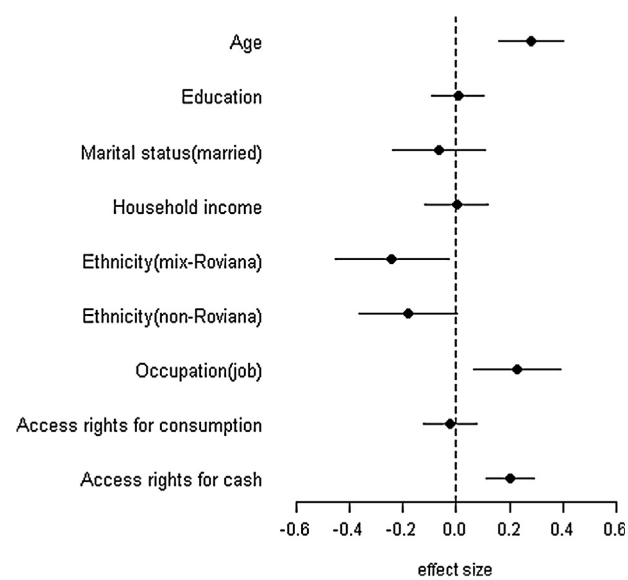

Fig. 2. Model-averaged effect size and 95% confidence intervals for the effect of resource user and governance system characteristics on contribution amount given in the public goods game. Intersection of confidence intervals with zero indicates lack of effect of the relevant user characteristic on contribution amount. The reference category for marital status, ethnicity (both levels) and occupation are single, Roviana, and subsistence, respectively. For example, players employed in a job tend to give more than those engaged in subsistence activities. Note that religion and the interactions, access for cash × ethnicity and access for subsistence × ethnicity, were not significant in the global model and were not present in the top 12 models selected for model averaging (Table 2), indicating that they have no impact on contribution amount.

4. Discussion

Given that cooperation between stakeholders is integral to the success of community-based and co-management approaches to marine protected area management, an understanding of the factors influencing people's propensity to cooperate to achieve shared benefits is essential. Using Ostrom's (2007) diagnostic framework to guide our study, we examined the role of individual-scale resource user characteristics and aspects of the governances system in influencing stakeholders' cooperative behavioral disposition, as indexed by contributions in a public goods game in eight villages across the Roviana and Vonavona lagoons, the Solomon Islands.

We found that users and governance system characteristics influenced contribution amount. The most important indicators were age, occupation and a belief in sharing access to fishing resources with neighbors, which represent the following second-tier variables of Ostrom's framework: socioeconomic attributes, importance of resource and property rights systems, respectively. A belief in sharing access to fisheries resources with neighboring villagers for the purpose of selling, and older age are associated with greater Public Goods Game contributions. Several studies employing experimental economic games similarly found that prosocial behavior is positively correlated with age (e.g., Bellemare et al., 2008; Lamba and Mace, 2011). Older men were likely to have larger families and in general are more likely than younger men to not discount the future and to be concerned with securing future fish populations. Village chiefs, leaders and respected elders are often older men who play an active role in insuring local norm adherence. The relationship between game contribution and beliefs related to access to fisheries for commercial gain was not expected. We predicted that stakeholders who endorsed granting access to others for commercial use of local fisheries would be less concerned with protecting the commons for exclusive local use, but we found instead that contributions were higher in the Public Goods Game among those most generous to outsiders. It is possible that permitting others to fish in their waters and greater Public Goods Game contributions are instead both aspects of a pro-social disposition for building social and political capital. It is also possible that those most amenable to permitting fishing access to others expect to be reciprocally granted similar access by others to exploit a larger range of fishing areas. Lastly, we found that men working for wages from government or private employers gave more in the Public Goods Game than did those engaged in subsistence activities.

Greater market involvement, commercial fishing and reduced dependency on the subsistence economy are usually viewed as detrimental to conservation (Cinner et al., 2012; Godoy, 2001); increasing reliance on local fisheries to secure a livelihood should associate with increasing concern for fisheries preservation. Instead, our results may suggest that wages can be consistent with or even promote fisheries management. A possible explanation (but untestable given our data) is that those working non-subsistence jobs may have had more prior exposure to conservation organizations and other NGOs that highlight the importance of favoring the commons.

Also noteworthy are the factors that were indicated by the analysis to have little effect on game contribution. The second-tier variable shared norms, which were represented by ethnicity and religion, had little effect on game contribution. Religion virtually had no effect on contribution amount as indicated by its absence in the top models, while ethnicity had a relatively weak effect on game contribution, with those of mixed ethnicity giving less than those of full Roviana heritage. In the Solomons, mixed-ethnicity often results in diffuse property rights, whereas clan-specific land claims often require full heritage (Aswani, 1999). Lower Public Goods Game contributions among mixed-ethnics are therefore consistent with potential land and property insecurity. Socioeconomic attributes of users, other than age, such as education, marital status and household income were not substantial predictors of Public Goods Game contributions. Previous studies which have employed experimental economic games have found inconsistent trends regarding the relationship between players economic situation and prosocial behavior. For example, Burns and Visser (2007) found that players with higher income behaved more cooperatively in a Public Goods Game, while Lamba and Mace (2011) found that multiple measures of wealth had little effect on Public Goods Game contribution, and Cardenas (2003) reported negative correlations between wealth and prosocial behavior. Hayo and Vollan (2012) contribute to understanding these inconsistencies by suggesting two mechanisms by which income may affect cooperation: (1) 'the basic needs hypothesis' whereby high income players are less needy and thus act more cooperatively, and (2) 'the behavioral type hypothesis' whereby high-income players have become wealthy through behaving selfishly and hence also behave selfishly in games. Although, we found no relationship between income and Public Goods Game cooperation, we cannot disregard the effect of economic factors on cooperation as we did not assess the impact of other economic measures, such as wealth, immediate demand for money, or market integration. Further, the lack of influence of wealth on contribution amount could be because variance in the wealth indicator was not large; although household income ranged from \$200 to \$40,000, 75% of players had a household income of less than \$10,000.

Inter-village variation accounted for only 5.4% of the variance in Public Goods Game contributions, indicating that differences between the villages did not have a large effect on the amount people contributed in the game. While we did not explicitly examine the role of village-scale resource user characteristics on players' contribution amount (our sample size of eight villages was too small to make robust statistical inferences), from our knowledge of the study area we expected that differences between villages would be important in predicting Public Goods Game contributions; the social and historical context, as well as success in marine protected area management differ substantially between the surveyed villages. For example we predicted that religious and ethnic homogeneity would favor prosocial behavior amongst players and that free-riding would be more common in socially heterogeneous villages. Ethnicities might share different cultural understandings, rules, norms and other contextual factors that could affect trust and expectations, and facilitate collective action (Castillo et al., 2011). However, we found that village-scale characteristics, such as ethnic homogeneity, had little effect on contribution amount compared to individual-scale characteristics. It is possible that the combination of marine protected area presence in the study villages, the fisheries framing of the Public Goods Game, and its administering by the authors (associated with the marine protected areas) may have helped minimize village differences in Public Goods Game contributions. A parallel study in the same area (Mills et al., in press), which examined the association of village-scale and household-scale variables with the presence of marine protected areas, similarly found that village-scale data was less important in predicting the presence of collective marine management than household-scale data.

The villages of Baraulu, Nusa Hope (Patmos), Kozou, Olive, and Saika are the least modernized, more socially homogenous, and have strong traditional governance, and thus we expected greater contributions to the public good by their inhabitants. However, only Saika and Nusa Hope players displayed general prosocial behavior through higher contributions per player, while Baraulu, Olive, and Kozou participants unexpectedly contributed substantially less on average. The population of these villages ranges from 50 to 1000 inhabitants and the majority of households rely on subsistence agriculture and fishing for the bulk of their nutrient intake. Cash is generated by diving for marine products or selling fish and vegetables, among other activities. These villages are surrounded by rich habitats, including extensive forests on the New Georgia mainland, expansive coral reefs and estuaries, and sustained fertile gardens on the barrier islands. However, logging and marine resource over-exploitation has degraded marine and terrestrial ecosystems to some extent. In response, local authorities, with our technical and financial support, established marine protected areas to manage marine resources (Aswani et al., 2007). Further, the most successful marine protected areas are found in Nusa Hope, Kozou and Saika, while those in Baraulu and Olive are less successful in terms of fish biomass, poaching incidents, and the function of village Resource Management Committees. Dunde and Kekehe are more culturally heterogeneous than the other hamlets, which are largely due to their history of missionaries, European colonial policies, the effect of WWII, and inter-marriage with foreigners. The Dunde and Kekehe people's history of engagement with the Western world has predictably increased their fear of outsiders, while simultaneously neutralizing their capacity to manage their marine resources autonomously due to eroding of pro-social behaviors, as confirmed by their lower contributions in the Public Goods Game. In sum, Dunde and Kekehe inhabitants cannot translate governance into actual marine protected area management because of the erosion of indigenous social and political institutions caused by conflict over natural resources between Dunde and Kekehe people, outsiders, and neighboring groups with overlapping rights.

Finally, Noro Town is the third biggest urban center in the Solomon Islands with a population of several thousand. Noro Town inhabitants are a mixture of groups from around the Western and Eastern Solomons and immigrants from the Gilbert Islands (Micronesia) brought by the British Government between the 1950s and 1970s. Noro was established in the 1970s as a cannery for a nascent tuna fishery industry in the Solomons. The area's cultural heterogeneity of the various migrant groups and increasing urbanization has rendered the customary sea tenure over the surrounding reef moribund thus making the establishment of a marine protected area virtually impossible. This is reflected in the Public Goods Game results which show inhabitants of Noro as having the lowest pro-social behavior of all villages.

When evaluating the management implications of studies which employ experimental economic games as proxies for public goods management, such as this one, it is crucial to consider whether behavior in the game actually reflects players' real-world behavior (Gurven and Winking, 2008). Experimental economic games are highly simplified models of the real-world decision making environment (Castillo et al., 2011; Travers et al., 2011). While this simplification of the social and ecological system is necessary to disaggregate the system into manageable components, it affects the external validity of game results. Few studies have examined whether behavior displayed in experimental economic games reflects real-world behavior (Vollan and Ostrom, 2010); the conclusions of those that have are mixed, with some finding correspondence between players' behavior in the game and the real-world (e.g. Rustagi et al., 2010) and others not (e.g., Gurven and Winking, 2008). Expecting similar behavior across contexts or situations assumes stability in pro-social motivations and behavior. However, even in the domain of economics games, only a proportion of individuals are consistent cooperators or defectors, while the majority tend to respond sensitively to variation in costs and benefits and other conditions of the public goods situation (Kurzban and Houser, 2005). Thus, one-shot games may not be very useful at discerning behavioral types. While we framed our Public Goods Game in a fisheries context, players may not have behaved as they would have in a real-world cooperation dilemma because of the absence of many contextual factors.

Further, caution should be exercised when interpreting the relationship between elements of the social and ecological systems from experimental economics games. Given the difficulty of simultaneously addressing all elements of social and ecological systems, we sought to investigate the impact of only some of the second-tier variables from two subsystems (i.e., 'users' and 'governance system') of Ostrom's (2007) framework. Since we conducted our study within one region of the Solomon Islands, we were able to control for the two other subsystems, 'resource system' and 'resource units'. However, there are many other aspects of the two subsystems that we did investigate which may influence cooperation, in particular characteristics of these systems at a village-scale. Village-scale resource user characteristics can have a significant impact on cooperation, for example ethnic or religious variability has been found to both enhance (Santos et al., 2008) and diminish (Habyarimana et al., 2007) social cohesion and cooperation in public goods situations. Further, the relationship between cooperation and resource user characteristics may manifest differently at a village-scale as opposed to the individual-scale. For example, Hayo and Vollan (2012) found that while individual wealth had no effect on cooperation, there was a negative effect of unequal group wealth distribution on cooperation. However, while Ostrom's framework describes a multitude of factors which influence social-ecological systems, the intention of the framework is not to prescribe that all these factors should be examined simultaneously, as not all components apply to every system (Ostrom, 2007). Rather, it provides a common language for researchers from various disciplines to allow them share and compile their research to advance understanding of social-ecological systems.

In sum, given that cooperation between stakeholders is integral to the success of community-based and co-management approaches to marine protected area management, an understanding of stakeholders' cooperative behavioral disposition and the factors affecting it is important for achieving successful collective fisheries management. We provide an approach to understanding cooperation through using a Public Goods Game in the context of Ostrom's (2007) framework to elucidate stakeholders' cooperative behavioral disposition and the socioeconomic factors affecting it. This is amongst the first papers to use a Public Goods Game in the context of small-scale fisheries management, and thus we introduce a new lens with which to study collective fisheries management. Further, through elucidating stakeholders' propensity to cooperate to achieve shared benefits and the factors affecting it, our analysis provides guidance in understanding cooperation in relation to collective management of marine resources. Using Public Goods Games tailored to specific commons problems in villages may be a useful pedagogical tool for illustrating the logic of public goods problems, and for discussing the potential relevance of village-specific effects encountered during data analysis. More work is needed to develop Public Goods Games as diagnostic and pedagogical tools. Additionally, a key area of inquiry critical to generating outputs relevant to managers and policy-making from this line of research is determining whether behavior in the game reflects players' real-world decisions about marine resources. Although we framed the Public Goods Game in a fisheries context, players' behavior in the game may not relate to their real-world decisions regarding fisheries. Further we demonstrate the utility of Ostrom's (2007) framework as a window for conceptually peeling back the various socio-economic and governance layers which influence cooperation. New research should look at the relative role of other characteristics of the subsystems of Ostrom's framework on cooperation, including village-scale resource user characteristics.

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