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# Strategically Integrating Human Dimensions into Marine Conservation Decision Making

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Marine Science

by

Rebecca Jean Twohey

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Strategically Integrating Human Dimensions into Conservation Decision Making

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# ABSTRACT

Strategically Integrating Human Dimensions into Marine Conservation Decision-Making

by

Rebecca Jean Twohey

There is a broad perception that many of the greatest knowledge gaps in marine conservation are in understanding and integrating human dimensions. Marine governance must go beyond the rhetoric that conservation will benefit from including human dimensions, and dig deeper into social science disciplines to find specific tools that may be useful. Bennett et al. (2017) advocate for "fostering knowledge on the scope and contributions of the social sciences to conservation" from the inception of conservation projects, during all stages of planning and implementation and at all scales, and encourage the mainstreaming of social science into conservation. However, the fractured nature of literature pointing to the importance of social science has left many unsure what is really important or what to do. This dissertation seeks to remedy this, first by mainstreaming how to strategically consider social equity, and second by learning from collective action studies.

Social equity is increasingly included in conservation mission statements – either because it is an intrinsic goal or because it is believed to have functional value to help reach other objectives. Until now, social equity has been vaguely defined, and therefore been difficult to include, monitor and evaluate in environmental governance. Chapter 1 presents a theoretical foundation for defining and distinguishing between different types of social equity and considering social equity's role in conservation outcomes. First, we introduce the

*equity landscape* as a way to describe the distributions of resources and participation rights in a society supported by social norms in a given community. We use case studies to illustrate how environmental management can benefit from considering the equity landscape in both short- and long-term strategy. Through collaborative efforts, we also describe social equity to include several dimensions – including participation (or input to conservation interventions), and spatial, access, and financial outcomes of a conservation intervention (Klein et al. 2015). Chapter 1 motivates collecting empirical evidence of how different types of equity are experienced in a community and their influence on stakeholder behavior.

Therefore, in Chapter 2 we investigate how fishers perceive and experience these different dimensions of equity, and how different dimensions of equity influence fisher compliance with social norms and willingness to punish defectors. Our interdisciplinary approach combines a behavioral experiment and surveys, and informs important decisions on critical design elements, such as should the intervention focus on participation, or outcomes of the intervention, such as access or financial benefits? Should equity objectives be equal or fair? And, how should managers measure these objectives? This research provides important empirical insight on how equity and conservation outcomes are interlinked and how management actions may influence stakeholder cooperation, thus presenting a unique insight into equity that is applicable to a wide range of settings.

Second, this dissertation highlights the potential benefits of integrating collective action literature in fisheries management. Most problems in fisheries management are rooted in some sort of tragedy of the commons. Understanding the conditions under which cooperation can emerge and how to create policies around those conditions is extremely important for successful fisheries governance. The collective action literature contains a wealth of knowledge on how diverse types of societies can solve cooperation problems and real-world management questions.

Chapter 3 investigates two such applied questions: Do self-assembled or randomly assigned groups cooperate better? And, if there are costs to random assignment, what strategies might help offset some of these costs? We show that self-assembly and the ability to communicate face-to-face both increase compliance with rules and punishment of defectors, although self-assembly has a greater effect.

This work is specific to artisanal fishing communities in Tañon Strait, Philippines, but provides an approach to solving questions managers have to make on a range of key issues that likely have big consequences on conservation outcomes. By combining interdisciplinary theory and methods, my dissertation highlights how social science can both integrate into and aid conservation efforts.

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# I. Defining and strategically considering social equity in environmental management

## Social equity is strategically important in environmental management

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**Summary**

Social equity is increasingly considered in environmental management plans, both for intrinsic and functional reasons. Here, we argue that equity plays an important strategic role in the success and failure of both short- and long-term environmental initiatives. A society's 'equity landscape'—its norms about, and distributions of, costs and benefits associated with resources and participation rights in decision making— may have strong inertia thereby influencing what types of management can be implemented. Thus, improving social equity may come at a short-term conservation cost, but can have compounding benefits over time. Environmental management will be most effective at achieving its environmental, economic, and social objectives when it strategically considers both the current equity landscape and its potential for change. We highlight how local equity, and the norms surrounding it, influence short- and long-term outcomes.

**Introduction**

Equity is increasingly recognized as an environmental management goal (FAO 2015), yet improvement in conservation outcomes has often not been coupled with improvement in socially equitable outcomes (Abreu et al. 2017). This raises the question: why not? One reason may be that equity is often considered in subjective and normative terms, often from an ethical, rather than a strategic, perspective, which belie its strategic importance. Compared to other aspects of conservation, little is known about its role in conservation success (Loomis and Ditton 1993; Miller et al. 2011; Halpern et al. 2013).

Local historical, political, and economic contexts matter in pursuing management objectives (Klein et al. 2015). These contexts create what we call an 'equity landscape'—a set of local norms that affect distributions of costs and benefits and participation rights in environmental management across class, gender, ethnicity, wealth and other social dimensions. The equity landscape characterizes the current distributions of resources and participation rights in a society supported by social norms. These factors influence what types of management are implementable in a society at a given time (Halpern et al. 2013; Morales and Harris 2014) by shaping the willingness and ability of local stakeholders and power brokers to participate in implementing new resource management plans (Brooks et al. 2013). For example, an equity landscape may promote equal access to a resource, such as in a publically managed forest, or it may support unequal access based on family lineage—such as in marine tenure systems (Ruddle et al. 1992). The social norms that shape an equity landscape may be subtle, yet it is only through explicitly recognizing these norms that an equity landscape can be understood (Morales and Harris 2014) and possibly challenged in order to benefit environmental management.

Here, we use case studies to illustrate how environmental management can benefit from considering the equity landscape in short- and long-term strategy (summarized in Box 1). Management plans that conform to the existing equity landscape tend to be easier to implement in the short term, which can create short-term tradeoffs between equity and other objectives (Halpern et al. 2013; Klein et al. 2015). In the long term however, any costs or benefits to management objectives of changing the equity landscape will compound, as changes in the equity landscape change what types of management will be most easily implemented in the future.

**Box 1**

| Social equity in environmental management strategy: Three considerations and examples | |
|---|---|
| 1. *What are the current equity norms and distributions of wealth, access, and power, and how do they affect what types of management work?* | Recognizing the market power of large international buyers of Brazilian soybean products, Greenpeace mounted successful campaigns targeting McDonald's and Cargill to combat deforestation in the Amazon, instead of working with local farmers (Tercek and Adams 2013). |
| 2. *How strong are the tradeoffs between pursuing short-term management objectives and maintaining the equity landscape?* | Stakeholder participation in the design of the marine protected area network under the California Marine Life Protection Act (CMLPA) was critical to its successful implementation (Weible, Sabatier and Lubell 2004), but stakeholder-proposed networks tend to be economically and ecologically inefficient, absent scientific guidance (Rassweiler et al. 2014). |
| 3. *What are the long-term consequences of changing the equity landscape?* | Increasing women's participation in African forest management may promote better long-term ecological and economic outcomes (Rocheleau and Edmunds 1997). In contrast, subsides to corn ethanol biofuels in the United States have created powerful lobbies that can hinder development of new alternative fuels, which may be more carbon-efficient (Fargione et al. 2008). |

## Short-term compromise

A society's equity landscape strongly influences what types of management can be implemented due to inertia—meaning equity landscapes tend to be self-reinforcing. Equity landscapes tend to reinforce themselves because communities are slow to adopt change (Castro and Batel 2006), especially when it involves the social norms and individual preferences associated with costs and benefits (Manfredo et al. 2017, Minato 2010). Moreover, changing the power structure of a community can meet resistance from current power brokers (Valente et al. 2015). The process by which people consciously and unconsciously draw on existing social and cultural arrangements to shape institutions in response to changing situations is known as 'institutional bricolage' (Cleaver 2001).

Management plans working within the existing equity landscape by conforming to current and familiar distributions of resources, access, and power, may face less sociopolitical resistance, thus expediting resource management actions in the short term. There may be incentive to change the equity landscape if conforming to it comes at a cost to achieving other objectives. When the current equity landscape poses challenges to the management objectives (which may include equity itself), compromise is key to balancing ideal outcomes with implementability. A plan that is implemented and achieves sub-optimal results may be better than a theoretically optimal plan that is never realized. The following examples illustrate such tradeoffs and compromise.

*Public works projects*

The locations and outcomes of public works projects, like renewable energy development and waste disposal sites, are often determined by a handful of people who do not reflect the will of the majority, but who have decision-making power. For example, renewable energy infrastructure projects have broad public support but have difficulty actually being implemented (Bell et al. 2005). In the UK, public opinion pools indicate the majority of people support wind power, but wind-power development projects are often blocked by a minority of decision makers who oppose it (Toke 2002). Similarly, in the United States when inactive hazardous waste disposal sites are both designated and cleaned up, it is often the marginalized or disadvantaged stakeholders who disproportionately take on the cost (Zimmerman 1993). These two examples of public works projects are implemented (or not) relatively quickly because they are following the path of least sociopolitical resistance (or not) by going through the designated decision making processes catering to an elite minority, despite having highly unequal outcomes.

*California Marine Life Protection Act (CMLPA)*

The California Marine Life Protection Act of 1999 required the Department of Fish and Game (now called the Department of Fish and Wildlife) to develop and implement a network of Marine Protected Areas (MPAs) along the California coast designed to increase the coherence and effectiveness of protecting the state's marine life, habitat, and ecosystems. MPAs are spatially explicit management tools that restrict the use and access areas of the ocean. The Department of Fish and Game failed twice to implement the Act. The first attempt caused public outrage because it involved only scientific experts and excluded input from affected stakeholders in the preliminary recommendations (Weible et al. 2004). The second attempt involved scientists and stakeholders, but was ultimately unsuccessful as well (Weible et al. 2004). The design and implementation of a network of MPAs was only possible when the Department of Fish and Game explicitly addressed participation equity and adopted a highly participatory process involving Stakeholder Working Groups (Weible et al. 2004). The CMLPA is regarded as a successful case study for participatory planning processes and program implementation (Weible 2006), yet it is likely sub-optimal from purely ecological or economic perspectives in the absent scientific guidance (Rassweiler et al. 2014). Thus, the CMLPA may provide an example of a management plan that navigated a tradeoff between implementability (associated with the equity landscape) and ability to meet other objectives.

*Greenpeace and Amazon deforestation*

In hopes of slowing deforestation from soybean agriculture in Brazil in the early 2000s, Greenpeace targeted key multinational buyers, McDonald’s and Cargill, rather than working directly with small-scale farmers (Tercek & Adams 2013). As a result, Cargill placed a moratorium on buying soy grown on land deforested post-2006. Farmers had to comply—not necessarily to their benefit—in order to sell their produce (Tercek & Adams 2013). The decision process and outcomes reinforced the existing unequal equity landscape, at the potential cost of social equity objectives, such as financial equality, but it was implemented quickly and was successful in slowing deforestation (Tercek & Adams 2013).

**Compounding effects of change**

Alternatively, managers may choose to change the equity landscape to build—though they occasionally diminish—important capacity for long-term resource management (Leisher et al. 2016). Inherent to changing the equity landscape is the challenge of "constituting, deploying, and normalizing" new power dynamics (Kesby 2005). Changing the equity landscape also affects what types of management are implementable in the future, the long-term tradeoffs between management objectives—including equity—will be fundamentally different than in the short term. An intervention that changes the equity landscape at a high short-term cost (in terms of failure, risk, time, capital investment, etc.) may be worthwhile in the long-term if the new equity landscape pays long-term dividends with respect to the management objectives (which may include aspects of equity itself). Conversely, management can sometimes change the equity landscape—usually inadvertently—in ways that diminish capacity for future management success. The following examples illustrate these points.

*Chilean bull-kelp (Durvillaea antartica) management*

An ill-considered change to the equity landscape can have long-term compounding costs. For example, the traditional management of bull kelp (*Durvillaea antartica*) in Chile was based on the allocation of informal access rights through a lottery system controlled by a complex web of traditional institutions that were shown to be successful in terms of equity and resilience (Gelcich et al. 2006). Its replacement by the 'parcela' co-management system caused long lasting negative social, economic and ecological impacts. Weakening of the traditional institutions shifted power structures and exacerbates differences between members' livelihoods and capabilities, which then negatively effects trust within the community and intensified conflict among users (Gelcich et al. 2006). The new system also has higher costs associated with decision-making, policy implementation, and permit applications, which makes fishers more vulnerable to disturbances and eliminates the incentives to maintain adaptive strategies (Gelcich et al. 2006).

*First-generation renewable energy technologies*

Many first-generation renewable energy technologies also provide examples of a management intervention inadvertently changing the equity landscape in a way that had adverse effects—in this case, on the future implementability of better, second-generation renewable energy technologies. Corn-ethanol biofuels, for instance, gained substantial government subsidies in the U.S., as one of the first biofuels (Sorda et al. 2010). These subsidies became the status quo (and thus part of the equity landscape) for U.S. corn growers who were already a powerful lobby group. Despite studies later finding that corn ethanol causes more carbon pollution than traditional fossil fuels, due to the amount of land required to grow the corn (Fargione et al. 2008), the public subsidies for corn ethanol as a 'clean energy' source have not been scaled back (Fiscal Year 2015 Analytical Perspectives).

*Scottish in-shore fishery*

It should be cautioned that management actions seeking to change the equity landscape may exasperate the existing inequities they aim to quell, and consequently diminish capacity for management success. For example, in 2009 the Scottish government implemented In-Shore Fisheries Groups (IFGs) in an attempt to “give commercial inshore fishermen a stronger voice in wider marine management developments” (IFG website). IFGs were intended to empower fishers, but have adverse effects because there is no acknowledgement of the difference between types of fishers, and fishers felt powerless, unknowledgeable, and uncomfortable in the “formal spaces” where the IFG meetings were held (Nightingale 2013). In a further attempt to empower diverse members, the Scottish Government eliminated funding the for the IFG coordinators in 2012, intending that the group be voluntarily led by fishers themselves, but those fishers who had been very active in the group were “totally disgusted” and saw this as a move to further disempower them (Nightingale 2013: 12). The resulting management actions were not well received by the fishers, and were thus less likely to succeed (Nightingale 2013). This example cautions that changes to the equity landscape must be carefully considered, and still reflect existing cultural assumptions and norms about how people expect to be treated and represented.

*Gender equality in African forest management*

Profound gender inequality is an aspect of many societies’ equity landscapes, and case studies overwhelmingly find that changing the equity landscape to increase women’s participation in environment management decision-making processes increases long-term management success (Leisher et al. 2016). Increasing gender equity also requires culturally appropriate changes to the equity landscape. A specific example comes from Rocheleau and Edmunds (Rocheleau and Edmunds 1997) who review cases in Africa where huge gender inequalities exist in participation and benefits of management of forest products. They describe resource management as characterized by “social and ecological diversity and complex webs of connection between various groups of people and the resource that sustain them" (Rocheleau and Edmunds 1997). They show how changing the traditional tenure decision-making processes, spatial allocations, and social organizations to prioritize women's access to forest resources, increases both a gender equal distribution of management rights and sustainable use of forest resources. Specifically, they list management actions that change the equity landscape that are culturally appropriate: (1) encourage the development of legal rights and administrative procedures that accommodate multiple uses and users, (2) a formal recognition of gathering as a valid land use, complementary involvement of men and women in the processing and marketing of particular products from particular land use systems, (3) a legal recognition of customary law, revised to restore a balance between men's and women's rights and responsibilities, or (4) procedural reforms to allow women's organizations and other organization with a strong representation of women to participate in the formation and enforcement of code, and (5) project contracts that protect men's and women's rights and responsibilities in established, evolving or experimental land use practices (Rocheleau and Edmunds 1997).

**Conclusion**

Environmental management increasingly seeks triple bottom line objectives (including equity). As social dimensions gain traction in design and implementation of environmental management, attention must be given to the strategic importance of equity. Ignoring equity is no longer a luxury resource managers can afford, and "drawing attention to norms and subjecting them to scrutiny can make us aware of choices we are making every day of which we had previously been unaware" (Raymond and Weldon 2013, also see Morales and Harris 2014). Therefore, environmental management will be most effective at achieving its triple bottom line objectives when it strategically considers both the current equity landscape and its potential for change (Box 1). Equity's impacts on success are real, and considering the equity landscape can help improve efficiencies and rates of success.

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**Social equity and the probability of success of biodiversity conservation**

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**Highlights**

- Social equity, economic efficiency and environmental effectiveness are often sought.
- Social equity can be necessary for success, but can compromise other goals.
- We enhance our understanding of the social equity-conservation success relationship.
- The best conservation outcome is often achieved without perfect social equity.

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**Abstract**

Conservation actions generally benefit some groups more than others, and this inequity is thought to affect the probability of achieving conservation objectives. This has led to the common assumption that triple bottom line solutions – those that are effective, efficient, and equitable – are best and most likely to achieve each individual objective. Although this may be true, it has been little tested, and importantly lacks a conceptual foundation for understanding, predicting and evaluating how equity affects conservation outcomes. We describe types of equity relevant to conservation and explore how they may affect the probability of successfully achieving conservation outcomes. Depending on the equity type and context, the relationship between equity and conservation success varies. We find that the best conservation outcome is often achieved without perfect equity; highlighting the risk of ignoring the relationship between equity and success. We offer a conceptual foundation for better addressing this important issue in future research and application.

**Keywords**

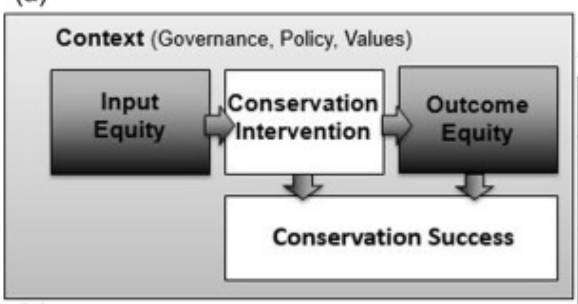
Biodiversity, Benefits, Conservation planning, Costs, Environment, Equity, Triple bottom line

## 1. Introduction

Social equity – the equitable distribution of costs or benefits between individuals or groups of people – is a highly sought after ideal in many aspects of society. Whether related to education, employment, or healthcare, equitable outcomes or opportunities can influence the creation, durability, and success of local, national, and international policies (Solar and Irwin, 2007). The conservation of biodiversity is no exception (Halpern et al., 2013). In contrast to health and education, however, relatively little work has been done to understand how, and in what cases, explicit consideration of equity influences effectiveness of a conservation plan or policy (henceforth 'conservation intervention', which can include, but is not limited to: protected area plans/policies, payments for ecosystem services plans/policies, etc.). Here we aim to enhance our understanding of the relationship between different types of social equity and success in biodiversity conservation interventions, with the goal of improving conservation outcomes. A rich body of literature exists on measuring the effectiveness of conservation interventions, and understanding factors affecting the probability of their success (Bottrill and Pressey, 2012; Ferraro and Hanauer, 2014; Mascia et al., 2014). Success in conservation is broadly defined by achievement of stated goals, which vary according to different values and beliefs. For example, a successful protected area plan could be measured by ecological representation, biodiversity persistence, or economic impact (Parrish et al., 2003; Klein et al., 2010), whereas a successful conservation policy could be measured by improved strength of legislation governing the use of natural resources (Gleason et al., 2010) or community support (Russ and Alcala, 1999). Other conservation outcomes might be measured by changes in social, institutional or human capital (Bottrill and Pressey, 2012; Ban et al., 2013). Ultimately, the success of conservation interventions is often evaluated on the basis of conservation benefit, social equity, and economic return, the three components to triple bottom line conservation outcomes (Halpern et al., 2013). Yet the feasibility of achieving such triple bottom line solutions, and the potential interactions and tradeoffs among the three components, remains largely untested. (Halpern et al., 2013). Yet found that social equity can compromise achieving efficient conservation outcomes, but highlighted the importance of further research focused on exploring how the relationship between social equity and conservation success might influence these trade-offs, in particular with respect to the many different types of equity. Here, we explore this relationship to provide insight to outstanding questions in conservation, including: Is probability of conservation success actually optimized when all three components are maximized? Or, does conservation success require approaches that deviate from the triple bottom line?

Equity is increasingly recognized as a component of conservation success (Ban et al., 2013; Campese, 2009). However, there are multiple types of equity (Fig. 1), and being clear about what type of equity is important and being measured is critical for understanding the relationship between conservation success and equity. Equity concerns can arise from both internal factors (e.g., composition of the project team), which tend to be within the control of the planning team, and external contextual factors (e.g., social, geographic or economic conditions of the planning region), which are generally beyond the control of the project. For example, the design of a stakeholder engagement strategy might consider equal participation of different groups in a consultation process designed to ensure representation from all affected stakeholders, an internal factor. Alternatively, the variation and spatial distribution of existing income levels in the planning region might determine which populations or communities are affected by restrictions on resource use recommended by a conservation plan, an external contextual factor. While external factors can rarely be controlled, understanding, anticipating and managing their influence on the design and implementation of a conservation intervention is likely to increase its probability of success (Berkes, 2004; Solar and Irwin, 2007). Internal factors can be inputs into, and/or outcomes of, a conservation intervention, and can influence its success (Fig. 1). We believe that consideration of different types of equity improves the chance of achieving conservation success.

(a)




(b)

| Equity Type | Description |
|---|---|
| Social class | Distribution of benefits or costs to each class, or people, according to set of hierarchical social categories |
| Gender | Distribution of benefits or costs to each gender group, where 50:50 ratio is perfect equity |
| Ethnicity | Distribution of benefits or costs to individuals or groups by cultural or indigenous status |
| Generational | Distribution of costs or benefits to each generation |
| Educational | Distribution of benefits or costs based upon level of education attainment (e.g., primary, secondary, tertiary) |
| Occupation | Distribution of benefits or costs to each occupational sector, where a sector could be individual types of fisheries (e.g., crab, tuna), different fishery groups (e.g., commercial, recreational), or different industries (e.g., wind farming, tourism) |

(c)

| Equity Metric | | Description |
|---|---|---|
| Participation | I | Representation by type of stakeholder group in participatory conservation process of decision |
| Access | O | Amount of non-spatial access allocated to individuals or groups, such as access (or no access) to natural resources during a particular time period or season. |
| Spatial | O | Amount of space or area on the landscape/seascape allocated to individuals or groups |
| Financial | O | Amount of income or profitability allocated to individuals or groups |

**Fig. 1.** (a) Conservation success can be influenced by several different types of equity (described in b), both as an input into (e.g., participation by stakeholder groups) and/or an outcome of the conservation

intervention (e.g., access to natural resources by individuals or groups). Each type of equity can be influenced by a variety of socioeconomic and political context determinants.

The focus of this manuscript is on how social equity, one of many potential conservation objectives and factors affecting conservation success, influences the probability a conservation intervention succeeds in meeting its stated goal. We acknowledge that cases exist where equity plays little to no role in conservation interventions and their success, for example when governments impose protected areas despite local protests (Brockington, 2004), but our emphasis here is on cases where equity matters. We identify different types of input and outcome equity and discuss their possible relationships with conservation success. Finally, we simulate how understanding these relationships can help us evaluate the feasibility of triple bottom line solutions, where social equity, environmental benefit, and economic return are maximized.

## 2. Social equity in conservation

A complex collection of social structures, economic systems, and policy frameworks determine the relevance of equity to conservation outcomes, and thus conservation success. These social determinants of conservation equity reflect the distribution of wealth, power, and access to resources within a society, and can in turn have different consequences for different types of conservation equity. We identified many types of conservation equity, and divided them into two main categories, input and outcome, that influence conservation success (Fig. 1), all of which can be influenced by socioeconomic and political context (described below in Section 2.1).

Several types of equity can be either input or outcome equity, or both, depending on the decision process and goals of the conservation action. The primary distinction is whether the type of equity is a dimension of the social context that influences the process of making a conservation decision, i.e., input equity, or is something affected by the conservation action, i.e., outcome equity. As such, potential metrics of these types of equity are often the same (Fig. 1b), but how they are used and interpreted will differ. Differences between input and outcome equity are further explained and illustrated below.

### 2.1. Socioeconomic and political context

Context variables encompass a broad set of structural, cultural, and functional aspects of a social system that exert a powerful formative influence on patterns of social stratification and, thus, influence conservation equity (Ostrom, 1990, Solar and Irwin, 2007). Fully characterizing all components of context is beyond the scope of this paper. Context determinants are often beyond the control of a conservation intervention, representing external factors influencing conservation success, except when the goal of the intervention is to change existing governance structures or policies. We highlight context here because it influences equity and thus affects conservation success. Examples of determinants related to context affecting conservation success include governance, cultural and societal values, and social/economic/public policies (Fig. 1).

### 2.2. Input equity

The socioeconomic and political context within a planning region gives rise to different forms of social position and hierarchy within groups of individuals. Populations can be stratified by socioeconomic position according to education, occupation, gender/age, race/ethnicity, generational, financial status and other factors (Fig. 1). In some cases, these different groups participate in the conservation intervention through a participatory process, and help guide decisions about what and where to protect; we classify this as a form of input equity. For example, a decision process that includes only men or only wealthy people would be inequitable for those two types of input equity, and this may ultimately affect the ability to achieve the conservation outcome. In particular, the existence and equitability of the participatory process can directly influence conservation success by slowing or stopping the decision process, where in extreme cases the lack of a participatory process is responsible for failure of the intervention (Gleason et al., 2010). In other cases, the participatory process can influence the outcome of the intervention (e.g., the size or location or regulations of a protected area plan), which can in turn indirectly influence conservation success.

### 2.3. Outcome equity

Outcome equity refers to the distribution of costs and benefits of the final outcome of the conservation intervention (e.g., a protected area plan) to different socio-economic groups and/or across space (Fig. 1). For example, a protected area plan can disproportionately impact different socioeconomic groups, such as different industry sectors (Adams et al., 2010); occupation equity), by restricting access to a natural resource (access or spatial equity). In many cases input equity can influence outcome equity, as those involved in the decision process may design a conservation intervention that favors themselves and thus leads to outcome inequity, often for the same type of equity (e.g., if men dominate the decision process, they may produce outcomes that produce greater benefits for men). Outcome equity can be independent of input equity when conservation interventions do not involve a participatory process.

**3. Equity and probability of conservation success**

Once the types of equity relevant to a conservation intervention have been identified, conservation success requires understanding how these types of equity affect the probability of success. Increased social equity is often assumed to improve the probability of conservation success (Brown, 2002; Halpern et al., 2013). In some cases, this assumption may be true; for example, in the implementation of locally managed marine areas, where self enforcement of new regulations is more likely to occur when local people perceive the regulations as equitable (Hatcher et al., 2000). However, it is also likely that conservation will fail if vocal or powerful individuals or groups are not satisfied with the outcome, in other words, if the outcomes of conservation planning and actions do not match the (often inequitable) local context. The relationship between equity and probability of conservation success is presumed to be positive (Brown, 2002), yet is poorly understood, and further complicated when values and perceptions among and between different groups are taken into account too (Ravallion, 2014, Fig. 2). Recognizing the difference between absolute, relative and perceived is critical for objective setting and evaluation of intervention outcomes. Absolute equity refers to every participant experiencing the same, or equal, outcome. For example, regardless of size, every boat is allowed to catch the same number of fish (Fig. 2). Relative equity refers to participants experiencing a proportional outcome related to a stated variable, e.g., boats receiving fish catch in proportion to their boat size as compared to other boats. Perceived equity is how those involved in the process perceive of their allotted outcome compared others, e.g., the size of fish catch relative to other fishers.

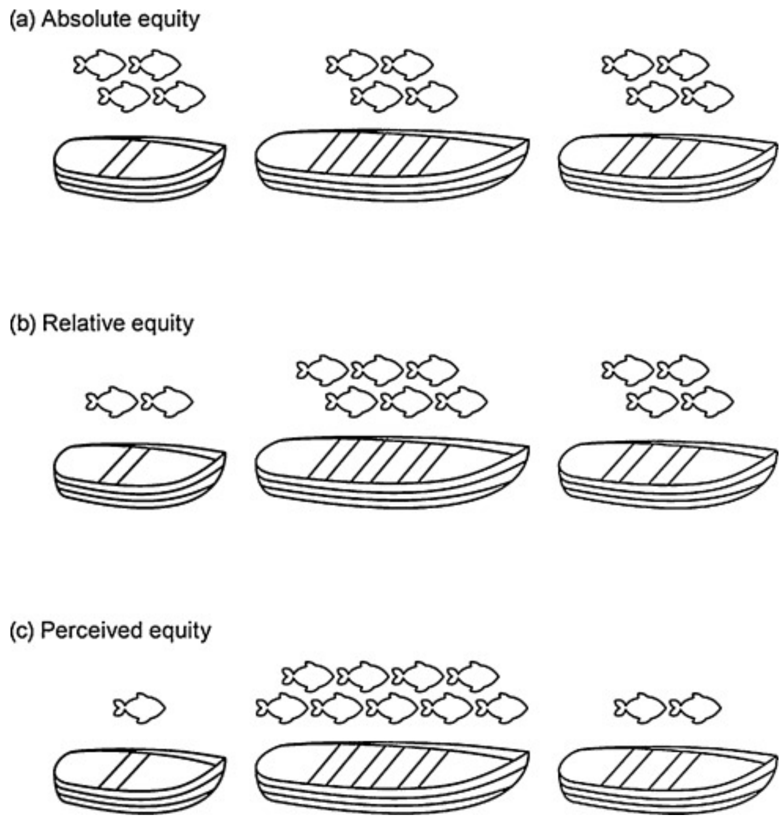



**Fig. 2.** Equity influences conservation success in different ways, depending on how it is measured and perceived. Potential measures and perceptions are illustrated for access equity, where a management plan limits fishing access to different fisher groups (each with a different size boat). When measured in absolute terms (a), each group benefits equally, represented by catching the same number of fish; when measured in relative terms (b), the benefit is distributed proportionally to the size of the boat. (c) the group with the largest boat has a positive perception of the relative benefits, whereas groups with smaller boats have a negative perception.

Here, we describe four general relationships that have been observed between equity and probability of conservation success ($P(x)$; Fig. 3): (A) Linear, where $P(x)$ increases proportionally with increasing equity; (B) Asymptotic, where $P(x)$ increases rapidly with initial increases in equity and then plateaus; (C) Humped, where $P(x)$ rises initially and then drops off with higher levels of equity, and (D) Sigmoidal, where $P(x)$ responds slowly at first to increases in equity and then rises quickly. For nonlinear shapes, the location of inflection points (i.e., change in slope) is likely connected to a contextual determinant, such as governance or cultural value. For each relationship, we describe it in the terms of individual types of equity and support it using empirical evidence, where possible. These four relationships are hypotheses; their frequency of occurrence and impact on overall conservation outcomes are still to be fully tested. We hope the conceptual foundation described here helps make such testing more rigorous. For any equity type, its relationship with conservation success will likely vary from case to case depending on how equity is considered in the process (as an input or an outcome), how equity is measured (as quantitative or qualitative values, e.g., dollars versus participation effort), and how equity is defined (as absolute, relative or perceived) (McClanahan et al., 2008) (Fig. 2).

### 3.1. Linear

Occupational and spatial equity are two of several types of equity that may relate linearly with conservation success (Fig. 3a). For example, it seems reasonable to expect conservation plans that produce more equitable relative impact to each key occupational sector, would be more successful. In California, the Marine Life Protection Act Initiative is an example of a successful conservation plan that made considerable effort to equitably impact commercial fishery sectors in each major region (Klein et al. 2010, White et al. 2013).

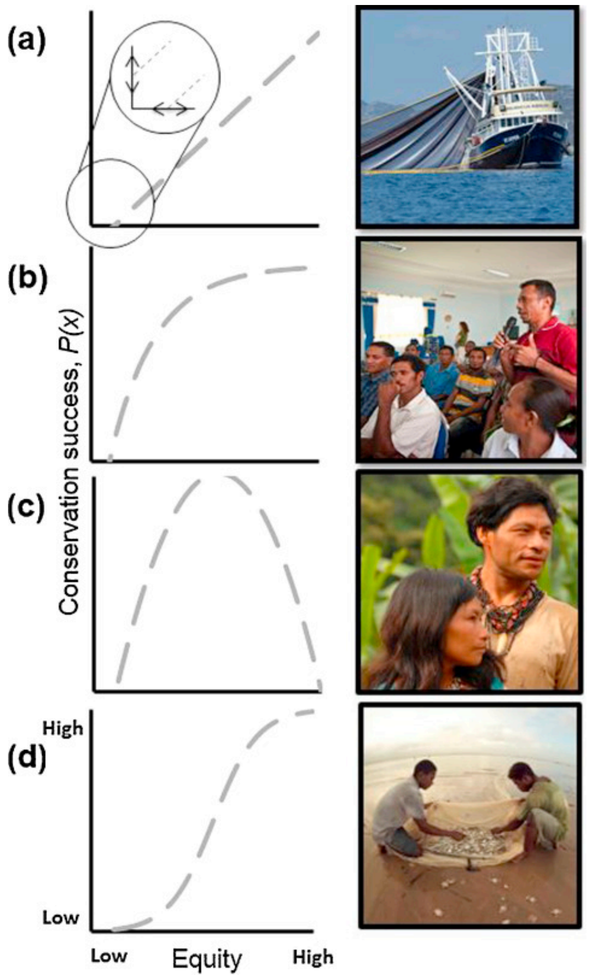



**Fig. 3.** Four broad classes of relationship between equity and the probability of conservation success, $P(x)$: (a) Linear; (b) Asymptotic; (c) Humped; and (d) Sigmoidal. A value of 1 indicates perfect equity and conservation success. For each relationship, we do not know where they cross an axis (shown in (a)). If there is a minimum threshold of equity, below which there is zero chance of success, then the lines would cross the $x$-axis; whereas if success is possible in inequitable situations, the lines would intercept the $y$-axis. Photos represent equity types that can exhibit the associated relationship, occupational, participation, gender, and access, respectively. Photos courtesy of (a) Urlich Karlowski; (b) World Wildlife Fund, Inc. Tory Read; (c) Trond Larsen; (d) Cristina Mittermeier.

With spatial equity, a linear relationship between equity and conservation success has been observed with a type of spatial fisheries management, Territorial User Rights in Fisheries (TURFs), which allow individuals or a set group of people to fish in a particular area. TURFs have demonstrated increasingly positive outcomes with increasing levels of both input and output equity. For example, Chilean TURF cooperatives allocate effort temporally and spatially via a pooling scheme (input equity), to equalize the work burden and spread effort in a more efficient manner (Cancino et al., 2007), and this program has successfully met conservation goals (by not exceeding the total allowable catch) and social goals (by equally distributing the transaction costs and benefits of the TURF)—an example of output equity.

3.2. Asymptotic

Financial and participation equity are two of several types of equity that could relate to conservation success asymptotically (Fig. 3b), where conservation success increases with increasing levels of equity to a point, after which equity does not influence success. With financial equity, conservation success is assumed to increase with increasing financial equity (i.e., distribution between groups regardless of financial status or profitability). However, in some cases conservation success is likely to peak, and remain constant, when more powerful or vocal stakeholders receive the greatest benefit. For example, when the Great Barrier Reef was rezoned, the government provided monetary compensation to commercial fishermen but not to other, more profitable industries (Macintosh et al., 2010). As fishermen were the most vocal stakeholder group, allocation of additional money to other groups, an example of output equity, may not have impacted conservation success, resulting in an asymptotic relationship.

Similarly to financial equity, the probability of success of conservation interventions could increase, to a point, with increasing participation from stakeholder groups (participation equity). An example of how stakeholder participation can lead to successful conservation was demonstrated using data from 84 forest management cases around the world (Persha et al., 2011); whereas, lack of stakeholder participation lead to an unsuccessful conservation was shown in the first attempt to implement the California's Marine Life Protection Act (Gleason et al, 2010). Similarly, in Alaska where all federal fisheries are managed by annual catch limits and some type of limited access program, stakeholders and the public have several opportunities for participation input during the development phase, which is recognized as critical for building stakeholder acceptance of the program and balancing divergent interests (Fina, 2011). However, this relationship is unlikely to be linear, as conservation success likely stabilizes once the most vocal or influential stakeholders are included in the process (i.e., engaging additional, less influential stakeholders in the decision process might increase equity but likely have little effect on conservation success).

3.3. Humped

Generational, gender, social, ethnicity, and financial (described above) are types of equity that could affect conservation success in a humped fashion, where the peak of the hump reflects the point in which conservation success is maximized. For example, some conservation initiatives favor current generations and disproportionately impose costs on future generations, indicating a humped shaped relationship that peaks early to reflect the bias towards current generations (Fig. 3c) (Dobbs, 1982).

Generational equity would be difficult to achieve as a type of input equity given timeframes involved in most decision processes. In many societies, conservation success is generally assumed to increase linearly with increased gender equity inputs and outputs (Agarwal, 2009; Fig. 3a). However, conservation success probably peaks at a point that matches the power structure of a society. In many places, decisions are often made by, or favor, a single gender (Martin and Lemon, 2001; Agarwal, 2009, Tsikata and Golah, 2010), thus conservation success would peak at the point that reflects this power structure. Other types of equity, in particular social class and ethnicity, often reflect different power and influence among groups within regions. In community forestry programs in Nepal, while socially dominant (higher caste) individuals make management decisions affecting all groups, lower caste social classes harvest a majority of the forest resources, and therefore conservation success is unlikely to occur until they are involved, even if at a minimal level. Yet, higher caste groups might not tolerate a substantial redistribution of decision-making rights among other social classes reflecting a humped relationship (Nightengale, 2002).

### 3.4. Sigmoidal

Types of equity that potentially have an asymptotic relationship to conservation success would exhibit a sigmoidal relationship in cases where some minimum threshold level of equity exists that is needed to achieve success. For example, in fisheries management based on individual transferable quotas, each fisher (or fisher group) is allowed a ‘catch share’ (i.e., access equity) that can be used, sold, or leased. This form of regulation is only likely to be successful if some minimum threshold of output equity is achieved, or in other words, fishermen are not entirely excluded from the process. If access equity increases, more people are given access to a smaller portion of the fishery, assuming a total allowable catch has been set and remains constant, and thus individual catch would decrease. In this case, probability of success likely plateaus at some intermediate level of equity (sigmoidal relationship). For example, the halibut and sablefish fisheries have historically supported a large number of small vessels (Fina, 2011). Both set individual fishing quotas (IQFs) to reflect historic fisheries access, but entry into the fishery is limited. Thus, probability of success increases to a point where enough of the fishers buy into the program, but probably plateaus at a point where entry (access equity) is limited and total allowable catch and catch shares remain steady.

3.5. Additional aspects of the curves

Some types of equity may express different relationship curves depending on the context. For example, with the catch allocation example in Section 3.4, if individuals become less satisfied with their shrinking allocation of catch with increasing equity, they may begin violating regulations, in turn decreasing conservation success at higher levels of equity (humped shape curve instead of sigmoidal). Similarly, the relationship between financial equity and conservation success may be humped if groups without much power or voice receive money that could have gone to groups that feel they deserve more, causing those groups to perceive the allocation as inequitable and unacceptable for success.

A key unknown about any of the potential relationships between equity and conservation success is where the curve crosses an axis (Fig. 1a, inset). It is often assumed that conservation interventions will fail without some minimum level of equity (Borrini et al. 2004), such that the curves would intersect the *x*-axis at some value greater than zero. Yet there are other examples where conservation has been successful despite highly inequitable outcomes, for example where top-down management displaces local communities (Brockington, 2004; De Santo et al., 2011). In these cases, the curves would intersect the *y*-axis at a value greater than zero.

Additionally, different types of equity, each with its own curve, may be relevant and important within the same management plan. Such differences further challenge incorporating equity into conservation planning, but can be resolved at least partially by efforts to elicit the relative importance of each type of equity to stakeholder groups and then incorporate those weights into formal multi-criteria decision making (Kittinger et al., 2014).

**4. Discussion**

We need a better understanding of the relationship between equity and conservation success, including when and how much social equity contributes to conservation success, to achieve conservation goals. We provide a conceptual foundation for understanding how and when different types of equity can influence conservation success relative to how equity is measured and perceived. Understanding the nature of these interactions between equity, conservation success, and economic return is fundamental for determining the feasibility of triple bottom line solutions. In conservation planning, expected conservation benefit is typically calculated as the product of probability of success and conservation benefit. In general, conservation benefit reflects both biodiversity conservation and economic efficiency objectives, addressing two pillars of the triple bottom line (Halpern et al. 2013). Here we demonstrate, in theory, how a third pillar, equity, potentially affects probability of conservation success (shown in Fig. 3), and how this in turn interacts with the way equity can limit potential conservation benefits (Fig. 4). The implication of these results is that equity can either exacerbate (Fig. 4b-d) or mitigate (Fig. 4a) the ability to achieve biodiversity and economic conservation objectives. In most cases, the optimal conservation outcome is achieved without perfect equity. In fact, high levels of equity could severely compromise conservation outcomes (e.g. Fig. 4c) if, for example, existing power structures are themselves inequitable, which highlights the risk of not considering the relationship between equity and probability of success.

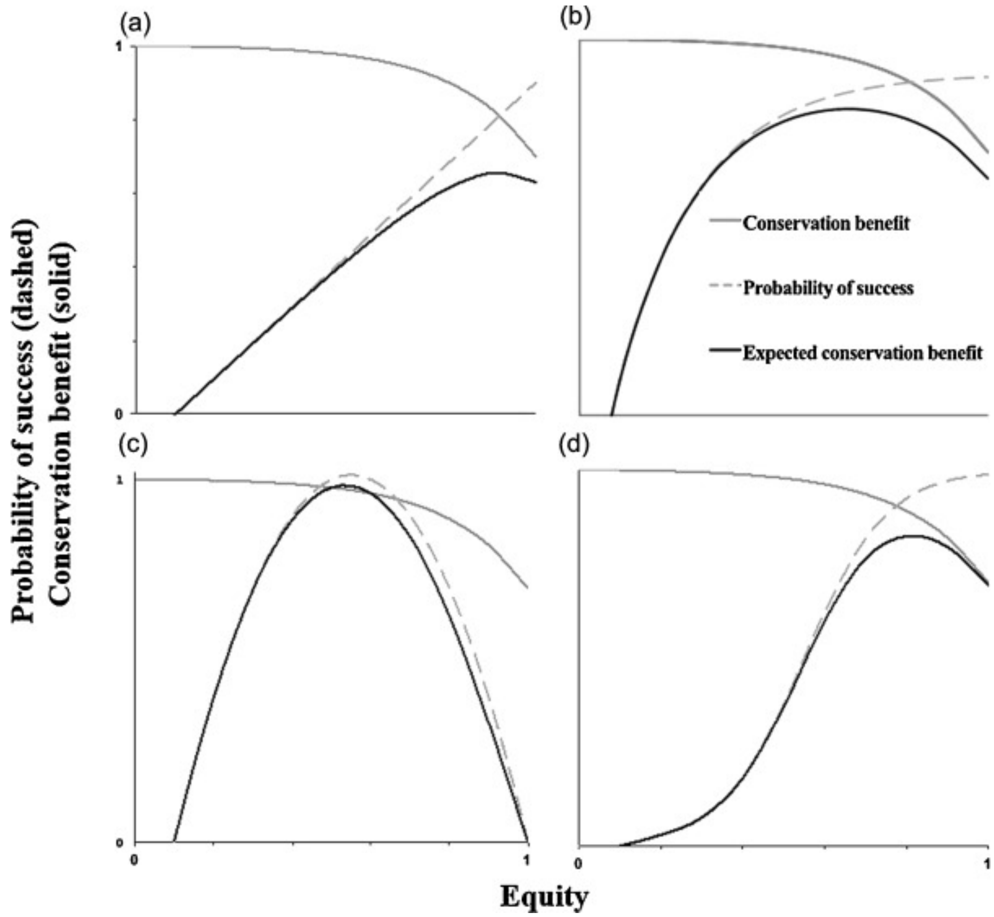



**Fig. 4.** The relationship between equity and conservation benefit (i.e., success), and how different relationships between probability of success ($P(x)$, from (Fig. 3), given different levels of equity modifies the ability of the conservation intervention to achieve biodiversity conservation outcomes. The solid gray line shows a general possible trade-off between conservation benefit and equity (taken from Halpern et al. 2013). The dashed gray lines show four possible relationships between equity and probability of success, described in Fig. 3. The solid black lines are the resulting consequence of these probability relationships on the degree to which conservation success is achieved (expected conservation benefit).

We simplified the problem by considering each type of equity separately, but acknowledge that complex relationships exist among specific types of equity and between context determinants (Adelman and Morris, 1973), and that these interactions influence the degree of success. Further, we acknowledge that additional relationships are likely to exist (e.g., nonlinear shapes with multiple inflection points, flat lines where equity has no bearing on conservation success), and that the relationships may change through time, as people learn and adapt, and among communities that have different contexts. Similarly, different groups within a planning process may value different types of equity, and if those types influence the process (input equity) or respond differently to the conservation intervention (outcome equity), then overall conservation success could be compromised. A more indepth understanding of these relationships and interactions is important and will require empirical research focused on determining or evaluating specific relationships between the probability of success and equity, as well as how different types of equity are valued by stakeholders within a planning process (i.e., how much weight to give each one in planning decisions). Embarking on this substantial research agenda requires a conceptual foundation, which is the crux of this manuscript.

Complicating matters further, the actual relationship between equity and conservation success may differ from the perceived relationship of equity for different individuals or groups (Webb et al., 2008). Perceptions of equity and conservation success reflect the values of those involved in, or affected by, a program or strategy, their expectations, and whether goals are achieved (Axford et al., 2008). Perceptions are important as they lead people to change their behavior (e.g., whether or not to comply to new regulations) and/or lead to new conservation actions (Claus et al., 2010). As with absolute equity, perceptions of equity will likely change through time and vary among individuals and communities, creating an additional challenge for understanding the relationship between equity and conservation success. Not all perceived values of conservation (associated with either costs or benefits) will be tangible or easily quantifiable; yet assessing their relative importance has merit. Any type of equity in principle could be measured subjectively on a unitless scale of low to high. Formalization of problems that involve values can be an anathema to some, but the benefits of explicating integrating these issues into formal conservation planning are greater than ignoring perceived values altogether.

Social equity in conservation has emerged from concern for environmental justice and fairness, in particularly, for those groups most affected by conservation interventions or most dependent on natural resources for their livelihoods. These issues reflect two important key ethical considerations. The first, which has been the primary focus of this paper, relates to how social equity among and between different groups might be represented in the process or outcomes of conservation planning. The second relates more specifically to how different types of equity are defined, by whom and for which groups. Goals reflect the values and beliefs of those individuals or groups that set them. We have suggested several key types of equity, but these are by no means exhaustive or prescriptive. Rather we provide a conceptual basis for articulating types of equity, the possible relationships between equity and conservation outcomes, and ways to interpret trade-offs among types of equity and between equity and conservation outcomes. Such a framework has the potential to inform and support rights-based approaches to conservation. It would be nearly impossible to consider all types of equity at once, thus conservation planners have to make some decision as to which types of equity to consider. Similar decisions are made when considering economic and ecological objectives, e.g., which actions to take to conserve which species (Bottrill et al., 2008). How these decisions are made will depend on the local context in which the conservation intervention occurs, but we recommend an explicit conceptual framework to promote transparency and balance different perspectives.

Our conceptual foundation provides a lens through which issues of equity and conservation success can be viewed and studied using empirical data. This foundation informs further research required to resolve outstanding issues, including: (1) empirical evidence to document and measure the frequency of occurrence and effect of different types of social equity on the probability of conservation success; (2) information on whether minimum thresholds of equity are required to achieve conservation success (Fig. 3a); (3) data on the contribution of equity versus other factors in affecting conservation success among different interventions, and potential tradeoffs among these factors; (4) a systematic review to synthesize existing evidence on which types of interventions, and their relative conservation success, are most influenced by which types of social equity; and (5) definitions and perceptions of conservation success among and across different groups and contexts. Greater knowledge of these issues will improve our understanding of how and when to consider equity in conservation decisions making.

Multiple objectives are common in conservation, yet there is not always consensus on objectives among individuals and groups. Conservation planning can only strive to achieve the stated objectives and ensure that the objectives are clear, measurable and identified through a transparent and participatory process with multiple stakeholders. Governments and organizations are increasingly moving away from purely biophysical approaches to biodiversity conservation to more holistic approaches based on sustainable human interactions, which require integration of environmental, social, and economic demands. Although substantial work has been done to promote the need for addressing social factors in effective planning design and implementation (Ban et al., 2013), there has been little focus on social equity and its influence on conservation outcomes, despite the assumption that triple bottom line solutions are commonly held as ideal. We hope our work here will help improve conservation success by shedding light on how and why equity influences the probability of success, the consequences of not adequately considering equity on conservation outcomes, and provide guidance on tradeoffs among social equity, economic efficiency, and conservation effectiveness for conservation interventions.

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## II. An approach to empirically investigate and include equity in conservation planning

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**Summary**

Equity is an increasingly important objective of conservation initiatives given both its influence on the likelihood of conservation success and its intrinsic value. However, research on and implementation of equity in conservation are compromised by two broad challenges — (1) equity is multidimensional and managers rarely know which dimensions matter most in their situation, and (2) scientific advances are compromised because experimentally manipulating equity outcomes in conservation interventions to advance our knowledge is beyond the scope of most conservation work and likely unethical in most cases. As a result, there is limited evidence on the types of equity that incentivize stakeholders to engage in conservation behaviors and little guidance for managers to

integrate equity effectively in their conservation actions. Here we overcome these hurdles using recent advances in describing equity and by linking stakeholder surveys with a behavioral experiment to examine how equity may be integrated into conservation more effectively. By understanding how different types of equity influence conservation behaviors in a community, managers can make better decisions about critical design elements that will affect conservation outcomes. Our results highlight a new approach using user surveys and behavioral experiments that may provide an efficient and cost-effective means to achieve better outcomes.

## 1. Introduction

Equity is an increasingly important objective of conservation initiatives because it has both intrinsic value and is commonly believed to influence the likelihood of conservation success. Evidence of this shift can be seen in new policies or organization mission statements that address inequality and promote equity broadly in sustainable development guidelines. One of the Food and Agricultural Organization's guiding principles is "ensuring justice and fair treatment – both legally and in practice- to all people" (FAO 2012). There has even been a shift in the framing of protected area conservation from sustainable livelihoods to equity (Schreckenber et al. 2016), as demonstrated by the IUCN's commitment to "promote social equity in conservation and natural resource management, within a vision that embraces sustainable development and human well-being, as well as maintenance and restoration of integrity and diversity of nature [due to the] recognition that social equity is not only a matter of basic human rights, but also a way to increase the efficiently and sustainability of our international efforts" (IUCN 2004). The Center for

Biological Diversity's Strategic Plan for 2011-2020 also states: "By 2020, at least 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape" (CBD Strategic Plan 2011-2020, Goal C, Target 11, Nagoya 2010). These issues are particularly relevant for small-scales fisheries, where the FAO aims "to contribute to the equitable development of small-scale fishing communities and poverty eradication and to improve the socio-economic situation of fisheries and fish workers within the context of sustainable fisheries management" (FAO 2015).

Despite the growing perceived importance of equity in conservation, there is still little empirical evidence about how equity actually affects conservation outcomes. As a result, managers have little practical guidance for how to strategically consider equity in conservation planning. Two challenges are key. First, equity is multidimensional, including issues of participation, access, or financial benefits. Yet, there is little clarity on which components of equity matter in particular contexts. For example, participation equity (e.g., stakeholder engagement) in the design process for a new management action may be most impactful in some settings, while equity in expected outcomes from the action may be most impactful in others. Second, advancing our scientific understanding of these equity issues is difficult because manipulating degrees of equity in conservation interventions is beyond the scope of most conservation work and is likely unethical and unwelcome by many communities.

Progress requires understanding how to first, describe and measure equity, then expand and consider if and how each measure affects outcomes, how different equities interact, and how these relationships vary in different locations and context. Only then can practitioners consider how to integrate equity into practice.

Different people have different opinions about what is equitable and which benefits and costs matter most (Gelcich et al. 2008), such that one ideally would map all of these connections and values for each individual within a community, not just each community. Although it is clear that people vary in how they value equity, disentangling the relevant dimensions relevant to management decision-making has been challenging.

Two recent and complementary approaches have attempted to describe equity in conservation. Klein et al. (2015) proposed a framework to categorize several general types of equity into input or outcome equity that relate to conservation interventions: participation, spatial, access and financial. Participation equity is an input into a conservation intervention (also referred to as process equity), whereas spatial, access and financial equities are outcomes of a conservation intervention. In contrast, Franks et al. (2016) propose an equity framework that describes a third category - recognition equity – along with procedure equity and distribution equity as interlinked principles that are critical to the establishment, assessment, governance, and management of protected areas.

These two approaches are similar but include slightly different focal issues. The Klein et al. approach offers categories of outcome (or distributional) equity by which to identify different recipients of costs and benefits. They describe different ways of grouping people that reflect common sociopolitical stratifications and predict that different groups of people have different experiences with different metrics of equity. The Franks et al.

approach highlights the importance of recognizing and accepting the legitimacy of rights, values, interests and priorities of different actors and respecting their human dignity. Depending on how they are measured, these could be included in Klein et al.'s participation (input) equity.

With all of these potential types of equity, we are faced with the challenge of understanding what types of equity matter to managers in particular situations, both normatively and in terms of achieving conservation outcomes. We have synthesized a growing interdisciplinary equity literature (Klein et al. 2015, Brown et al. 2017, Halpern et al. 2013) to investigate three key questions managers have to navigate: which equity dimensions matter most, whether equity or equality is more important, and how to measure each equity dimension. These decisions likely have large consequences for conservation outcomes (Klein et al. 2015). Any misjudgment could result in wasted resources, lack of community support, and ultimately failed conservation.

The first question managers have to navigate is which components of equity are most important for conservation success (Klein et al. 2015). There are different schools of thought. Some political science literature suggests that process equity may matter more than outcomes (Tyler and Steven 2003, MacCoun 2005) as evident by a number of influential natural resource management policies seeking social equity through participation (such as the United Nations Economic Commission for Europe, 1998, Berkes 2004, Reed 2008). Other literature suggests that outcome equity is more important (Mills 1963, Cohen-Charash and Spector 2001, Loomis and Ditton 2011). Different types of equity may also interact (De Cremer et al. 2010, Nicklin et al. 2014). For example, managers may believe that participation and outcome equities are related, or that access equity and financial equity are linked. There may also be demographic differences in perceived importance (e.g., across ages or gender) that require managers to take targeted responses to different subgroups.

As an example, implementing the California Marine Life Protection Act (CMLPA) required managers to consider the most appropriate type of equity and navigate tradeoffs between different types of equity. The CMLPA of 1999 required the Department of Fish and Game (now called the Department of Fish and Wildlife) to develop and implement a network of Marine Protected Areas (MPAs) along the California coast to increase the coherence and effectiveness of protecting the state's marine life, habitat, and ecosystems. MPAs are spatially explicit management tools that restrict the use and access areas of the ocean. The CMLPA failed twice to implement because stakeholders felt excluded from the design process (Weible et al. 2004). Success was only possible when the Department of Fish and Game explicitly addressed participation equity and adopted a highly participatory process involving Stakeholder Working Groups (Weible et al. 2004). In this case, participation equity was critical for implementation but resulted in a sub-optimal network of MPAs in terms of achieving other types of outcome equities (Rassweiler et al. 2014).

The next question managers have to address is whether equal or equitable outcomes will be more successful. Equity and equality are different concepts, and often an equal outcome is not the most equitable one. Optimal or successful management actions would differ depending on whether stakeholders' value. For example, many fisheries are moving towards a quota share system where certain users are allocated a portion of a total allowable catch. One major question managers have to answer is how to allocate the shares: Does everyone get an equal share or are shares allocated based upon past catch or some other measure?

Lastly, managers must decide how to measure equity (Klein et al. 2015). Measuring equity allows for 1) consideration of how successful efforts were at targeting the right types of equity, 2) evaluation of equity as its own objective, and 3) consideration of equity in relation to other conservation objectives. Determining the appropriate way to measure equity requires consideration of subjective and objective approaches (Halpern et al. 2013). The subjective approach can measure equity when it is used synonymously with fairness (Blanchard 1986). Subjective measurements of equity emphasize the evolution of a person's own life, especially their life situation (a cognitive evaluation, Morales and Harris 2014, Nightingale 2011). In contrast, the objective approach often measures equity in terms of *equality*, and uses indicators such a material resources (e.g. income, food, housing, boat) and social attributes (e.g. social connections, education, political processes) to describe distributions.

To address these practical challenges, we explore an interdisciplinary approach that combines surveys and behavioral experiments to assess what aspects of equity matter most to stakeholders in a given context. We use small scale fisheries in the Philippines as a case study to explore how critical information about equity that can be gleaned from surveys and a behavioral experiment. We focus on 5 different municipalities in the Tañon Strait in the Philippines to get the information needed to inform management efforts to integrate equity into practice. Our approach is designed to be easily replicable and offers a pathway that managers can take to operationalize their effective integration of equity issues into their management plans and actions.

## 2. Methods

*2.1. Conceptual approach*

The different dimensions of equity as put forth by Klein et al. motivates investigating how people perceive the different dimensions of equity and how well these equity dimensions predict peoples' conservation behavior (i.e. resource extraction and willingness to punish defectors). We demonstrate how managers can use surveys and behavioral games grounded in theory to answer important equity related questions and guide management actions. Our approach can be applied to a variety of settings where equity plays a role in outcomes.

We first document peoples' conservation behaviors, then document how people perceive equity. We examine if the perceived importance of different types of equity relate to each other and if different user groups cluster together in their perceptions of equity. These insights are gleaned from individual surveys. We then ask whether subjective perceptions of equity relate to conservation behaviors observed in a behavioral experiment. Behavioral experiments are uniquely suited to revealing the relationships between equity and conservation outcomes, because they present real world scenarios where practitioners and academics alike can glean rapid insights into what dimensions of equity are associated with conservation behaviors without the ethical dilemmas of doing real world experiments on people.

Finally, we compare subjective and objective measures of economic equality to each other. Objective measures of equity typically use metrics of equality – e.g., economic equality as measured by the Gini coefficient (Halpern et al. 2013, Voss et al. 2014, Brown et al. 2017). However, if stakeholders perceive economic equity as a fair distribution of returns that is not necessarily equal across stakeholders, objective metrics such as a Gini coefficient may misrepresent stakeholder goals.

The potential insights from a combination of stakeholder surveys and behavioral experiments allows managers to gain practical insights for the strategic integration of equity into conservation planning. Surveys provide rapid insights into stakeholder perceptions relevant to equity. Well-designed behavioral experiments provide complementary tests of how these perceptions affect individual actions, because participants bring their real-world experiences and biases into the game scenario. The combination of these two complementary approaches may provide managers with practical tools for greatly enhancing the efficacy of conservation actions.

### *2.2. Case Study*

The Tañon Strait in the Philippines is an excellent setting to investigate equity and conservation. It lies between the islands of Negros and Cebu in the Philippines. The Strait is one of the greatest nearshore fish biodiversity hotspots on the planet (Carpenter and Springer 2005), making it a prime conservation target. It hosts many different ecosystems and habitats, including coral reefs, mangroves, and seagrass meadows, many protected marine mammals, and over 7,100 fish species. Although the Strait has the largest marine protected area in the Philippines, anthropogenic pressure has caused the reefs to become severely degraded; now only 5% of the approximately 27,000 square kilometers of reefs are listed as being in "excellent condition" (Gomez et al. 1994). This pressure is primarily the result of insufficient enforcement, destructive and illegal fishing activity, and pollution. Roughly 2.1 million people (NSO 2010) from the 42 surrounding municipalities and cities in the three provinces of Cebu, Negros Oriental and Negros Occidental depend on the resources of Tañon Strait for food, livelihood, and shelter (Lucas and Kirit 2009). The majority of coastal residents engage in fishing, and about one quarter of those who fish report all of their cash income to be derived from fishing (TSPS-GMP). The most popular fishing-related activities are catching and selling fish and intertidal invertebrates. Fishers in Tañon Strait use a variety of fishing gears, including gillnets, hook-and lines, squid jigs, and beach seines. Although all of these gears are technically illegal, all are tolerated.

The Tañon Strait Protected Seascape – General Management Plan (TSPS-GMP) envisions "a Protected Seascape with natural biodiversity and integrity, which is effectively managed by all stakeholders to ensure ecological integrity and resilience, sustainable socio-economic development and communities living in harmony with nature" (TSPS-GMP). Prior to TSPS-GMP, nearshore fisheries in Tañon Straight have been open access, meaning there are no restricted users. TSPS-GMS is now implementing territorial user rights fisheries (TURFs), which provide exclusive fishing access to a defined group of fishers. The TURFs are also divided into two types of zones with different resource uses: core areas that ban all fishing and surrounding areas that allow fishing only by TURF owners.

In total, we studied 245 fishers from 5 different municipalities on the island of Cebu – Alegria, Sanboan, Santander, Ginatilan, and Badian. This collection of municipalities was chosen to explore the broader analytical goal of describing variation in the perceptions of equity. Fishers completed surveys and participated in behavioral games. All participants were fishers and were recruited by local NGO partners. Fishers were randomly assigned a number to remain anonymous. Each fisher received 500 pesos (USD10) for attending and had the opportunity to earn an additional 50 to 500 pesos (USD1-10) depending on how they played the behavior experiment. This pay out reflects real-world and opportunity costs for these fishers.

*2.3. Procedure*

Fishers were divided into four groups that each played at a separate time. Note that the groups were treatments that varied in group formation and ability to communicate (See Chapter 3) and required us to consider "post-treatment" bias in our analysis. All game instructions and materials were written and communicated verbally. The written game instructions included examples and possible actions and outcomes. Facilitators explained three hypothetical game scenarios and asked participants a series of pay out questions based on the given scenario. After each question, facilitators talked through the correct answer and answered any questions. Then facilitators played a mock PDG. Players were encouraged to ask questions if they did not understand. Fishers played three different games with three different partners within their group. There was no opportunity to learn what the other person played at any point. This is referred to as a "one shot" game, and it prevents participants from learning and altering their future game behavior and from retaliating in the real world outside of the game context. After the game participants completed two surveys designed to measure individual differences in experiences of equity primarily outside of the game in participants' real-world lives.

*2.4. Survey*

We developed our survey with Rare, our local partner in the Philippines, in order to ensure we asked contextually appropriate questions that would allow us to capture meaningful and relevant responses. Our surveys use “fairness” synonymously with “equity” (Blanchard 1986). Given that equity is often vaguely defined and subjective, our surveys were designed so players considered equality and fairness separately and considered overall, participation, access, and financial types of equity separately. Players therefore completed one survey right after playing the Prisoner’s Dilemma game about overall equality, and participation, access, and financial fairness in their real-world lives, as well as how fair the games rule were. Several hours later players then completed the second survey about overall fairness and participation, access, and financial relative benefits compared to others, and overall wellbeing. During this “wash out” time, participants ate food and listened to music, so that their answers to the second survey were less likely influenced by their answers to the first survey. All responses are in a Likert scale format. We also asked two comprehensive questions immediately post play to test participant understanding, resulting in a sample size of 210 people who showed full understanding. We were able the run the analyses with all players and without players who did not show full understanding, and found no significant difference in our results. Survey variables are presented in Table 2 (See Appendix Survey). Each fisher’s pay out was from a randomly selected round at the end of the day to ensure there were no repercussions during play or while filling out the surveys.

*2.5. The Prisoner’s Dilemma Game*

We used a common behavioral experiment to explore the influence of equity issues on conservation behaviors. The standard PDG presents a scenario where two individuals can achieve the highest overall collective benefit by cooperating or can achieve the highest individual benefit by acting in their own self-interest. The catch is that if both parties act selfishly, a response known as defecting, both participants fare worse than if they had cooperated.

We customized the PDG to reflect real world conditions in small scale fisheries like those in the Tañon Strait. Fishers have to make decisions about how many fish to harvest and if they are willing to punish those who violate fishing regulations at the potential risk of facing social repercussions. Fisheries management increasingly relies on fishers to punish perpetrators, even when punishing is not the cultural norm (as in Tañon Strait). As such, those who punish are often subject to community backlash. Behavioral scientists call this "altruistic punishment," because it means imposing punishment comes at a personal cost (Fehr and Gächter 2002).

We use a specific game known as a one-shot Prisoner's Dilemma game,[1] because it provides a simple measure of relevant cooperation that is easy to execute in the field (Janssen 2008). Two players must weigh the individual versus group benefit when deciding how much of a shared resource harvest. They also must decide if they want to punish their partner if s/he over harvests. The payoff structure for this Prisoner's Dilemma game is presented in Table 1. If both players harvest the mandated amount, they both get to keep six fish and a sustainably healthy fish stock will be maintained. By contrast, if one player defects and harvests more than the norm (10 fish), then the other player gets a much smaller catch (two fish as opposed to 6 fish), because there are not enough fish to sustainably

[1] Flood and Dresher developed the Prisoner's Dilemma Game in 1950. The Prisoner's Dilemma game describes a situation where two prisoners are suspected of robbery and taken into custody. However, police do not have enough evidence to convict them of the crime, only to convict them on the charge of possession of stolen goods. If neither of the prisoners confesses (i.e. they cooperate with each other), they will both be charged the lesser sentence of one year. The police will question them on separate interrogation rooms so the two prisoners cannot communicate. The police will try to convince each prisoner to confess the crime by offering them a "get out of jail free card", while the other prisoner will be sentenced to a ten years term. If both prisoners confess, each prisoner will be sentenced to six years. Both prisoners are offered the same deal and know the consequences of each action and are completely aware that the other prisoner has been offered the exact same deal.

harvest 16 fish. However, if the player who complied punishes the defector, the defector's payout will be 5 fish (10 minus the punishment of 5 fish), and the punisher's payout will be 0 fish (1 minus the cost to punish of 1 fish). If both players defect (10 fish each, 20 fish in total, called *mutual defection*), and don't punish, each player will only receive 1 fish. Both players have the same opportunities and know the consequences of each action. For our purposes here, we will not discuss the full game scenario, payout structure and game theory. Please refer to Chapter 3 for a more detailed description of the game and note that there exists an extensive literature on game theory that applies to marine conservation.

| | Player 2 | | | | |
|---|---|---|---|---|---|
| | | P, C | N, C | P, D | N, D |
| Player 1 | P, C | 6, 6* | 6, 6 | 0, 5 | 0, 5 |
| | N, C | 6, 6 | 6, 6 | 1, 10* | 1, 10 |
| | P, D | 5, 0 | 10, 1* | -4, -4 | 1, -3 |
| | N, D | 5, 0 | 10, 1 | -3, 1 | 2, 2* |

**Table 1** Prisoner's Dilemma payout bi-matrix with opportunity to altruistically punish. Strategies are represented as follows: P= Punish, N = No punish, C = Comply, D = Defect. Comply = 6 fish, Defect = 10

fish, Cost to punish = -1 fish, Punishment for defecting = -5 fish. Asterisks represent pure Nash equilibria. Each strategy has a probability of being played, shown in parentheses.

### *2.6. Analytical goals and approaches*

We aimed to answer three key questions, summarized in Table 2, that focus on understanding how stakeholders perceive and are influenced by it in their conservation behaviors. Conservation interventions will either reinforce or change how people perceive equity, and approach allows managers to describe equity and to strategically consider how its actions might influence stakeholder behaviors that influence conservation outcomes.

| Key question | Approach to get the empirical evidence needed to inform the key |
|---|---|
| *Are equity inputs or outcomes more important for conservation success?* | Describe variation in perceptions of equity.<br>Show the relationship between different experiences of equity and conservation behaviors.<br>Investigate how different types of equity interact with each other. |
| *Are equal or equitable inputs and/or outcomes more important for conservation outcomes?* | |
| *How should equity be measured?* | Investigate the relationship between subjective and objective measures of equity. |

**Table 2.** Managers can answer these three key questions relevant to the design and implementation of conservation interventions with empirical evidence and the approach suggested.

In order to describe the variation in equity, we first quantified the heterogeneity of perceptions of different types of equity among user groups. The 5-point Likert-scale survey data for measures of fairness, marine resource dependence, age and sex were treated as numeric data, whereas data for measures of overall and relative equality were treated as ordinal data (Agresti and Finlay 1997). Because our data are in Likert scale the differences between responses are not necessarily equal, so the mean may appear to be the neutral or middle response but may not fairly characterize the data. We categorized the data as binomial because players who harvested 6 fish were "cooperators" and players who harvested 10 fish were "defectors" (R code included in Supplemental Materials).

We completed regression analysis relating different dimensions of equity to conservation behaviors. This approach is most appropriate for our analytical goal, because it allows us to estimate the relationship among many independent variables (equity and demographics) and one dependent variable (behavior). The main parameters of interest in our regression models are the outcome variables for behavior- if fishers cooperate or defect in number of fish harvested, and if they choose to punish defectors or not. We fit two generalized linear regression models (GLMs), clustering by individual, for both harvest and punishment. The response variable, $Y_i$, is binomially distributed (participants either cooperate or defect), $\alpha$ is the intercept and $\beta$ is the slope:

$$logit\left(p(y)\right) = \alpha + \beta_1 \times X_{i1} + \cdots + \beta_q \times X_{iq} + \varepsilon_i$$

The GLM included clustering by individual, since each participant played three rounds and there is a lack of independence between observations. We also clustered standard errors by individual. We completed all analyses twice - once restricted to players who correctly answered both questions that checked for understanding, and once with no exclusions.

Multicollinearity was tested for and found not to be a problem in compliance (i.e., there were no variance inflation factors, VIF, above 10, e.g. Kutner, Nachtsheim, and Neter 2004). However, we did find multicollinearity in punishment (Relative Access and Relative Participation VIF > 10). We then ran the model with Relative Access removed and used an analysis of variance to identify significant differences in mean scores between the original model and the slimmed down model. We did this for Relative Participation as well. We found both variables to be significant and were therefore unable to remove them from the original model. Next, we used a Ridge Regression to shrink the collinearity between estimates towards zero. In our ridge model, $p(x)$ is the probability of punishment for a given value of $x$, $\alpha$ is the intercept and $\beta$ is the slope:

$$logit\ (p(y)) = \log\left(\frac{p(x)}{1 - p(x)}\right) = \alpha + \beta x_1 + \beta x_2 + \beta x_3 \ldots + \beta x_{12}$$

We considered if equity mediate the relationship between treatment effect and cooperation to meet our analytical goal of understanding how equity predicts behavior. Since our surveys were completed after the game (i.e. “post-treatment”), we took precautions interpreting the results. We completed mediation analysis and are satisfied that treatment conditions did not affect equity responses, with the exception of how fair people perceived the rules of the game to be (which was expected). Our methods do not allow for causal inference, but by understanding what experiences of equity are predictive of conservation behaviors managers may select interventions that better integrate these dimensions and ultimately arrive at better conservation outcomes even when the underlying causal drivers are not known.

To investigate how different types of equity relate to each other, we performed a cluster analysis. We used the mclust package in R (3.3.1) to find the Pearson correlation coefficient measuring the strength (linear association) of relationship between different types of equity. This approach applies the maximum likelihood estimation and Bayes criteria to identify the most likely model and number of clusters. The mclust package selects the optimal model according to Bayesian Information Criterion (BIC) for expectation maximizing (EM) initialized by hierarchical clustering for parameterized Gaussian mixture models. We report the model and number of clusters with the largest BIC (-8285.639).

Lastly, we ran a linear regression to compare perceived financial fairness and equality (subjective measurements) and estimated weekly income (an objective measurement). We ran the model with only participants who identified as having high income dependence on marine resources under the assumption that they would be more sensitive to financial implications and thus more aware of the relationship. However, we our results are similar across all levels of income dependence.

### *2.7. Precautions*

Both surveys were completed after the PDG, so we are aware of the potential for post treatment bias (meaning that the treatment conditions of the game may have somehow influenced player survey responses). We therefore conducted a mediation analysis to determine if treatment influenced survey responses (see Supplemental Material). We also ensured there was no significant difference in survey responses across treatments (with the exception of whether players believed the rules of the game were fair or not).

## 3. Results

### *3.1. Variation in perceptions of equity*

Our study is the first that we are aware of that specifically documents heterogeneity in how people perceive different types of equity and how different types of equity relate to each other. Overall, Tañon Strait fishers vary widely in their perceptions of equity (Table 3, Fig. 2). The medians and means show fishers perceive themselves as having medium wellbeing and a somewhat equal and fair distribution of benefits associated with marine resources (all medians = 3). Likewise, more fishers perceive themselves as having equal access to marine resources. Fishers believe financial benefits are fairly distributed, but also that they have slightly more than others in their community (both medians = 2). This may reflect the open access nature and largely subsistence economy of the Strait. Fishers also believe they participate more than others in marine resource decision-making (median = 2), suggesting the current management does a good job of making people feel engaged.

| | Variable | Question | Mean | Median | Std. Deviation |
|---|---|---|---|---|---|
| 1 | Overall equality | How equal do you think overall benefits associated with marine resources are distributed in your community? | 2.76 | 3 | 1.37 |
| 2 | Overall wellbeing | What is your overall wellbeing? | 2.72 | 3 | 1.40 |

| | | | | | |
|---|---|---|---|---|---|
| 3 | Overall fairness | How fair do you think overall benefits associated with marine resources are in your community | 2.81 | 3 | 1.42 |
| 4 | Fair access | How fair do you think access is to marine resources in your community? | 2.94 | 3 | 1.34 |
| 5 | Fair financial | How fair do you think financial benefits are distributed in your community? | 2.57 | 2 | 1.50 |
| 6 | Fair participation | How fair do you think participation in fisheries management is in your community? | 2.94 | 3 | 1.46 |
| 7 | Relative access benefits | How does your access to marine resources compare to others' access to marine resources? | 3.64 | 3 | 1.53 |
| 8 | Relative financial benefits | How do you feel you benefit financially from fisheries compared to others in your community? | 2.66 | 2 | 1.60 |
| 9 | Relative participation benefits | How does your participation in fisheries management activities compare to others' participation in fisheries management activities? | 2.60 | 2 | 1.45 |

**Table 3** Survey variables and questions with means, medians and standard deviations. For variable 1, responses are in a Likert scale where 1 = Completely equal and 5 = Completely unequal. For variable 2, responses are in a Likert scale where 1 = high wellbeing, and 5 = low wellbeing. For variables 3-6, response are in a Likert scale where 1 = Very Fair and 5 = Very unfair. For variables 7-9, responses are in a Likert scale where 1 = I have a lot more than others, 3 = I have the same as others, and 5 = I have a lot less than others.

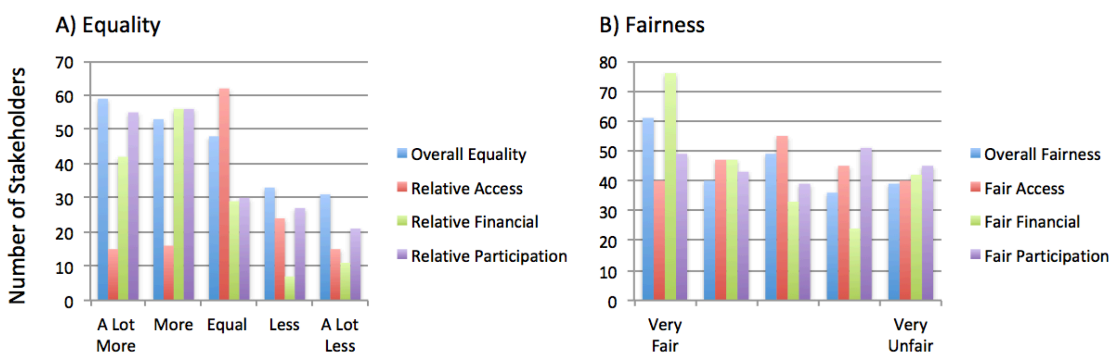


**Figure 2** Heterogeneity of participants' dimensions of equity. There is large variability in how stakeholders perceive different types of equity – we highlight equality (a) and fairness (b) here.

### *3.2. Equity's interaction with each other types of equity*

There are no clear associations between different types of equity in this community of fishers (Fig. 3, SM 3). This is also a surprising result and suggests to managers in Tañon Strait that how people perceive participation management decision-making is not related to how they perceive conservation outcomes. Across all the equity measures, the strongest association is between perceived wellbeing and overall fairness (Fig. 3, r = 0.53).

We find that perceived measures of how fair marine resources are distributed throughout the community do not reflect how equal fishers perceive the distribution of benefits throughout the community to be (Fig. 4). If perceived equity and equality aligned, fishers who perceived a very fair distribution would also perceive an equal distribution, and fishers who perceived a very unfair distribution would also perceive an unequal distribution – which they do not. Rather, we find that a fair outcome is associated with an unequal distribution of benefits (Fig. 4).

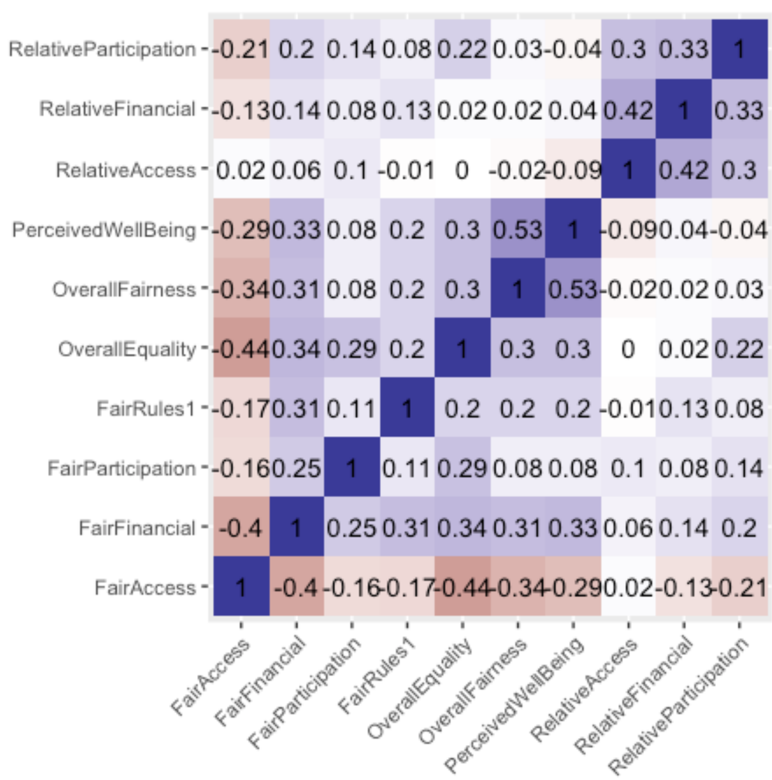


**Figure 3** Descriptive correlation matrix of different types of equity**.**

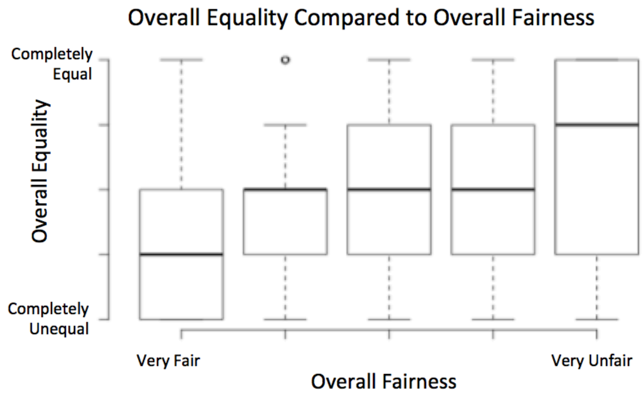


**Figure 4** Perceived fairness of how marine resources are distributed throughout the community compared to how fishers perceive the equality of the distribution of benefits throughout the community.

*3.3. Relationship between subjective and objective measures of equity*

Lastly, our results show that objective and subjective measures of equity do not always align (Fig. 5). Although we acknowledge that our experiment was not designed to make strong inferences comparing subjective and objective measures, our results indicate that an objective measure of income does not relate to how people perceive financial benefits or equality. If subjective and objective measures were related, average earners would identify as earning relatively the same as others, and high earners would identify as earning relatively more than others. Neither is true. We find no significant relationship between perceived financial fairness and weekly income ($\beta = 40.68$, $p = 0.623$). We also find no significant difference in the scores for relative financial benefits and weekly income ($\beta = -70.68$, $p = 0.391$).

However, low earners accurately identify having a lot less than others (Fig. 5), perhaps because they are more aware of their hardships than higher earners.


**Figure 5** Subjective measure of financial equality compared to and objective measure of financial equality.

*3.4. Demographic differences in conservation behaviors*

We observe a number of significant differences in conservation behaviors by different demographic groups (Fig. 6, Tables 4 and 5). Female fishers significantly comply more than their male counterparts (*ß* =1.029, *p* = 0.004) and punish significantly less (*ß* =-3.201, *p* = 1.045e-05). We find that older fishers punish significantly less than younger fishers (*ß* =-3.201, *p* < 0.000). Fishers who depend a lot on marine resources for their income punish significantly more (*ß* = 1.124, *p* = 0.001), whereas fishers who depend a lot on marine resources for subsistence punish significantly less (*ß* = -1.669, *p* = 9.867e-08).

*3.5 .Relationship between equity and conservation behavior*

Certain perceptions of equity predict conservation behaviors in our experimental game (Fig. 6, Tables 4 and 5). The key results include:

*3.5.1. Fair rules*

Both compliance and punishment significantly decrease when fishers perceive the rules of the game to be unfair (*ß* = -0.471, *p* = 8.2e-06; *ß* -0.844, *p* = 0.001).

*3.5.2. Access*

Perceived access also plays an important role in cooperation – perceptions of relative access to marine resources significantly predict compliance and punishment. Fishers who perceive the same (*ß* = 1.254, *p* = 0.002), more (*ß* = 1.311, *p* = 0.008), or a lot more (*ß* = 1.413, *p* = 0.013) relative benefits comply the most. Fishers who perceive themselves as having less or the same access to marine resources as other community members punish significantly more (*ß* = 4.961, *p* = .242e-05; *ß* = 3.73 8, *p* = 7.630e-06), versus fishers who perceive themselves as having more or a lot more access as compared to others punish significantly less (*ß* = -4.241, *p* = 0.003; *ß* =-3.796, *p* = 0.003). Likewise, punishment is also significantly associated with how fair access to marine resources is perceived, where perceptions of unfair access have a significantly negatively effect on punishment (*ß* = -1.259, *p* = 3.178e-07).

*3.5.3. Participation*

Our results point to the importance of participation in resource management decision making for punishment in Tañon Strait. Unfair perceptions of participation have a significantly negative association with punishment (*ß* = -1.240, $p < 0.000$). By contrast, fishers who perceive themselves as participating in the middle categories (i.e., less, the same or more), punish significantly more (*ß* = 0.905, *p* = 0.058; *ß* = 1.265, *p* = 0.015; *ß* = 1.750, *p* = 0.005) than fishers who perceive their participation at the extremes (i.e., much less or much more).

*3.5.4. Finances*

Lastly, we find that fishers who perceive themselves as having more financial benefits punish significantly more ($\beta = 23.799$, $p < 2.2e\text{-}16$).

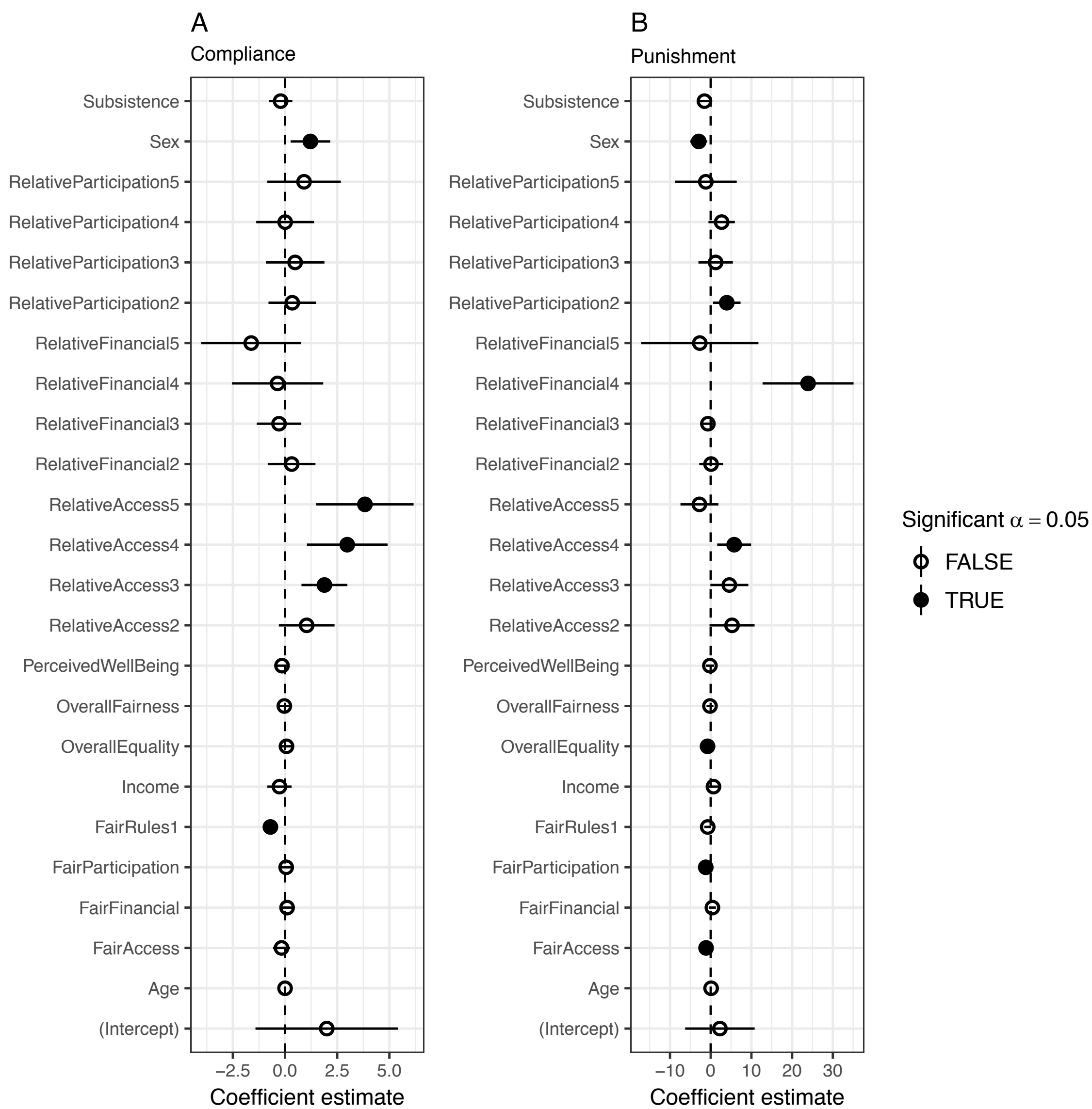


**Figure 6 (A)** Compliance and **(B)** Punishment predicted by survey variables using a generalized linear model (Model 1 in Tables 2 and 3).

| | *Dependent variable:* | |
| --- | --- | --- |
| | Compliance | |
| | (1) | (2) |
| Fair Game Rule | -0.701 (4.8e-05***) | -0.471 (8.2e-06***) |
| Perceived Wellbeing | -1.145 (0.376) | |
| Overall Fairness | -0.032 (0.851) | |
| Overall Equality | 0.0710 (0.646) | |
| Financial Fairness | 0.099 (0.584) | |
| Access Fairness | -0.166 (0.4232) | |
| Participation Fairness | 0.056 (0.674) | |
| Less Financial Benefits | 0.320 (0.581) | |
| The Same Financial Benefits | -0.288 (0.597) | |
| More Financial Benefits | -0.357 (0.749) | |
| A Lot More Financial Benefits | -1.620 (0.185) | |
| Less Participation | 0.345 (0.552) | |
| The Same Participation | 0.484 (0.499) | |
| More Participation | 0.007 (0.992) | |
| A Lot More Participation | 0.911 (0.311) | |
| Less Access | 1.0378 (0.127) | 0.830 (0.104) |
| The Same Access | 1.888 (0.001***) | 1.254 (0.002**) |
| More Access | 2.981 (0.003**) | 1.311 (0.008**) |
| A Lot More Access | 3.829 (0.001**) | 1.413 (0.013*) |
| Income Dependence | -0.267 (0.367) | |
| Subsistence Dependence | -0.209 (0.463) | |
| Age | 0.001 (0.951) | |
| Sex | 1.216 (0.012*) | 1.029 (0.004**) |
| Constant | 2.001 (0.199) | 0.968 (0.045*) |
| Akaike Inf. Crit. | 263.72 | 361.94 |

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

**Table 4** Compliance results. Baseline treatment conditions show that participants comply 54% of the time.

| | *Dependent Variable:* Punishment | | |
|---|---|---|---|
| | (1) | (2) | Adjusted for Multicollinearity |
| Fair Game Rules | -0.855 (0.002 **) | -0.844 (0.001 ***) | -0.319 |
| Perceived Wellbeing | -0.031 (0.903) | | -0.085 |
| Overall Fairness | -0.246 (0.260) | | -0.123 |
| Overall Equality | -0.719 (0.002 **) | -0.675 (0.006 **) | -0.344 |
| Financial Fairness | 0.272(0.380) | | 0.070 |
| Access Fairness | -1.198 (1.027e-07 ***) | -1.259 (3.178e-07 ***) | -0.489 |
| Participation Fairness | -1.226 (0.002 **) | -1.240 (0.000 ***) | -0.627 |
| Less Financial Benefits | -0.199 (0.816) | -0.416 (0.523) | 0.134 |
| The Same Financial Benefits | -0.323 (0.500) | -0.556 (0.345) | -0.084 |
| More Financial Benefits | 23.917 (3.444e-14 ***) | 23.799 (< 2.2e-16 ***) | 4.298 |
| A Lot More Financial Benefits | -0.239 (0.923) | -0.384 (0.869) | -0.349 |
| Less Participation | 3.974 (0.003*) | 3.930 (0.001 ***) | 1.723 |
| The Same Participation | 1.022 (0.407) | 1.265 (0.015 *) | 0.276 |
| More Participation | 2.464 (0.033 *) | 1.750 (0.005 **) | 0.793 |
| A Lot More Participation | -1.762 (0.305) | -1.848 (0.332) | -1.092 |
| Less Access | 5.012 (0.001 ***) | 4.961 (1.242e-05 ***) | 1.728 |
| The Same Access | 4.115 (0.001 ***) | 3.73 8(7.630e-06 ***) | 1.237 |
| More Access | -4.556 (0.007 **) | -4.241 (0.003 **) | -1.370 |
| A Lot More Access | -3.467 (0.005 **) | -3.796 (0.003**) | -1.628 |
| Income Dependence | 0.890 (0.031 *) | 1.124 (0.001 **) | 0.455 |
| Subsistence Dependence | -1.512 (0.000 ***) | -1.669 (9.867e-08 ***) | -0.623 |
| Age | 0.093 (0.000 ***) | 0.081 (0.000 ***) | 0.031 |
| Sex | -2.981 (2.454e-06 ***) | -3.201 (1.045e-05 ***) | -1.727 |
| Constant | 2.832 (0.193) | 3.636 (0.091 .) | 2.358 |
| Akaike Inf. Crit. | 168.89 | 164.81 | |

*p<0.1; **p<0.05; ***p<0.01

**Table 5** Punishment results. Note that when adjusting for multicollinearity with Ridge Regression, collinearity shrinks close to zero. However, there is some collinearity effect still present. Thus there is no concept of significance. Baseline treatment conditions show that participants punish 25.7% percent of the time.

## 4. Discussion

Given that equity is increasingly a sought-after goal in conservation, managers need guidance how to incorporate it into decision-making and measure it. Our results were attainable in a reasonable amount of time and effort using complementary surveys and a behavioral experiment that provide important insights to managers looking for ways to improve outcomes. Since there are no other studies that have produced such a comprehensive view of the diverse roles of equity, we cannot evaluate the generality of the findings to other settings. Nonetheless, there are important lessons learned for Tañon Strait resource management.

### *4.1. Which type of equity should managers focus on?*

Our results suggest that Tañon Strait managers focus on several types of equity. First, actions promoting equal access to marine resources will likely increase compliance and punishment. Second, actions promoting fair participatory processes will likely increase punishment. Third, actions that make fishers feel as though they have a financial advantage will bolster punishment. These three findings suggest specific actions could enhance the success of future management actions.

### *4.2. Equal or unequal outcomes for fairness?*

Our results show that Tañon Strait fishers consider the fairest distribution to be an unequal distribution, supporting social psychology literature finding that fishers perceive fairness and equality differently on average (Tornblom and Jonsson 1985). This finding suggests management plans in this region that understand and include the pre-intervention hierarchy of access benefits may have more success than if access rights are given out equally to all stakeholders.

Our result that fishers both comply and punish more when they perceive the game rules to be fair suggests that in the real world they will be more likely to participate in conservation behaviors if they perceive management regulations to be fair. Fishers who perceive the game rules as unfair may be compared to stakeholders in the real world who perceive regulations to be unfair, who then become dissatisfied (Adams 1965, Karriker and Williams 2009). This dissatisfaction can potentially cause intervention failure (Pitcher et al. 2009, Agnew et al. 2009, Loomis and Ditton 1993) because they do not cooperate. These results lend support to other findings in behavioral ecology (Nielsen and Mathiesen 2003, Fehr, Fischbacher, and Gatcher 2002) and natural resource management (Zubair and Garforth 2006, Klein et al. 2009, Karriker and Williams 2009, Lam and Pitcher 2012) that stakeholders' cooperation is largely determined by whether or not they perceive the regulations as fair. Likewise, managers cannot use the simplest objective metric for a trade-off analysis unless there is evidence that it truly represents the outcomes of interest.

### *4.3. How should managers measure equity outcomes?*

Managers in Tañon Strait are now armed with the knowledge that objective and subjective measures of equity do not always align. This finding may have broader implications since the subjective approach has been used to measure perceived distributions of costs and benefits and may be a composite self-weighted evaluation of multiple types of objective socioeconomic status (Marmot and Wilkinson 1999, McDate 2001, Operario, Alder and Williams 2004). By contrast, the objective approach has typically been used to measure the equality of participation in decision-making processes – as measured by the number of people involved in the process – or financial outcomes – as measured by dollars per individual. However, objective measures often fail to capture less obvious aspects of an individual's life, such as household conditions, perceived mobility, social networks and community influences, that could inform the "lived experience" of wellbeing and inequality (Heuveline, Guillot and Gwatkin 2002, Richmond et al. 2005). Therefore, clearly identifying the motivation for a particular equity objective may help managers determine which measurement is most appropriate. For example, if the equity objective has a functional value by influencing stakeholder behavior, an inappropriate objective measure would lead to misleading evaluations and poor management decisions.

## 5. Limitations and future directions

This study looked at equity and behavior in 5 different municipalities in one region of the world. Our approach is a starting point for further integrating social dimensions into natural resource management. One productive way to expand on this research would be to first investigate how well different types of objective and subjective measures of equity align. There is also enormous potential to expand this research to other communities facing resource management decisions. Most importantly, managers may use this approach to guide their decision-making processes, rather than as a research question.

## 6. Conclusion

Simply including "equity" in conservation is too limited a perspective, especially when equity and conservation outcome are interlinked. Managers may focus on input or outcome equities, fair or equal inputs and/or outcome, and how they are going to measure equity. The implications of targeting the wrong types of equity may result in less stakeholder cooperation and unsuccessful conservation. In the absence of clear theoretical guidance, managers need empirical evidence to help make these decisions. We offer a unique approach to investigating equity that is applicable to a much wider range of settings where equity may have strategic importance. It provides a framework that managers can use to make better decisions with likely better outcomes. This work also contributes to a growing body of interdisciplinary research both advocating for social equity (Schreckenber et al. 2016) and investigating its role in facilitating (or impeding) desirable outcomes in environmental governance (Halpern et al. 2013, Klein et al. 2015, Franks et al. 2016, Brown et al. 2017).

We provide empirical insight into how managers may use this framework in one specific context. We have shown that how fishers in Tañon Strait perceive the rules influences how they cooperate, suggesting that these communities would fare better to adopt contextually fair management plans. Our research suggests that equity is context dependent, and best measured in subjective terms. What stakeholders perceive to be real may have huge implications for if/how the conservation intervention is implemented and how successful it ultimately is. If perceptions and reality differ, there can be roadblocks for policy change and management success (even if people would be benefiting more or less than they think). Furthermore, before conservation tradeoffs can accurately be considered, researchers and resource managers must have a better understanding of what types of equity are contextually relevant and how to measure them.

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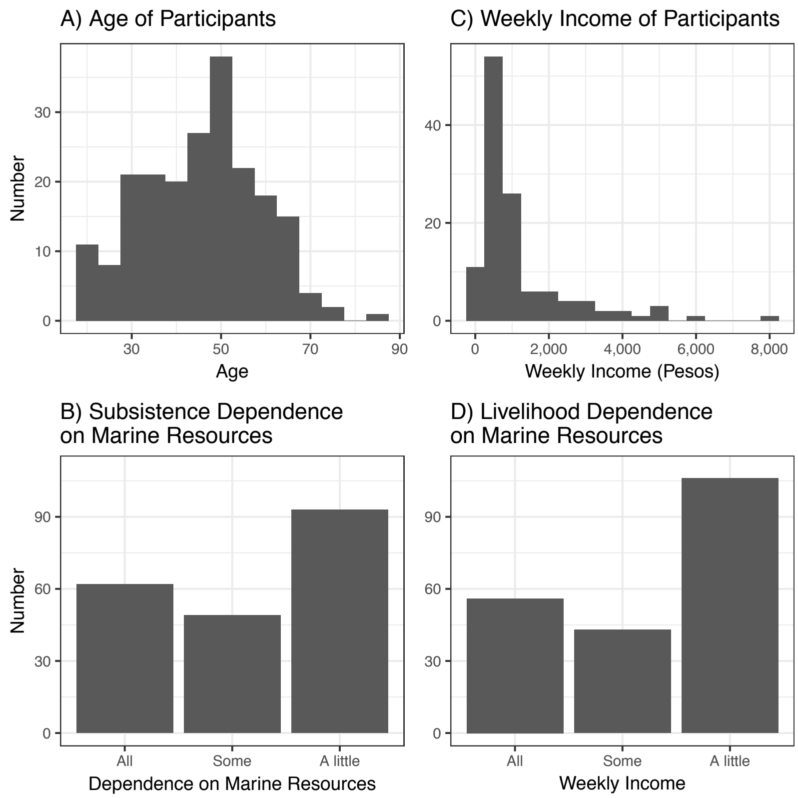
**SUPPLEMENTAL MATERIAL**

***1.*** ***Demographic information***

| Variable | Value |
|---|---|
| Age | Average = 45.66 years |
| Sex | Male = 222, Female =28 |
| Alegria | 64 |
| Badian | 39 |
| Ginatilan | 37 |
| Santander | 25 |
| Samboan | 36 |
| Other | 3 |
| Income dependence on marine resources | Mean = 2.25, Median = 2 (1 = All, 2 = Some, 3 = A little) Std. Deviation = 0.86 |
| Subsistence dependence on marine resources | Mean = 2.16, Median = 2 (1 = All, 2 = Some, 3 = A little) Std. Deviation = 0.86 |

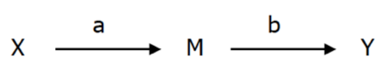
***SM Table 1*** Participant demographic information. Note that some questions were not answered so the total number does not equal 250 people.



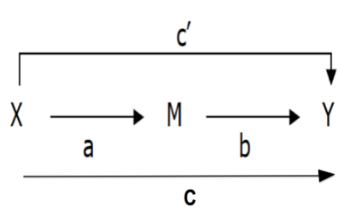

***SM Figure 1*** Distribution of participants' age, estimated weekly income, subsistence dependence on marine resources, and livelihood dependence on marine resources.

### *2. Mediation analysis*

Mediation is a hypothesized causal chain in which one variable affects a second variable that, in turn, affects a third variable. The intervening variable, M, is the mediator. It "mediates" the relationship between a predictor, X, and an outcome. Graphically, mediation can be depicted in the following way:



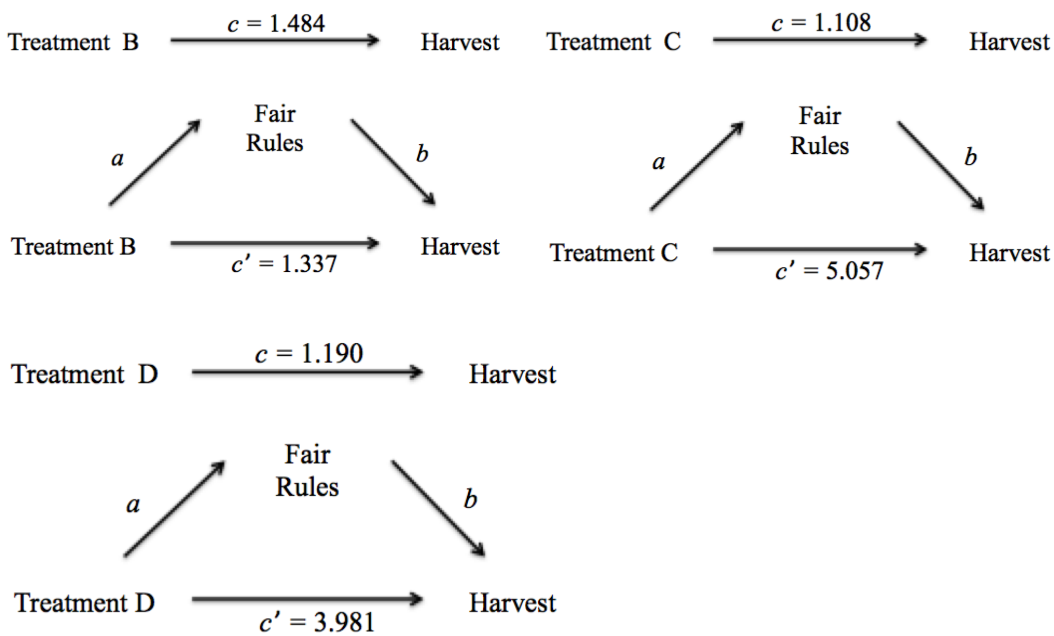

Paths *a* and *b* are called direct effects. The mediational effect, in which X leads to Y through M, is called the *indirect effect*. The indirect effect represents the portion of the relationship between X and Y that is mediated by M.



We performed a mediation analysis to determine if treatment had any relationship on survey responses. We used a classical mediation approach (Baron and Kenny 1986) which estimates the effect of the intervention on the mediator, of the mediator on the outcome, and of the intervention on the outcome when controlling for the mediator (Coffman 2011), using a regression analysis procedure to test for mediation (MacKinnon et al. 2007). We followed Baron and Kenny (1986) steps for mediation, and use diagram below to visually represent our analysis (note that *c′* is called a direct effect).

The standard regression approach to mediation analysis assumes *sequential ignorability* of the mediator, meaning that equity is effectively randomly assigned given baseline covariates and the randomized treatment. We used independent covariates in our mediation analysis regressions and are satisfied that there is nothing about the game's treatment conditions that would affect participant's perceived equity of their day-to-day lives. Specifically, we used Age, Sex and Municipality.

| Analysis | | Equation | Result |
|---|---|---|---|
| *Step 1* | Conduct a simple regression analysis with X predicting Y to test for path *c* alone | $Y = B01 + B11X + e$ | *Yes* – When we regress the dependent variable (play) on the independent variable (treatment) to confirm that the independent variable is a significant predictor of the dependent variable there is a significant interaction. |
| *Step 2* | Conduct a simple regression analysis with X predicting M to test for path *a* | $M = B02 + B12X + e$ | *Yes – Perceived Wellbeing, Overall Equality, Overall Fairness, Fair Access, Fair Financial, Fair Participation, and Fair Rules are significant.*<br>*No – Relative Access, Relative Financial, Relative Participation are not significant.* |
| *Step 3* | Conduct a simple regression analysis with M predicting Y to test the significance of path *b* alone | $Y = B03 + B13M + e$ | *Yes – Fair Rules is significant.*<br>*No – Perceived Wellbeing, Overall Equality, Overall Fairness, Fair Access, Fair Financial, Fair Participation, and Relative Access, Relative Financial, Relative Participation are not significant.* |
| *Step 4* | If significant in Steps 2 and 3, then compare *c* and *c′* to give mediation effect | *Mediation effect = c - c′* | *The mediation effect is:*<br>*Treatment B: = 0.147*<br>*Treatment C: -3.949*<br>*Treatment D: = -2.791* |




***SM Figure 2*** Mediation effect of how fair the rules of the game were perceived on player's harvest.

### *3. Results including participants who did not show full understanding of the game rules.*

Compliance Regression Results

| | *Dependent Variable:* | | |
|---|---|---|---|
| | Compliance | | |
| | (1) | (2) | (3) |
| Fair Game Rule | -0.553 (8.992e-05 ***) | -0.372 (0.000 ***) | -0.370 (2.27e-05 ***) |
| Perceived Wellbeing | -0.042 (0.767) | | |
| Overall Fairness | -0.138 (0.331) | | |
| Overall Equality | -0.129 (0.322) | | |
| Financial Fairness | 0.254 (0.128 .) | 0.002 (0.980) | |
| Access Fairness | -0.162 (0.316) | | |
| Participation Fairness | 0.054 (0.629) | | |
| Less Financial Benefits | 0.329 (0.472) | | |
| The Same Financial Benefits | -0.442 (0.376) | | |
| More Financial Benefits | -0.407 (0.680) | | |
| A Lot More Financial Benefits | -1.252 (0.121) | | |
| Less Participation | 0.097 (0.841) | | |
| The Same Participation | 0.160 (0.781) | | |
| More Participation | -0.036 (0.389) | | |

| | | | |
|---|---|---|---|
| A Lot More Participation | 1.056 (0.108) | | |
| Less Access | 1.056 (0.108480) | 0.653 (0.168) | 0.656 (0.1563) |
| The Same Access | 1.665 (0.002 **) | 0.954 (0.007 **) | 0.909 (0.012 *) |
| More Access | 1.889 (0.012 *) | 0.843 (0.051 .) | 0.838 (0.056 .) |
| A Lot More Access | 3.137 (0.002 **) | 1.026 (0.040 *) | 1.003 (0.038 *) |
| Income Dependence | -0.240 (0.352) | | |
| Subsistence Dependence | -0.051 (0.819) | | |
| Age | 0.015 (0.357) | | |
| Sex | 1.066 (0.016 *) | 0.961 (0.009 **) | 1.000 (0.010 **) |
| Constant | 1.2745(0.408) | 1.092 (0.0131 *) | 1.090 (0.008 **) |
| Akaike Inf. Crit. | 320.4 | 413.15 | 428.13 |

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

***SM Table 2A*** Compliance results with all participants regardless of understanding.

Punishment Regression Results

| | *Dependent variable:* | |
|---|---|---|
| | Punishment | |
| | (1) | (2) |
| Fair Game Rules | -0.602 (0.003 **) | -0.538 (0.002 **) |
| Perceived Wellbeing | 0.172 (0.425) | |
| Overall Fairness | -2.120 (0.186) | |
| Overall Equality | -0.802 (0.000 ***) | -0.758 (2.150e-05 ***) |
| Financial Fairness | 0.422 (0.060 .) | 0.404 (0.061 .) |
| Access Fairness | -0.963 (0.000 ***) | -0.894 (4.394e-05 ***) |
| Participation Fairness | -0.931 (2.897e-06 ***) | -0.951 (1.280e-06 ***) |
| Less Financial Benefits | -0.200 (0.645) | -0.192 (0.649) |
| The Same Financial Benefits | -0.998 (0.040 *) | -0.977 (0.050 *) |
| More Financial Benefits | 18.568 (< 2.2e-16 ***) | 18.927 (< 2.2e-16 ***) |
| A Lot More Financial Benefits | -1.317 (0.351) | -1.405 (0.286) |
| Less Participation | 2.196 (0.000 ***) | 2.172 (0.000 ***) |
| The Same Participation | 0.697 (0.254) | 0.756 (0.205) |
| More Participation | 1.867 (0.002 **) | 1.762 (0.003 **) |
| A Lot More Participation | -0.448 (0.756) | -0.234 (0.864) |
| Less Access | 3.137 (0.000 ***) | 3.194 (0.000 ***) |
| The Same Access | 1.572 (0.014 *) | 1.444 (0.032 *) |
| More Access | 1.748 (0.023 *) | 1.603 (0.043 *) |
| A Lot More Access | -1.924 (0.220) | -1.639 (0.198) |
| Income Dependence | 1.075 (0.015 *) | 1.071 (0.003 **) |
| Subsistence Dependence | -1.219 (0.005 **) | -1.300 (0.001 ***) |
| Age | 0.05244 (0.009 **) | 0.048 (0.006 **) |
| Sex | -2.0956 (1.392e-05 ***) | -2.032 (6.255e-06 ***) |
| Constant | 3.692 (0.0755) | 3.581 (0.0785 .) |
| Akaike Inf. Crit. | 244.67 | 242.36 |
| *Note:* | | *p<0.1; p<0.05;* p<0.01 |

***SM Table 2B*** Punishment results with all participants regardless of understanding.

***4. Multicollinearity***

We use variance inflation factors (VIFs) as a measure of the amount of multicollinearity in our survey variables. A VIF is the ratio of variance in a model with multiple terms, divided by the variance of a model with one term alone. It quantifies the severity of multicollinearity in an ordinary least squares regression analysis. VIFs over 10 indicate collinear variables (Kutner, Nachtsheim, and Neter 2004).

VIF Compliance Models

| | (1) | (2) | (3) |
|---|---|---|---|
| Fair Game Rules | 1.643 | 1.216 | 1.060 |
| Perceived Wellbeing | 1.797 | | |
| Overall Fairness | 2.138 | | |
| Overall Equality | 1.575 | | |
| Fair Financial | 1.978 | 1.170 | |
| Fair Access | 2.139 | | |
| Fair Participation | 1.338 | | |
| Relative Financial | 6.998 | | |
| Relative Participation | 4.117 | | |
| Relative Access | 5.965 | 1.088 | 1.070 |
| Income | 1.659 | | |
| Subsistence | 1.829 | | |
| Age | 1.451 | | |
| Sex | 1.264 | 1.019 | 1.010 |

VIF Punish Models

| | (1) | (2) |
|---|---|---|
| Fair Game Rules | 2.137 | 1.845 |
| Perceived Wellbeing | 2.330 | |
| Overall Fairness | 2.027 | |
| Overall Equality | 2.089 | 1.611 |
| Fair Financial | 2.418 | 2.273 |
| Fair Access | 3.237 | 2.643 |
| Fair Participation | 2.136 | 2.097 |
| Relative Financial | 3.072 | 2.805 |
| Relative Participation | 3.715 | 3.112 |
| Relative Access | 6.683 | 5.054 |
| Income | 2.703 | 2.317 |
| Subsistence | 2.339 | 2.137 |
| Age | 1.610 | 1.512 |
| Sex | 1.392 | 1.351 |

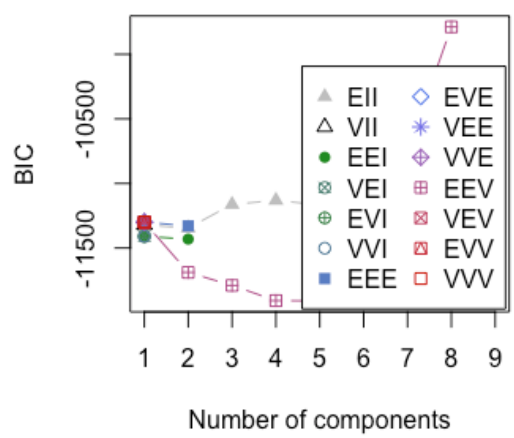
VIF Punish Models

| | (1) | (2) |
|---|---|---|
| Fair Game Rules | 2.452 | |

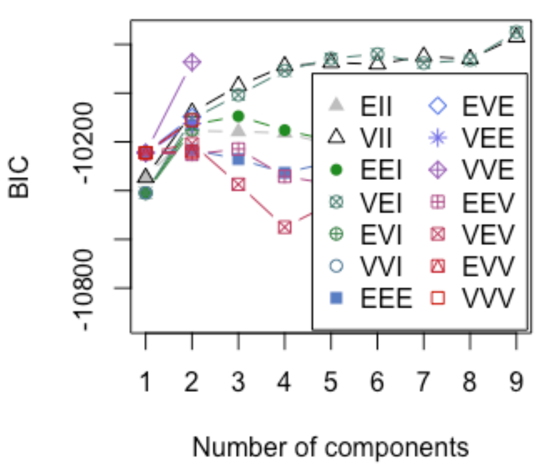
| | | |
|---|---|---|
| Perceived Wellbeing | 3.100 | |
| Overall Fairness | 2.930 | |
| Overall Equality | 2.601 | |
| Fair Financial | 1.966 | |
| Fair Access | 4.568 | 1.683 |
| Fair Participation | 3.333 | 1.594 |
| Relative Financial | 7.651 | |
| Relative Participation | 12.052 | 1.615 |
| Relative Access | 31.162 | 2.291 |
| Income | 3.801 | 2.317 |
| Subsistence | 3.186 | 1.148 |
| Age | 2.016 | 1.231 |
| Sex | 1.513 | 1.299 |

***SM Table 3*** Compliance and Punishment Variance Inflation Factors.

### *5. Cluster analysis*




***SM Figure 3*** Cluster analysis plot showing 8 clusters of equity and demographics. From the cluster analysis we determined that there were no significant clusters.




***SM Figure 4*** Cluster analysis plot showing 8 clusters of different types of equity. From the cluster analysis we determined that there were no significant clusters.

**Supplemental References**

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## III. The influence of group choice and communication in natural resource management

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### Summary

Successful natural resource management requires users comply with the prescribed regulations and often to punish those who break the regulations. Not surprisingly, natural resource management increasingly turns towards interventions that incentivize a defined group of users to participate in these cooperative behaviors so that they may see the rewards. Many arrangements rely on an existing group of users to take collective ownership over resources. An alternative model has emerged in a limited number of situations where a group of people self assemble and apply for ownership, raising the question of how the process of group formation affects the performance of natural resource management. We investigate if self-assembled or assigned groups cooperate more using a framed field experiment with participants from artisanal fishing communities in Tañon Strait, Philippines that are undergoing management changes. When there are costs to groups for being assigned, we explore whether promoting face-to-face communication among group members can offset some of these costs. We show that self-assembly and the ability to communicate face-to-face both increase compliance with rules and punishment of defectors, although self-assembly has a greater effect. Given the increased awareness of local agency in conservation decision-making, self-assembly may facilitate cooperation among stakeholders and thereby foster more sustainable resource management.

## 1. Introduction

A general challenge in the management of resources that provide multiple users social and economic benefits is how to get individuals to cooperate and prevent over-exploitation of a common pool resource (Ostrom 1990). Common pool resources (CPR) are potentially subject to over-exploitation, depletion or degradation because the core resource (e.g., fish stock) is limited in quantity and it is challenging to limit the number of people who benefit from them (Ostrom, Walker & Gardener 1994). The challenge of collectively managing a CPR sustainably is fundamental to a variety of problems where the narrow interests of individuals are in conflict with the broader interests of the collective.

Two cooperative behaviors critically important for successful CPR management are compliance and punishment. Compliance is reflected by how much a person harvests when there are pro-social and anti-social options. Successful resource management almost always requires participants comply with the prescribed harvest amount, which is one potential reason why it is often used to define successful participant behavior, or cooperation.

Punishment may be very important for management success as well, although studies of punishment in the natural resource management literature are sparse. This may be because punishment is a taboo subject in some communities or is difficult to monitor. Regardless, most community-based conservation interventions require professional, community and/or self-punishment to enforce punishment on those who violate the regulations.

Local context together with management decisions likely determines which aspects of cooperation behaviors are most relevant and feasible. The manner in which cooperative behaviors are encouraged and enabled in CPRs becomes particularly relevant with the increasingly popular management strategy of rights-based approaches, where specific harvest or access rights are granted to individuals or groups such as cooperatives or fisher organizations (DFID 2000). For example, harvest rights, or "catch shares," may be allocated as a fraction of the allowable catch to incentivize fishers to both harvest the resource sustainably (Fujita et al. 1998) and punish defectors (Costello et al. 2010).

Another rights-based approach in small-scale fisheries is Territorial Use Rights Fisheries (TURFs), which provides a well-defined user group of fishers exclusive rights to an area of the ocean. The majority of TURFs are established by conforming to the existing power and resource dynamics by giving existing users governance and access rights to the resource (Twohey et al. In review). Conforming to historical patterns of catch is also characteristic of the allocation of initial quotas in many catch shares. An alternative implementation model has only been used in a limited number of situations (e.g., Chile) where groups self-assemble and apply for a TURF. This approach is believed to further empower fisher organizations (Gallardo Fernandez and Friman 2011).

This variation in how groups are formed motivates understanding the consequences of group formation on its members' willingness to participate in cooperative behaviors. A variety of lessons learned from broader social sciences, including behavioral economics, human behavioral ecology and evolutionary psychology gives insights into why group formation ultimately influences cooperation. First, group formation likely influences social (or group identify), which increases cooperation (Turner 1982, 1984). Social identification is the perception of oneness within a group of persons (Ashford and Mael 1989). It is a cognitive construct and is associated with loyalty to, and pride in, the group and its activities (Turner 1982, Turner 1984, Tajfel and Turners 1985). Having a strong social identity reduces people's tendency to free ride on others' cooperation (Tajfel and Turner 1979, Turner et al. 1987). People with strong social identity still seek to avoid being 'suckered' (Simpson 2006), so exercise the ability to punish. Social identity also enhances perceptions of trust among group members (Kramer and Goldman 1995), where then group members expect others group members will reciprocate their efforts (Pruitt & Kimmel, 1977; Yamagishi, 1986). There also exists a synergy between social identify and social norms (Turner 1991). Social norms may be defined as regularities in attitudes and behavior that characterize a social group and differentiate it from other social groups (Hogg and Reid 2006). Similar to social identity, social norms play an enormous role influencing cooperative behavior (Herrman et al. 2008, Fehr and Gatcher 2002). Research shows people are more willing to comply and punish when there are strong social norms (Herrman et al. 2008), and evidence suggests negative emotions towards defectors are the proximate mechanism behind altruistic punishment (Fehr and Gatcher 2002). Finally, how a group is formed is also likely to influence its member's sense of agency. Evolutionary psychology research predicts that the presence of choice influences people's behavior (Bandura 2006), and experimental economic research suggests democratic institutions may affect cooperation (Bardhan 2000), especially compared to policies that were exogenously imposed (Dal Bo et al. 2010).

Forming, or defining, a group is relatively easy in experimental lab settings, but often difficult in applied settings. Indeed, defining the “community” for a conservation intervention presents many obstacles and is often one of the initial challenges facing decision-makers. It remains unclear if the insights from studies of group dynamics will materially affect cooperation in a group that manages natural resources. Here we build off these past findings and apply them in the context of CPR management, where the presence of choice may be facilitated or constrained by the community’s political context. Specifically, we ask if self-assembled groups of stakeholders cooperate more than assigned groups. Given the evidence that how a group is formed likely influences its member’s sense of group identity and its social norms, we predict that group formation will influence its members’ cooperation.

In cases where self-assembly proves to provide distinct cooperation benefits, we then have to consider real world situations where self-assembly is not a viable option (perhaps due to political or geographic constraints) but where cooperation is required for successful management. For example, Chilean TURFs are quite small (few hundred hectares), which allows for many self-assembled TURFs in the vicinity of a single community. However, if TURFs need to be relatively large for more mobile species, the opportunities to subdivide an area are more limited, which makes self-assembly less viable.

For such constrained settings, we also explore whether there are options to reduce the lost benefits of cooperation through other means. One possibility is increasing communication within the group to counter the challenges of assigned group membership. Enhanced communication within the group has been shown to increase cooperation in other settings (Ostrom et al. 1994, Messick and Brewer 1983, Sally 1995, Brandts et al. 2015, Abatayo and Lynham 2016), and management actions commonly encourage communication between stakeholders through participation in working groups and meetings. Specifically, face-to-face communication (also known as “cheap talk”) has been shown to increase cooperation in lab settings (Isaac and Walker 1988). In a real-world setting, face-to-face communication allows for nonbinding announcements of possible harvest and commitment to punishment that might improve the efficiency of compliance by allowing people to convey the threat of punishment to potential over harvesters. We explore the role of communication in CPR management by investigating if face-to-face communication does indeed increase cooperation.

We use experimental play, called “Common Pool Resource Games,” and a survey to address our research questions and empirically test if the mechanisms of group formation and face-to-face communication influence compliance and punishment. We show that self-assembly and the ability to communicate face-to-face both increase compliance with rules and punishment of defectors, although self-assembly has a greater effect.

## 2. Methods

### *2.1 Research setting*

This research is linked to a large international project called Fish Forever that is focused on implementing TURFs to enhance the management success in small-scale artisanal fisheries. Small-scale fisheries are challenged by multiple issues. In particular, coordination challenges lead to overfishing (Costello et al. 2012), destructive fishing practices (McClanhan et al. 2009), environmental degradation, inadequate funding and lack of government support, which often results in weak governance (Berkes et al. 2001). TURFs are widely believed to incentivize cooperation and sustainable fisheries (Fujita et al. 1998, Costello et al. 2010) and are being implemented in a variety of settings, including Tañon Strait in the Philippines.

Tañon Strait is home to roughly 2.1 million people (NSO 2010) who depend on its marine resources for food and livelihood. It is one of the region's major fishing grounds and supports at least 26,850 fishers (Green et al. 2004). The fishers in Tañon Strait use a variety of fishing gear, including gillnets, hook-and line, squid jigs, and beach seines, which despite being illegal, are tolerated. The nearshore reefs are highly diverse, including species from over 24 families (Carpenter 2005). Fishers target nearshore commercially valuable species including triggerfish, sweetlips, emperors, snappers, solider fish, and goatfish, as well as pelagic species including anchovies, billfish, mackerels and tuna.

Tañon Strait became a protected seascape in 1988 because of its high biodiversity. It spans three Provinces in two regions – Cebu, Negros Oriental and Negros Occidental – and is considered the largest protected seascape and protected area in the Philippines. The Tañon Strait Protected Seascape – General Management Plan (TSPS-GMP) envisions "a Protected Seascape with natural biodiversity and integrity, which is effectively managed by all stakeholders to ensure ecological integrity and resilience, sustainable socio-economic development and communities living in harmony with nature" (TSPS-GMP). Prior to TSPS-GMP, nearshore fisheries have been open access, meaning there were no restricted users, access restrictions, quota, or maximum allowable catch. Community members are not responsible for complying with, enforcing or punishing fishing regulations. TSPS-GMP will implement three types of zones designating different levels of resource use, including TURFs.

With the introduction of TURFs and changing fisheries management, fishers will be asked to comply with new regulations including physical access to fishing grounds and catch allocations. It is unclear how fishers will comply with new regulations that change their access to fishing grounds and require new behaviors. Some managers believe fishers are generally law-abiding and will comply. Others believe fishers say they will comply but will not. Fishers will also be expected to report those who do not comply (which will lead to the perpetrator being punished). In Tañon Strait, reporting may be costly and impose risk of social retaliation. For example, a fisher who reported another community member using illegal gear was blacklisted from selling his catch to a local restaurant in adjacent areas where regulations have been implemented (personal conversation). There are also incidents of boats being tampered with after their owners report violations. Thus, this potential cost forces fisheries managers to look for ways to encourage and incentivize punishment.

*2.2 Participants*

In total, our study includes 232 fishers from 5 different municipalities on the island of Cebu – Alegria, Sanboan, Santander, Ginatilan, and Badian. Participant characteristics – such as age, sex, number of dependents – were balanced between treatments (see Supplemental Materials). Two potential sources of bias exist and must be considered when evaluating external validity. First, participation was voluntary and participants were recruited by Fish Forever partners on the sole basis of them being artisanal fishers. Results could reflect participation of more community-oriented participants or those that are more comfortable with Fish Forever. Second, these 5 local communities are preparing for a management change, resulting in participants being more attune to sustainable management practices and cooperative behavior.

### *2.3 The Common Pool Resource Game*

In a Common Pool Resource Game, players must weigh the individual versus group benefit when deciding how much of a common pool resource to harvest. Such games build upon traditional economics models to inform the development of resource management mechanisms that influence stakeholder behavior (Ostrom et al. 1994, Cardenas and Ostrom 2004, Busurto et al. 2016), but differ in that they are often conducted in the field (rather than in a lab at a university). These “lab-in-field” experiments better facilitate the complex set of motivations that drive behavior (OECD 2012) and benefit from subjects that are more familiar with the problems (Cardenas and Carpenter 2008) compared to most experimental studies conducted with college students from distant settings.

We use a specific game known as a one-shot Prisoner’s Dilemma game because it provides a simple measurement of relevant cooperation that is easiest to execute in the field (Janssen 2008). This approach presents the ideal opportunity to test and refine theory about the conditions that encourage cooperation in a context that is relevant to natural resource managers because participants, i.e. artisanal fishers, share a natural resource, i.e. an artisanal fishery, and “play” a real CPR game in their daily lives. In particular, it presents the opportunity to study how unrelated people, i.e., exogenously imposed groups of fishers from the community, cooperate in a given context that abstractly represents the real-world challenges of a fishing community overcoming mutual defection, or over harvesting. Both fishing and punishment in Tañon Strait are often solo activities, and individuals have to make daily decisions regarding harvest and punishment within the community's social norms. The Prisoner's Dilemma game applies to natural resource management scenarios where two people both use a common pool resource (e.g., they are fishing in a community pond). There are no fishing regulations, or rules, as to how many fish one person can choose. In this example choosing 6 fish means a fisher complies with pro-social behavior and cultural norms to harvest the sustainable amount (6 fish each, 12 fish in total). Their choice is kept private from their partner, and everyone benefits equally when all fishers harvest the socially acceptable amount of fish. However, when certain individuals harvest more, these increases come at a cost to others. In the real world, such costs could arise from fewer fish to catch or deflated market prices. This reflects real world conditions in many artisanal fishing communities where fishers have to decide how many fish to harvest knowing that it is an open access common pool resource, that there is a culturally acceptable number of fish to harvest, but that they can gain more individually in the short term by overharvesting.

If both fishers harvest the norm, then they both get to keep six fish and a healthy fish stock will be maintained. If one fisher complies with the norm but the other defects and harvests more than the norm (10 fish), then the defector gets to keep all of his catch, whereas his partner gets a much smaller catch (two fish as opposed to 6 fish) because there are not enough fish to sustainably harvest 16 fish. If both fishers defect (10 fish each, 20 fish in total, called *mutual defection*), each player will only receive 1 fish. Both fishers have the same opportunities and know the consequences of each action.

This is considered to be a *simultaneous game,* because the fishers cannot communicate and will make their decision at the same time. Table 1 shows the payoff structure for this classic Prisoner's Dilemma game. To determine what each fisher will do, they will each analyze their best strategy given the other fisher's possible strategies. If fisher 2 overharvests (defects), fisher 1 will get either 1 or 2, and if fisher 2 complies with the social norm, fisher 1 will get either 6 or 10. Fisher 1 must choose his best strategy given that he does not know how fisher 2 will respond. The rational thing for fisher 1 to do purely from self-interest is to defect, since he will individually be better off under either options chosen by fisher 2. Similarly, analyzing the best strategy for fisher 2 with regards to fisher 1's strategies gets us to the same point: the individually rational thing to do for fisher 2 to do is to defect, making mutual defection the dominant strategy even though both fishers would be far better off if they had cooperated and both complied. The Nash equilibrium in this game (denoted in Table 1 with an asterix) is the set of strategies that maximizes each fisher's payout (or *utility*) given the other fisher's strategy. Mutual defection in the real world with respect to natural resources leads to over exploitation of the natural resource, and in the case of fish, failed fisheries stocks. Overcoming this defection dilemma requires coordination and mutual compliance.

| | | Fisher 2 | |
|---|---|---|---|
| | | Comply (6 fish) | Defect (10 fish) |
| Fisher 1 | Comply (6 fish) | 6, 6 | 1, 10 |
| | Defect (10 fish) | 10, 1 | 2, 2* |

**Table 1** Standard Prisoner's Dilemma game where payouts are defined as 10 > 6 > 2> 1 and where 2*6 > 1 +10. * Denotes pure Nash equilibrium. The *Prisoner's Dilemma* game presents the problem of how to escape from the inefficient stable equilibrium, e.g. Nash equilibrium, of mutual defection.

Our experimental one-shot Prisoner's Dilemma game presented a scenario similar to the example above, but with one major addition – punishment. Prior to playing the game and before they know who their partner is, players answer the following question that pre-commits them to altruistic punishment for all three rounds: If your partner defects by choosing 10 fish, you can punish them by taking away 5 of their fish (they will be left with 5 fish) but it will cost you one fish. Would you like to punish them? This reflects real choices fishers in Tañon Strait will have to make about reporting fishing violations where there is often social pressure not to report and punish community members who defect, and fishers who report defectors often experience threats and negative social ramifications.

In our experimental design, punishing a defector may be irrational. However, people are more likely to punish when they have a strong negative emotion towards defectors (Fehr and Gatcher 2002). The willingness for someone to punish another who violates a norm at a personal cost and without obtaining any personal benefit is known as "altruistic punishment" or "strong reciprocity". In this case, punishment is altruistic because the outcome is fixed from one round, meaning that the benefits of punishing on future cooperation are not experienced in the punisher's payout. Altruistic punishment has been argued to maintain and even enforce cooperative group norms (Fehr et al. 2008, Fehr and Gatcher 2002) suggesting that a rational player who believes altruistic punishment is possible will be more likely to comply.

We designed our experiment to force players to make the decision to punish (or not) simply based on their knowledge of their treatment, or game conditions, without the opportunity to evaluate their partner's potential for cooperating or defecting behavior. This was done strategically to isolate the initial effects of group membership from other dynamics that could influence the likelihoods of cooperation and punishment as the game evolves. The simplicity of a one-shot game allows us to look at the general sentiment, or social norms, towards punishment among fishers in Tañon Strait, because we can investigate willingness to comply and punish independent of previous play (thus eliminating compliance and punishment based on retaliation) and with no future commitment of cooperative behavior (thus eliminating punishment for the sake of future earnings). Our one-shot design eliminates any kind of reputation formation so that purely selfish people will never cooperate or punish others, because cooperation and punishment are costly and yield no pecuniary benefits (Lotem et al. 1999), thereby heightening the incentive to defect and highlighting the potential power of the treatment to overcome selfish incentives. In other words, in repeated games punishment might have confounding effects on cooperation through reputation building, but defection is preserved as the dominant action in a one-shot game. We can assume that treatment conditions were ultimately responsible for players' behavior, because social identity and social norms were not able to evolve through repeated interactions. The limitation of a one-shot game is that players do not learn and adapt their behaviors through repeated interactions (Embrey et al. 2017) like they would in the real world. This game is not meant to investigate the myriad of other aspects of group dynamics that could affect fishery performance, such as the evolution of leadership, reputation, reciprocity, or costly signaling that would be investigated through a game with repeated interactions and where players would learn and adjust their play.

| | | Player 2 | | | |
|---|---|---|---|---|---|
| | | P, C (4/5, 1) | N, C (1/5, 1) | P, D (4/5, 0) | N, D (1/5, 0) |
| Player 1 | P, C (4/5, 1) | 6, 6* | 6, 6 | 0, 5 | 0, 5 |
| | N, C (1/5, 1) | 6, 6 | 6, 6 | 1, 10* | 1, 10 |
| | P, D (4/5, 0) | 5, 0 | 10, 1* | -4, -4 | 1, -3 |
| | N, D (1/5, 0) | 5, 0 | 10, 1 | -3, 1 | 2, 2* |

**Table 2** Prisoner's Dilemma payout bi-matrix with opportunity to altruistically punish. Strategies are represented as follows: P= Punish, N = No punish, C = Comply, D = Defect. Each strategy has a probability of being played, shown in parentheses. Underlined numbers denote player's best response and * denotes pure Nash equilibrium.

The payoff structure for this Prisoner's Dilemma game is shown in the bi-matrix presented in Table 2. The experimental design is presented in Table 3. Participants were randomly assigned to four different treatments in which we manipulated how groups are formed and their ability to communicate. The four treatments are described in Table 3.

| Treatment | Conditions | Sample size |
|---|---|---|
| *(I, Control) Randomly assigned group with no communication* | Players are randomly assigned a partner, and players are not allowed to communicate | 56 |
| *(II) Randomly assigned group with communication* | Players are randomly assigned a partner, and players get to communicate with their partner for 5 minutes before they play | 63 |
| *(III) Self-Assembled* | Players have two minutes to choose their partner from others in the same treatment after they are told they are playing a cooperation game but before they know the rules. Players may communicate while pairing off but not during play | 55 |
| *(IV) Self-Assembled + Additional Communication* | Players have two minutes to choose their partner from others in the same treatment after they are told they are playing a cooperation game, but before they know the rules. Players get to communicate with their partner for 5 minutes before they play | 58 |
| Total | | 232 |

**Table 3** Experiment treatments.

We intended to have 64 individuals (32 pairs) per Treatment I and 62 individuals (31 pairs) per Treatments II, III, and IV. However, we modified our design to reflect participant turn out – each treatment ultimately had between 55 and 63 individuals. Treatments I and IV had an odd number of participants, meaning that a different participant sat out each round. In Treatment I, the partner to the missing participant sat out. In Treatment IV, we randomly selected a number each round and the corresponding participant sat out.

Each participant received 500PhP (~USD10) for participating and had the opportunity to earn an additional 50 to 500PhP (~USD1-10) depending on his/her actual payout from one randomly selected round of the Prisoner's Dilemma game. This payout amount reflects the real-world opportunity costs of one day's worth of fishing for the participants. Likewise, the punishment cost reflects the real-world risk associated with retaliation against the punisher and of breaking social norms. The payout was randomly selected from one of the three rounds to ensure players did not face repercussions from their play outside of game in the real world. The payout was not revealed until after participants completed the games and the surveys, so there was no opportunity to learn and adapt their behavior.

To summarize, the order of events went as follows:

1. Participants were randomly assigned to treatments.
2. Treatments were separated. All participants within a treatment played the game at the same time, and each of the four treatments played at separate times.
3. Treatment conditions and game rules were explained in multiple formats.
4. Participants committed (or not) to punishing their partners if they harvested 10 fish. Note that this commitment holds for all three partners and rounds.
5. Participants paired off according to treatment conditions. Self-assembled treatments were allowed to communicate during the pairing off process because this best reflects real group selection processes in which participants communicate about the common pool resource. Note that even self-assembled with no communication treatments were allowed to communicate during this pairing process and we were unable to prevent communication about strategies. Random treatments were assigned based on partner identification numbers.
6. Communication treatments were allowed to communicate in the form of in-person open communication, meaning there are no limits to what players can discuss, including the game (also referred to as "open chat" by Cooper et al. 2014).
7. Each participant secretly harvested 6 or 10 fish.
8. Repeat pairing and harvest process (steps 5-7) twice more so that each participant played three rounds, each round with a different partner.
9. Participants completed a post-game survey.
10. Payouts received their payouts.

*2.4 Nash equilibrium*

Solving for the Nash equilibrium yields both players' most rational strategy (or strategies). In solving for equilibria we are also able to calculate the frequency and expected payout of each strategy. Figure 1 is a game tree that represents the two points in the game where players have to simultaneously decide to punish or not, and to comply (6 fish) or defect (10 fish). Working from the last node backwards Player 2 has to choose to comply or defect; that is, Player 2 has to choose a harvest of 10 or 6. If Player 1 anticipates that Player 2 is a rational player, Player 1 would harvest the maximum amount of fish (10) to maximize the expected return. If Player 1 chose to punish, his payoff will be 1 fish. Likewise, if he did not punish, his payoff will be 0 fish. In the scenario where Player 2 plays punish and defect, expressed as PD, Player 1's best response is to not punish and comply (NC). The resulting payout would be 10 fish for Player 2, and 1 fish for Player 1, expressed (1, 10). Now consider if Player 1 also defects by harvesting 10 fish, his payout would be -4 or -3 depending on if he also punished or not. The payouts of -4 or -3 are both less than if he complied (0 if he punished as well, or 1 if he did not punish). Thus, when one player defects, there is an asymmetrical equilibrium, because the other player's best response is to not punish and comply – thus the paired strategy (NC, PD) and its inverse (PD, NC) are pure Nash equilibria.

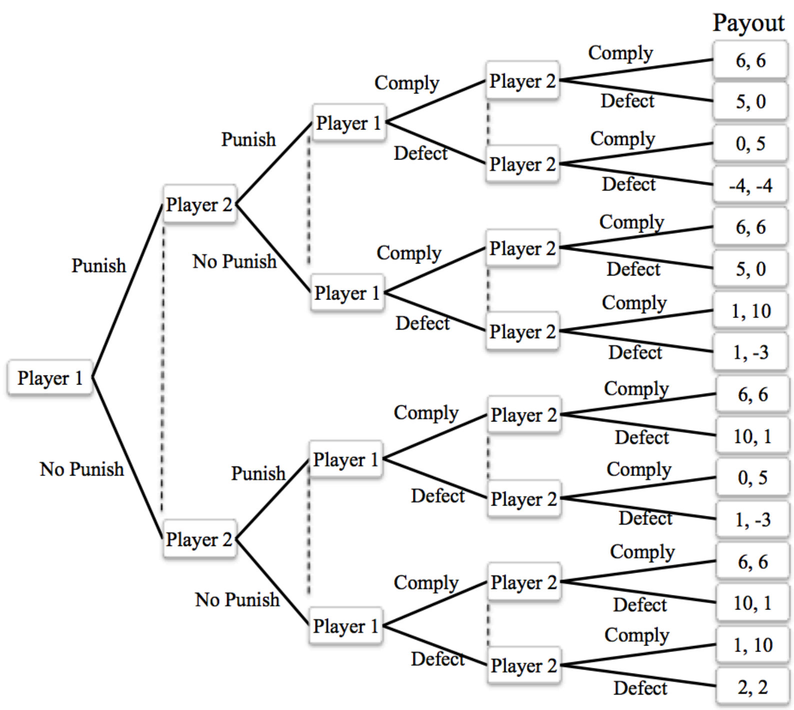


**Figure 1** Game tree representing where players have to make decisions. The first decision both players must make is to punish or not for all three rounds. The second decision is to comply or defect. The dashed lines mean that both players have the same information and are making their decisions simultaneously.

Following the same logic, if one player does not punish and defects (ND), that player will get 5, 10, -3 or 2 depending on how the other plays. The first player's best response is to also not punish and defect (ND). The resulting payout would be 2 fish for each player (2, 2) and the paired strategy (ND, ND) is also a pure Nash equilibrium. Lastly, if one player punishes and complies (PC) the other player's best response is to punish and comply (PC), making (PC, PC) with a payout of (6, 6) the last pure strategy Nash equilibrium. Thus, there are four *pure strategy* Nash equilibria: (PC, PC), (PD, NC), (NC, PD), and (ND, ND).

### *2.5 Mixed strategy Nash equilibrium*

In our game there is no certainty that players will play certain strategies. This is called a *mixed strategy game*. In a mixed strategy game the Nash equilibrium is a player's mixed strategy (meaning that probabilities of play may fall between 0 and 1) as a best response to the other player's mixed strategy. For our purposes here, we can consider the equilibrium components for the solved mixed strategy summarized in Table 4. For a full explanation of the solved mixed strategy Nash equilibrium, see the Supplemental Materials.

| Player 1 | Player 2 | Translation |
|---|---|---|
| $\sigma^1_{PC} = 4/5$, $\sigma^1_{NC} = 1/5$, $\sigma^1_{PD} = 0$, $\sigma^1_{ND} = 0$ and $\sigma^1_{PC} = 0$, $\sigma^1_{NC} = 1$, $\sigma^1_{PD} = 0$, $\sigma^1_{ND} = 0$ | $\sigma^2_{PC} = 1$, $\sigma^2_{NC} = 0$, $\sigma^2_{PD} = 0$, $\sigma^2_{ND} = 0$, and $\sigma^2_{PC} = 4/5$, $\sigma^2_{NC} = 1/5$, $\sigma^2_{PD} = 0$, $\sigma^2_{ND} = 0$. | Player 1 mixes between one strategy where he has 4/5 probability of punishing and complying and 1/5 probability of not punishing and complying, and another strategy where he will not punish and comply. Player 2 will mix between one strategy that is to punish and comply, and another strategy that has the probability of punishing and complying at 4/5 and not punishing and complying at 1/5. |
| $\sigma^1_{PC} = 4/5$, $\sigma^1_{NC} = 1/5$, $\sigma^1_{PD} = 0$, $\sigma^1_{ND} = 0$ | $\sigma^2_{PC} = 0$, $\sigma^2_{NC} = 0$, $\sigma^2_{PD} = 1/5$, $\sigma^2_{ND} = 4/5$ and $\sigma^2_{PC} = 0$, $\sigma^2_{NC} = 0$, $\sigma^2_{PD} = 1$, $\sigma^2_{ND} = 0$ | Player 1 will punish and comply with the probability of 4/5 and not punish and comply with the probability of 1/5, and Player 2 will mix between one strategy where he has 1/5 probability of punishing and defecting and 4/5 probability of not punishing and defecting, and another strategy where he punishes and defects |
| $\sigma^1_{PC} = 0$, $\sigma^1_{NC} = 1$, $\sigma^1_{PD} = 0$, $\sigma^1_{ND} = 0$, and $\sigma^1_{PC} = 0$, $\sigma^1_{NC} = 0$, $\sigma^1_{PD} = 0$, $\sigma^1_{ND} = 1$ | $\sigma^2_{PC} = 4/5$, $\sigma^2_{NC} = 1/5$, $\sigma^2_{PD} = 0$, $\sigma^2_{ND} = 0$ | Player 1 mixes between two strategies, one where he does not punish and complies, and one where he does not punish and defect, and Player 2 has 4/5 probability of punishing and complying and 1/5 probability of not punishing and complying. |

**Table 4** Mixed strategy Nash equilibrium output from the bimatrix equilibrium algorithm (Avis et al. 2010). Our game has three complicated equilibrium components.

*2.6 Precautions*

We took several precautions to ensure people understood the game, including presenting the materials in different formats and following up with a post game survey that asked two comprehensive multiple-choice questions about the game (see Supplemental Material). Our treatments shared similar levels of non-understanding (Assigned + No communication = 14.3%, Assigned + Communication =8.3%, Self-assembled + No communication =16.4, Self-assembled + Communication =17.5%). We include all responses from all players regardless of whether they answered both questions correctly to address concerns about "post treatment bias". Excluding participants who did not show full comprehension, however, yielded similar results. We report the results excluding participants who did not show full comprehension in the Supplemental Material.

*2.7 Analyses*

All of our analyses are designed to investigate the conditions that inspire cooperation. Since participants who harvested 6 fish were "cooperators" and those who harvested 10 fish were "defectors," we categorized the data as binomial. We fit two types of models to investigate treatment effect on cooperation. First, we looked for treatment's interaction significance by fitting an ordinary least squares (OLS) model. We use an OLS model to minimize the sum of the squared residuals. This model clustered responses by individuals, because each participant played three rounds and there is a lack of independence between observations. Our model also included robust standard errors.

Second, we looked at how many rounds individual participants cooperated on average using a linear model (LM) where individuals' behaviors were averaged into one data point. Treatment conditions were broken up into the ability to self assemble (or not) and additional communication (or not). The main difference between these two methods is how treatment and individuals' behavior are considered.

The regression analyses do not give any insight into how theoretical behavior compares to actual behavior, nor do they identify the conditions that may inspire individual or paired cooperation. We therefore also compare how participants play relative to the theoretical predictions based on probabilities (Nash Equilibrium predictions) to provide additional insight into the circumstances that inspire cooperation and perhaps overcome incentives not to.

Finally, we calculated a participant's payout (or utility) using probabilities to express the uncertainty about what the other player will do (see Supplemental Materials). For example, Player 1's expected utility for the strategy punish and comply may be expressed by equation 1:

$$EU^1(NC) = 6(\sigma^2_{PC} + \sigma^2_{NC}) + 1(\sigma^2_{PD} + \sigma^2_{ND}) \qquad \text{(Eq. 1)}$$

where $\sigma^2$ represents the probability of Player 2 playing each of the four strategies. Solving the expected utility for each strategy then allows us to replace the theoretical probability with the actual probability of each strategy being played for each treatment (see Supplemental Materials). For example, Player 1's expected utility for the strategy punish and comply in the control treatment may be expressed by solving equation 1 using the played probability values:

$$EU^1(NC) = 6(0.11 + 0.36) + 1(0.16 + 0.37) \qquad \text{(Eq. 2)}$$

Comparing the frequencies of individual behavior (and corresponding payoff) to the predicted behavior (and payoff) gives insight into when participants deviate from the rational strategy that would otherwise give the highest payoff.

## 3. Results

### *3.1 Treatment effect*

Self-assembled treatments both comply and punish significantly more than assigned treatments (Fig. 2). Both group assembly and the ability to communicate have a positive effect on cooperation. However, group assembly has a significantly greater effect than communication on both compliance and punishment, and the positive effect of communication is not significant (Table 5). Our results were obtained from an ordinary least squares (OLS) model displayed in Table 5 and a generalized linear model (GLM) displayed in Table 6.

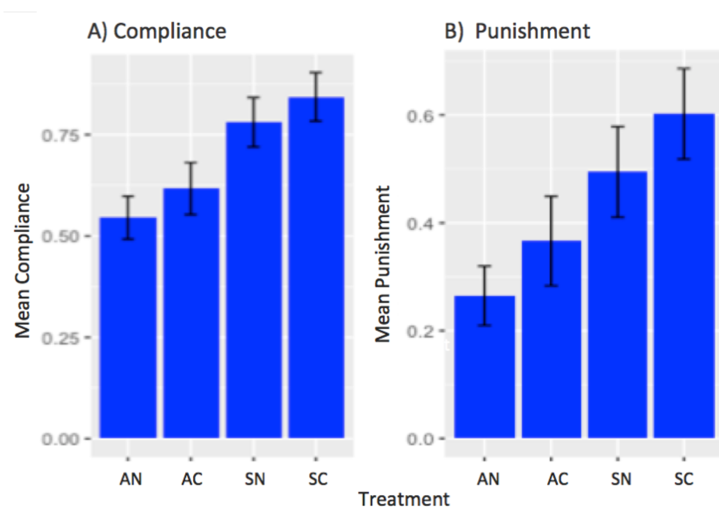


**Figure 2** Mean rates of A) compliance, and B) Punishment, by treatment with standard errors and clustering by individual. AN = Assigned + No communication, AC = Assigned + Communication, SN = Self-assembled, SC = Self-assembled + Communication.

| | Compliance | | | | Punishment | | | |
|---|---|---|---|---|---|---|---|---|
| | Estimate | Std. Error | t value | Pr (>\|t\|) | Estimate | Std. Error | t value | Pr (>\|t\|) |
| (Intercept) | 0.541 | 0.053 | 10.205 | 0.000 | 0.257 | 0.056 | 4.638 | 0.000 |
| Assigned + Communication | 0.072 | 0.064 | 1.139 | 0.255 | 0.102 | 0.083 | 1.220 | 0.222 |
| Self-Assembly | 0.236 | 0.061 | 3.886 | 0.000 | 0.230 | 0.084 | 2.753 | 0.006 |
| Self-Assembly + Communication | 0.298 | 0.060 | 4.989 | 0.000 | 0.338 | 0.084 | 4.013 | 0.000 |
| | *p<0.1;* ***p<0.05;*** p<0.01 | | | | | | | |

**Table 5** Treatment effect on cooperation with an ordinary least squares model including clustering and robust standard errors. Note that significance is relative to the baseline.

| | Compliance | | | | Punishment | | | |
|---|---|---|---|---|---|---|---|---|
| | Estimate | Std. Error | t value | Pr (>\|t\|) | Estimate | Std. Error | t value | Pr (>\|t\|) |
| (Intercept) | 0.545 | 0.041 | 13.409 | < 2e-16 | 0.254 | 0.060 | 4.188 | 3.95e-05 |
| Assembly | 0.237 | 0.057 | 4.157 | 4.48e-05 | 0.230 | 0.085 | 2.697 | 0.008 |
| Communication | 0.052 | 0.058 | 0.898 | 0.379 | 0.119 | 0.087 | 1.364 | 0.174 |
| Assembly: Communication | 0.011 | 0.082 | 0.128 | 0.898 | 0.000 | 0.123 | 0.001 | 0.999 |
| | *p<0.1;* ***p<0.05;*** p<0.01 | | | | | | | |

**Table 6** Effect of communication and assembly on individual cooperation with a generalized linear model where individuals' behaviors were averaged into one data point.

*3.2 Cooperation*

Participants generally comply with rules (54% of people in baseline treatment comply). When we look at the baseline individual compliance, we find that individuals comply on average 1.8 times over the three rounds (Table 6). Participants are generally not willing to punish defectors (25.7% of people in baseline treatment are willing to punish). The lack of punishment in the baseline conditions suggests that in a one-shot game people are reluctant to waste the resources on punishment, likely because they either expect people to generally comply or because they will not see the rewards from punishing through others' compliant behavior until future iterations of the game.

Self-assembly has a significantly large positive effect on compliance (Table 5, increases compliance by 23.6%, $p < 0.0001$). Communication has a non-significant positive effect (Table 5, increases compliance by 7.2%, $p = 0.255$). When we look at the average responses of individuals across the three rounds, we similarly see that self-assembly has a significantly positive effect on compliance (Table 6). Self-assembly also has a significantly large positive effect on punishment (increase of 23%, $p = 0.006$), whereas communication again only has a non-significant marginally positive effect (increase of 10.2%, $p = 0.222$). Similarly, analyzing the average responses of individuals across rounds suggests that self-assembly has a significant 25.4% positive effect on punishment (Table 6).

*3.3 Paired behaviors*

The most common paired behavior in the self-assembled with additional communication treatment is for both players to punish and comply (Fig. 3, PC, PC). As demonstrated in the solved utility values for each behavior (see Supplemental Materials), this equilibrium (PC, PC) occurs when neither player can do better than punish and comply when the other player plays punish and comply, and only holds when the probability of the other player defecting is zero. This would suggest that players in this treatment strongly believe, likely due to the self-assembly process and ability to communicate, that the probability of their partner defecting is near zero.

The most common paired behavior in both assigned treatments is for one player to punish and comply and for the other player to not punish and defect (PC, ND) or (ND, PC)

(Fig. 3). This supports the pure Nash equilibrium strategy where one player defects and there is an asymmetrical equilibrium, because it is the other player's best response to not punish and comply. The frequency of this paired behavior compared to the next highest frequency (PC, NC), suggests that in assigned situations some people will cooperate and others will not, but that communication may persuade a non-punishing defector to comply; when communication is present in assigned groups, there is a 10% increase in (PC, NC) paired behavior and a 5% decrease in the (PC, ND) paired behavior as compared to no communication.

The most common paired behavior in the self-assembled with no additional communication treatment is for one player to punish and comply and for one player not to punish and to comply (PC, NC) or (NC, PC), followed closely by one player punishing and complying and the other player punishing and defecting (PC, PD) or (PD, PC). When compared to the frequency of (NC, NC), this finding suggests the addition of communication may again persuade non-complying types to comply (Fig. 3).

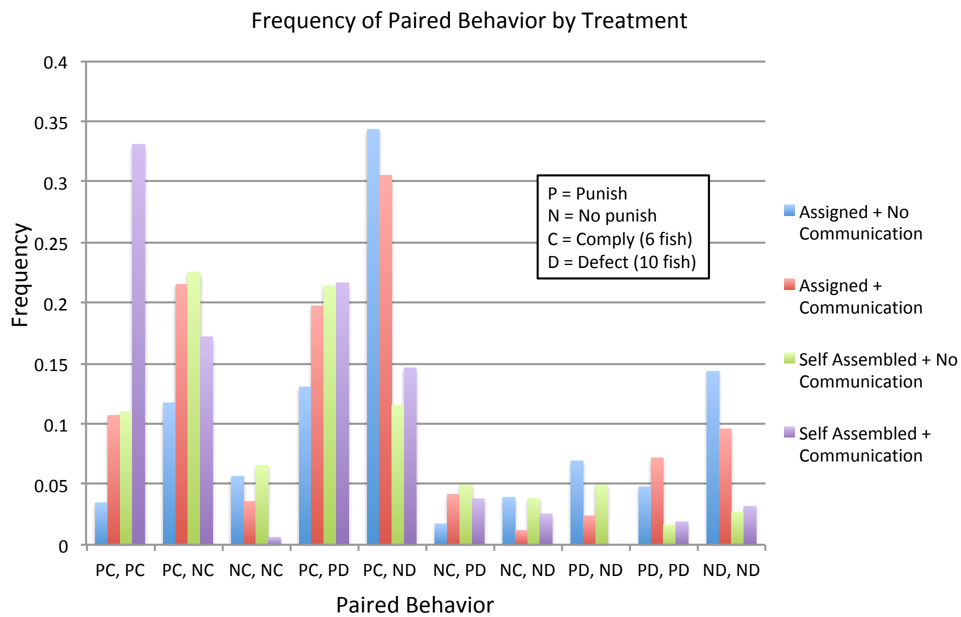


**Figure 3** Frequency of paired behavior by treatment. Note that duplicate strategies (i.e. (PC, ND) and (ND, PC)) are shown as one paired strategy.

### *3.4 Individual strategies*

Players did not commonly play the strategy that would have maximized one's payout for any of the treatments (Fig. 4). The most frequently played individual strategy differed greatly across the four treatments. Deviation from the rational behavior suggests treatment conditions influenced behavior, and comparing actual behavior to the theoretical predictions provides insight into the conditions that increase cooperation the most.

The largest proportional deviations from rational behavior are in the self-assembled treatments where punish and comply was the most common strategy, where no punish and defect had the highest payout (Fig. 4). This result suggests self-assembly inspires conservation behaviors.

The highest payout for the assigned with no communication treatment comes from playing punish and defect, but individuals most frequently chose not to punish and were almost as likely to punish and comply as they were to punish and defect (Fig. 4). The highest payout for the assigned with communication treatment comes from playing no punish and defect, but individuals most frequently did not punish and complied (Fig. 4).

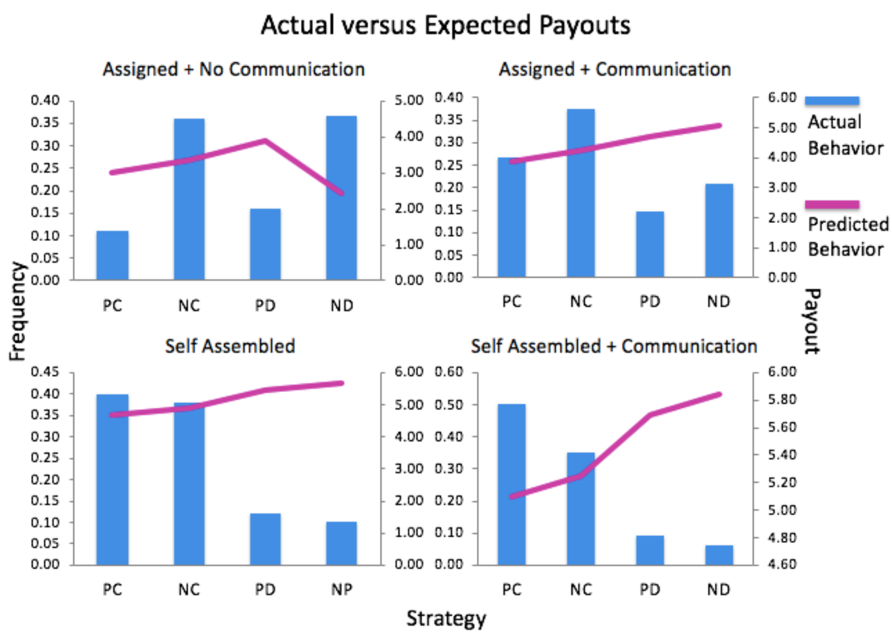


**Figure 4** Comparison between the frequency of each strategy played by treatment against how the payoff relative to other strategies in the treatment given the other strategies players will play. (i.e. the payout calculated considering both player's strategy). PC = Punish and Comply, NC = No punish and Comply, PD = Punish and Defect, NP = No punish and Defect.

## 4. Discussion

We investigated two important cooperation behaviors that are particularly relevant for successful natural resource management – compliance and punishment. In almost all cases of resource management, individuals are required to comply with prescribed regulations. Some management regimes rely on professional enforcement and punishment, while others rely on self-enforcement and punishment. Cooperative behaviors can also be synergistic in different ways – e.g., those who participate in one cooperative behavior are more likely to engage in the other cooperative behaviors, and enforcement and punishment can result in compliance (Fehr and Gächter 2002). However, the cause and effect nature of these relationships likely depends on how effective enforcement is and how credible the punishment is (McGillivray and Smith 2006, Horai and Tedeschi 1969). Therefore, the local context together with management decisions likely determine which aspects of cooperation behaviors are most relevant and feasible.

*4.1 Management benefits of self-determination*

We predicted that both self-assembly and face-to-face communication would increase cooperation. However, we find that only self-assembly significantly increases cooperation. Communication has a positive but not significant effect on cooperation. One possible explanation may be that individuals in self-assembled groups have shared norms and can anticipate one another's strategy before the game is played, making the additional communication only marginally beneficial. The larger impact of group assembly relative to communication was surprising given the large volume of literature that finds communication benefits cooperation (Dawes, McTavish and Shaklee 1977, van de Kragt, Orbell and Dawes 1983, Balliet 2009, Ostrom et al. 1994, Messick and Brewer 1983, Sally 1995, Brosig et al. 2003). It is commonly believed face-to-face communication increases a sense of accountability and makes the threat of punishment more credible (or less cheap), thereby incentivizing players not to defect (Brosig et al. 2003). It is unlikely, but possible, that participants were able to cheat the no communication rule in our experiment. For example, there could have been subtle body language or comments made that the facilitators did not pick up on. It was also possible that we did not allow our participants long enough to communicate face-to-face, or that the benefits of communication may have been absorbed in the self-assembly process making additional communication non-significant. However, this implies that communication is more important in assigned groups, which our results neither support or rule out. Recently and post field work, our local colleagues in Tañon Strait are investing more time and energy into strategies building social trust in addition to face-to-face communication, because they believe the benefits of face-to-face communication are not enough to inspire cooperation.

The finding that self-assembled two-person groups cooperate significantly better than assigned two-person groups may or may not be generalizable to the real world where group size will typically be much larger. Whether the benefits of self assembly extend to far larger groups warrants further investigation. Laboratory experiments suggest agency in group formation will increase contributions to group benefits (Isaac and Walker 1988, Charness and Yang 2014), but this has not been investigated in the field. If larger self-assembled groups do indeed cooperate more than their assigned counterparts, it is in a resource manager's best interest to allow people to self assemble into groups that manage a common pool resource, like fisheries. Our findings offer evidence in support of efforts to increase self-determination in political processes (Agarwal 2009, Ostrom 2011), including catch share systems like TURFs.

*4.2 Future directions*

Further research is needed to understand the management decisions fostering group dynamics that can help facilitate larger cooperatives (like a TURF) or even networks of cooperatives. In our behavioral experiment we framed group assembly as either self-assembled or assigned. However, there are many instances where an imposed group may not have the same performance cost as being completely "random," because people know each other well and there may be higher levels of trust than predicted by random assemblies. We looked at communication, but it is likely that there may be other social, political and economic characteristics that help mitigate the shortcomings of exogenously assembled groups. For example, there may be management strategies for building rapport that do not involve face-to-face communication, such as transparent harvest reporting and decision-making processes. Further behavioral experiments may investigate how these characteristics and alternative strategies influence conservation behaviors.

Resource management has a lot to gain from integrating social science (Bennett et al. 2017, Hicks and Cinner 2016, Karieva and Mavier 2012, Mascia 2003). For example, TURF design elements primarily focus on fish ecology (e.g. species mobility – White and Costello 2011) or geography (e.g. physical barriers – Bonzon et al. 2013), whereas the social side of TURF design has received far less attention by comparison. Successful resource management plans almost always require individuals to comply, and in most small- scale fisheries, to self-enforce and to punish defectors. Therefore, managers will benefit by applying experimental approaches like ours to consider the social dimensions and management actions that influence conservation outcomes.

## *5.* Conclusion

We demonstrate that the presence of choice in one's community increases cooperation, and that communication alone cannot be counted on to counter these reductions in cooperation. Our findings are significant for behavioral scientists and natural resource managers alike and are in line with the trend towards co-management practices that encourage self-assembly and locally determined rules of engagement.

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## Supplemental Material

### *1. Precautions*

We needed to ensure we knew who fully understood the game and who did not. All experiment instruction was presented orally and visually and included a set of examples and possible actions and outcomes. Before play began, players were asked a series of hypothetical pay out questions to ensure they understood the nature of the game and the correct answers were discussed by the facilitators. The facilitators played a mock game for demonstration and then the one-shot Prisoner's Dilemma game was played.

### *2. Solved mixed strategy Nash equilibrium and Utility*

Let $\sigma$ = probability of playing a particular strategy, $\sigma_{PC}$ = probability of playing punish and comply, $\sigma_{NC}$ = probability of playing no punish and comply, $\sigma_{PD}$ = probability of playing punish and defect, and $\sigma_{ND}$ = probability of playing no punish and defect. The sum of all the probabilities of each of the Player's four strategies must equal 1: $\sigma_{PC} + \sigma_{NC} + \sigma_{PD} + \sigma_{ND} = 1$.

Let an arbitrary player be called player *i*. Let $S_i$ denote the set of strategies available to player *i,* and let $s_i$ denote an arbitrary member of this set. Let ($s_{PC}, s_{NC}, s_{PD}, s_{ND}$) denote the combination of strategies for each player, and let $E^1$ denote player *i*'s payoff function: $E^i(s_{PC}, s_{NC}, s_{PD}, s_{ND})$ is the payoff to player *i* if the players choose the strategies ($s_{PC}, s_{NC}, s_{PD}, s_{ND}$). Collecting all this together, we denote the game by G = {$s_{PC}, s_{NC}, s_{PD}, s_{ND}$ ; $E_{PC}, E_{NC}, E_{PD}, E_{ND}$}. From above, we know that the mixed strategy for player *i* is a probability distribution $\sigma^i = \sigma^i_{PC} + \sigma^i_{NC} + \sigma^i_{PD} + \sigma^i_{ND}$ where $\sigma^i = 1$. If Player 1 plays punish and comply (PC), then Player 1's expected payoff is a function of $\sigma^2$:

$$EU^1(\text{Punish + Comply}) = 6(\sigma^2_{PC} + \sigma^2_{NC}) + 0 + 0$$
$$EU^1(\text{No Punish + Comply}) = 6(\sigma^2_{PC} + \sigma^2_{NC}) + 1(\sigma^2_{PD} + \sigma^2_{ND})$$
$$EU^1(\text{Punish + Defect}) = 5\sigma^2_{PC} + 10\sigma^2_{NC} - 4\sigma^2_{PD} + 1\sigma^2_{ND}$$
$$EU^1(\text{No Punish + Defect}) = 5\sigma^2_{PC} + 10\sigma^2_{NC} - 3\sigma^2_{PD} + 2\sigma^2_{ND}$$

|  | Random + No Communication | Random + Communication | Self Assembled | Self Assembled + Communication |
|---|---|---|---|---|
| PC | 0.1118 | 0.2685 | 0.3958 | 0.5000 |
| NC | 0.3602 | 0.3758 | 0.3819 | 0.3500 |
| PD | 0.1615 | 0.1477 | 0.1181 | 0.0929 |
| ND | 0.3665 | 0.2081 | 0.1042 | 0.0571 |

***SM Table 1*** Frequency of each strategy per treatment.

|  | Random + No Communication | Random + Communication | Self Assembled | Self Assembled + Communication |
|---|---|---|---|---|
| PC | 3.00 | 3.87 | 4.67 | 5.10 |
| NC | 3.36 | 4.22 | 4.89 | 5.25 |
| PD | 3.88 | 4.72 | 5.43 | 5.69 |
| ND | 2.42 | 5.07 | 5.65 | 5.84 |

***SM Table 2*** Expected payout solved by replacing theoretical probabilities in the utility function for each strategy with actual game values.

Now consider the pure Nash equilibrium from before given that each strategy has a probability assigned to it. Consider the paired strategy (PC, PC). This equilibrium only holds for $\sigma^2_{NC} = 0$, and $\sigma^2_{NC} = 0$, thus if there is any probability that Player 2 will not comply (i.e. for $\sigma^2_{NC} > 0$, and $\sigma^2_{NC} > 0$) then the paired strategy (PC, PC) is no longer at equilibrium. Therefore, if the probability of one player defecting is greater than zero, it is the other player's best response not to punish.

Player 1 punishes with the probability $\sigma^1_P$ and complies with the probability $\sigma^1_C$, and does not punish with the probability $1- \sigma^1_P$ and defects with the probability $1- \sigma^1_C$. Likewise, Player 2 has the same probabilities: $\sigma^2 = \sigma^2_P + \sigma^2_C + (1- \sigma^2_P) + (1- \sigma^2_C)$. We want to know what should Player 1's probability of complying ($\sigma^1_C$) and probability of punishing ($\sigma^1_P$) be to maximize his strategy given a particular strategy of Player 2 (e.g. What is his best response function?).

Player 1's expected utility to Player 2's profile of mixed strategies ($S$) is:

$$E[u_1(S)] = \sigma^1_C[\sigma^1_P(6\sigma^2_C\sigma^2_P + 6\sigma^2_C(1- \sigma^2_P) + 0 + 0 + (1- \sigma^1_P)(6\sigma^2_C\sigma^2_P + 6\sigma^2_C(1- \sigma^2_P) + (1- \sigma^2_C)(\sigma^2_P) + (1- \sigma^2_C)(1- \sigma^2_P))] + (1- \sigma^1_C)[\sigma^1_P(5\sigma^2_C\sigma^2_P + 10\sigma^2_C(1- \sigma^2_P)) - 4(1- \sigma^2_C)\sigma^2_P + (1 - \sigma^2_C)(1- \sigma^2_P)] + (1- \sigma^1_P)(5\sigma^2_C\sigma^2_P + 10\sigma^2_C(1- \sigma^2_P) - 3(1- \sigma^2_C)\sigma^2_P + 2(1- \sigma^2_C)(1- \sigma^2_P))]$$

Given Player 2's mixed strategy, if Player 1 plays the pure strategy punish and comply (PC), Player 1's payoff may be written:

$$E^1(\text{PC}) = 6\sigma^2_C\sigma^2_P + 6\sigma^2_C(1- \sigma^2_P) + 0 + 0$$
$$= 6\sigma^2_C\sigma^2_P + 6\sigma^2_C - 6\sigma^2_P$$

Likewise, if Player 1 plays no punish and comply (NC), Player 1's payoff is

$$E^1(\text{NC}) = 6\sigma^2_C\sigma^2_P + 6\sigma^2_C(1- \sigma^2_P) + (1- \sigma^2_C)(\sigma^2_P) + (1- \sigma^2_C)(1- \sigma^2_P)$$
$$= 6\sigma^2_C\sigma^2_P + 5\sigma^2_C - 6\sigma^2_P + 1$$

If Player 1 plays punish and defect (PD), Player 1's payoff is

$$E^1(\text{PD}) = 5\sigma^2{}_C\,\sigma^2{}_P + 10\sigma^2{}_C(1-\sigma^2{}_P) - 4(1-\sigma^2{}_C)\sigma^2{}_P + (1-\sigma^2{}_C)(1-\sigma^2{}_P)$$
$$= 9\,\sigma^2{}_C - 5\sigma^2{}_P + 1$$

And if Player 1 plays no punish and defect (ND), Player 1's payoff is

$$E^1(\text{ND}) = 5\sigma^2{}_C\,\sigma^2{}_P + 10\sigma^2{}_C\,(1-\sigma^2{}_P) - 3(1-\sigma^2{}_C)\,\sigma^2{}_P + 2(1-\sigma^2{}_C)(1-\sigma^2{}_P)$$
$$= 8\sigma^2{}_C - 5\sigma^2{}_P + 2$$

Player 1 will mix between the four strategies if the expected payouts are the same:

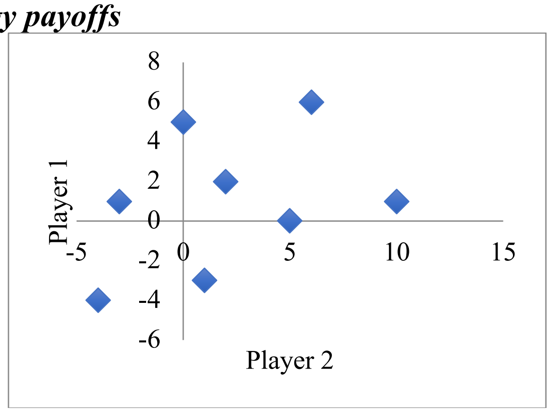
$$E^1(\text{PC}) = E^1(\text{NC}) = E^1(\text{PD}) = E^1(\text{ND})$$

Substituting in our utility values, we get:

$$6\sigma^2{}_C\sigma^2{}_P + 6\sigma^2{}_C - 6\sigma^2{}_P = 6\sigma^2{}_C\sigma^2{}_P + 5\sigma^2{}_C - 6\sigma^2{}_P + 1 = 9\sigma^2{}_C - 5\sigma^2{}_P + 1 = 8\sigma^2{}_C - 5\sigma^2{}_P + 2$$

Which, upon simplification, yields $\sigma^2{}_C = 1$ and $\sigma^2{}_P = 4/5$. Solving $\sigma^2{}_C = 1$ and $\sigma^2{}_P = 4/5$ allows us to then solve $\sigma^2{}_D = 0$ and $\sigma^2{}_N = 1/5$, which is shown in Table 1.

### 3. *Possible paired strategy payoffs*




***SM Figure 1.*** Possible payoffs for Player 1 and Player 2 give the opportunity to punish, or not punish, and comply or defect.

```
4 x 4 Payoff matrix A:

  6   6   0  0
  6   6   1  1
  5  10  -4  1
  5  10  -3  2


4 x 4 Payoff matrix B:

  6   6   5   5
  6   6  10  10
  0   1  -4  -3
  5  10  -3   2

EE = Extreme Equilibrium, EP = Expected Payoff

Decimal Output

  EE  1  P1:  (1)  0.8  0.2  0.0  0.0  EP=   6.0  P2:  (1)  1.0  0.0  0.0  0.0  EP=   6.0
  EE  2  P1:  (1)  0.8  0.2  0.0  0.0  EP=   6.0  P2:  (2)  0.8  0.2  0.0  0.0  EP=   6.0
  EE  3  P1:  (2)  0.0  1.0  0.0  0.0  EP=   1.0  P2:  (3)  0.0  0.0  0.2  0.8  EP=  10.0
  EE  4  P1:  (2)  0.0  1.0  0.0  0.0  EP=   1.0  P2:  (4)  0.0  0.0  1.0  0.0  EP=  10.0
  EE  5  P1:  (3)  0.0  0.0  0.0  1.0  EP=  10.0  P2:  (5)  0.0  1.0  0.0  0.0  EP=  10.0
  EE  6  P1:  (4)  1.0  0.0  0.0  0.0  EP=   6.0  P2:  (2)  0.8  0.2  0.0  0.0  EP=   6.0
  EE  7  P1:  (4)  1.0  0.0  0.0  0.0  EP=   6.0  P2:  (1)  1.0  0.0  0.0  0.0  EP=   6.0
  EE  8  P1:  (5)  0.0  0.0  1.0  0.0  EP=  10.0  P2:  (5)  0.0  1.0  0.0  0.0  EP=   1.0

Rational Output

  EE  1  P1:  (1)  4/5  1/5  0  0  EP=   6  P2:  (1)    1    0    0    0  EP=   6
  EE  2  P1:  (1)  4/5  1/5  0  0  EP=   6  P2:  (2)  4/5  1/5    0    0  EP=   6
  EE  3  P1:  (2)    0    1  0  0  EP=   1  P2:  (3)    0    0  1/5  4/5  EP=  10
  EE  4  P1:  (2)    0    1  0  0  EP=   1  P2:  (4)    0    0    1    0  EP=  10
  EE  5  P1:  (3)    0    0  0  1  EP=  10  P2:  (5)    0    1    0    0  EP=  10
  EE  6  P1:  (4)    1    0  0  0  EP=   6  P2:  (2)  4/5  1/5    0    0  EP=   6
  EE  7  P1:  (4)    1    0  0  0  EP=   6  P2:  (1)    1    0    0    0  EP=   6
  EE  8  P1:  (5)    0    0  1  0  EP=  10  P2:  (5)    0    1    0    0  EP=   1

Connected component 1:
{1, 4}  x  {1, 2}

Connected component 2:
{2}  x  {3, 4}

Connected component 3:
{3, 5}  x  {5}
```

***SM Figure 2*** Output from bimatrix algorithm (Avis et al. 2010).

## 4. *Results filtering out participants who did not show full understanding.*

| | Compliance | | | | Punishment | | | |
|---|---|---|---|---|---|---|---|---|
| | Estimate | Std. Error | t value | Pr (>\|t\|) | Estimate | Std. Error | t value | Pr (>\|t\|) |
| (Intercept) | 0.541 | 0.053 | 10.205 | 0.000 | 0.254 | 0.060 | 4.224 | 0.000 |
| Assembly | 0.236 | 0.061 | 3.886 | 0.000 | 0.231 | 0.092 | 2.502 | 0.012 |
| Communication | 0.072 | 0.061 | 1.139 | 0.255 | 0.148 | 0.090 | 1.641 | 0.101 |

***SM Table 3*** Results from analysis filtering out participants who did not show full understanding.

## IV. Conclusion

In response to growing threats to global fisheries, fisheries managers recognize the importance of integrating human dimensions with natural science (Mascia et al. 2003, Kareiva and Marvier 2012, Kittinger et al. 2014). However, there remains a knowledge and disciplinary gap preventing human dimensions from being successfully incorporated into management practices (Mascia 2003, Lundquist and Granek 2005, Bennett et al. 2017a,b). This dissertation seeks to remedy this by dig deeper into social science disciplines to find specific tools to guide in the design, implementation, monitoring and evaluation of marine governance.

Building from Bennett et al. and others' (Mascia 2003, Lundquist and Granek 2005, Kareiva and Marvier 2012, Hicks and Cinner 2015) compelling cases for mainstreaming social science into marine conservation, this dissertation shows how marine governance can use interdisciplinary techniques that combine behavioral experiments and surveys to increase stakeholder cooperation and management success. This dissertation demonstrates how decision-makers can rapidly gain critical information needed for the design, implementation and management of marine resources and how insight gained from such an approach can efficiently address specific social challenges facing natural resources managers.

The first part of this dissertation advances how social equity is considered and integrated into marine conservation. Chapter 1 presents a theoretical foundation for defining social equity and considering its role in conservation outcomes. It distinguishes between different types of equity and introduces the *equity landscape* as a way to describe the distributions of resources and participation rights in a society supported by social norms in a given community. A society's equity landscape will influence stakeholder behaviors and what types of management are implementable, as well as short- and long-term conservation outcomes. Chapter 1 motivates empirically testing how different types of equity are experienced in a community and how these different types of equity influence stakeholder behavior.

Chapter 2 builds from concepts presented in Chapter 1 to empirically investigate how different types of equity are experienced in one community and how these different types of equity influence stakeholder behaviors (compliance with social norms and willingness to punish defectors). The results from this work inform decisions on critical design elements, such as should the intervention focus on participation, or outcomes of the intervention, such as access or financial benefits? Should equity objectives be equal or fair? And, how should managers measure these objectives?

The second part of this dissertation leverages advances in the field of collective action to investigate real world management decisions. Chapter 3 uses a behavioral experiment to investigate 1) how does the process of group formation affect the performance of natural resource management? and, 2) does promoting face-to-face communication among group members can offset some of these costs associated less agency? This research shows that self-assembly and the ability to communicate face-to-face both increase compliance with rules and punishment of defectors, although self-assembly has a greater effect.

Most problems in natural resource management are rooted in some sort of social dilemma, and the collective action literature contains a wealth of knowledge on how diverse types of societies can solve these problems. While this work is specific to artisanal fishing communities in Tañon Strait, Philippines, it provides an approach to solving a range of social problems that may have huge impacts on conservation outcomes. Ultimately, conservation outcomes are determined by people, which requires people be a part of the solution.

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## V. Appendix

This Appendix contains more information about the field work conducted in the Philippines.

***Random assignment***
Upon arrival participants were randomly assigned a number, which was how they were identified and kept anonymous. Each participant was given a player packet (envelope) with a welcome letter, their assigned round, written instructions for the prisoner's dilemma game, a "willingness to punish" card, paper cards for anonymously reporting their harvest, and two surveys.

***Recruitment tool to local mayor***
Dear Mayor,

Rare and the University of California Santa Barbara invite you and your community to Alegria to participate in experimental games on November 17$^{th}$, 2016. These games are designed to learn about how fishers cooperate, and will help design better management strategies. Your participation is very important and valued!

This is a full day event. Food and transportation will be provided. Participants have the opportunity to earn a full day's wage.

Please be in contact with Roxanee Jul Lumactud-Tandang regarding your attendance.

Many thanks,
UCSB & Rare collaborators

***Player Packet***
*Welcome letter*
Dear Participant,

Thank you for joining us today. This is a joint project between the University of California Santa Barbara and Rare. We are very excited to be here.

You will be playing two games that will help us inform future fisheries management. You will be paid PhP500 and have the opportunity to make an additional 45 – 450 Pesos. How you play the games will determine how much money you make. The rules of the game will be explained to you before you play each game.

Below you will find an itinerary of the day's events. Your packet tells you which groups are in. We are on a tight schedule, so please be ready when your group is called.

Your player packet also has several other papers in it. We will tell you when to pull out each paper – please do not look at these papers before it is time. After you play each game, please complete the survey in your player packet, and put it back inside the envelope. Please return your envelope to us before you leave. You will receive your final payout before you leave.

Please note that all information will be kept completely confidential – your name is not recorded anywhere in the documents we keep. We do not foresee any risks or discomforts but if you have any concerns or questions, please feel free to ask us now, or contact Rare later.

*Punishment card*

If your partner choses to not cooperate by choosing 10 fish, you can punish them by taking away 5 of their fish (they will be left with 5 fish) but it will cost you 1 fish. Would you like to punish them?

Yes / No

*Game 1 Instructions and Game cards*

*Instructions*

*Prior to play, fill out the Punishment Card and return in back into your player packet.

1. Both you and your partner can harvest either 6 or 10 fish from a pond.
2. If you both harvest 6 fish, than you both get to keep 6 fish.
3. If you both harvest 10 fish, than you both get to keep 2 fish.
4. If one of you harvests 10 fish and one you harvests 6 fish, the person who harvested 10 fish gets to keep those 10 fish, and the person who harvested 6 fish only gets 1 fish.
5. You are not allowed to communicate unless told so by the facilitator.
6. You will play 3 different rounds with 3 different partners.
   (Treatments A & B: Partners are randomly assigned to you)
   (Treatments C & D: You are allowed to select your partner)
7. Individual harvest is never announced and kept private.
8. For each round, you will circle how many fish you chose to harvest on the scorecard with the correct round number (1, 2 or 3).
9. Rip off the scorecard, and place it face down with your partner's scorecard.
10. The facilitator will staple them together and collect them.
11. You will not know the results of each round.
12. We will randomly pick one of the rounds to calculate the payouts.

*Game cards*

| | | |
|---|---|---|
| 1 # <br> 6 or 10 | 2 # <br> 6 or 10 | 3 # <br> 6 or 10 |

Treatment A: 54
Treatment B: 55
Treatment C: 51
Treatment D: 50

*Survey 1- completed post game play.*

1. On a scale of 1 – 5 (1 being completely fair, and 5 being completely NOT fair), how fair did you think the rules of the game were?

   1 2 3 4 5
2. How many fish do you get to keep if you harvest 6 fish and your partner harvests 10 fish?

- ☐ 1 fish
- ☐ 2 fish
- ☐ 6 fish
- ☐ 10 fish

3. How many fish do you get if both you and your partner harvest 10 fish?
   - ☐ 1 fish
   - ☐ 2 fish
   - ☐ 6 fish
   - ☐ 10 fish
4. One a scale of 1 – 5 (1 being completely trustworthy, and 5 being completely untrustworthy), how trustworthy did you think your partner in the *first* round was?
   1 2 3 4 5
5. One a scale of 1 – 5 (1 being completely trustworthy, and 5 being completely untrustworthy), how trustworthy did you think your partner in the *second* round was?
   1 2 3 4 5
6. One a scale of 1 – 5 (1 being completely trustworthy, and 5 being completely untrustworthy), how trustworthy did you think your partner in the *third* round was?
   1 2 3 4 5
7. (Treatments A & B) How do you feel about being randomly paired with partners?
   (Treatments C & D) How/why did you chose your partners?
8. Why did you harvest the number of fish that you did?
9. Which municipality do you live in?
10. How old are you?
11. Are you male or female?
12. How many dependents do you have?
13. How much of your income depends on marine resources?
    All / Some / A little
14. How much of your subsistence (food) depends on marine resources?
    All / Some / A little
15. In a typical week during the high season, how much money do you make?
16. On a scale of 1 – 5 (1 being completely equal, and 5 being completely NOT equal), how equally do you think the benefits from marine resources are spread throughout your community?
    1 2 3 4 5
17. On a scale of 1 – 5 (1 being completely fair, and 5 being completely NOT fair), how fair do you think overall benefits associated with marine resources are in your community?
    1 2 3 4 5
18. On a scale of 1 – 5 (1 being completely fair, and 5 being completely NOT fair, how fair do you think access is to marine resources in your community?
    1 2 3 4 5
19. On a scale of 1 – 5 (1 being completely fair, and 5 being completely NOT fair), how fair do you think financial benefits are distributed in your community?
    1 2 3 4 5
20. On a scale of 1 – 5 (1 being completely fair, and 5 being completely NOT fair), how fair do you think participation in fisheries management is in your community?

1 2 3 4 5

*Survey 2 – conducted several hours after game play and Survey 1.*

1. On a scale of 1 – 5 (1 being high, and 5 low), what is your overall well-being?

   1 2 3 4 5

2. On a scale of 1 – 5 (1 being completely fair and 5 being completely unfair), how fair do you think marine resources are managed in your community?

   1 2 3 4 5

3. How does your access to marine resources compare to others' access to marine resources?

   I have a lot more access than others / I have more access than others /
   I have the same access as others / I have less access than others /
   I have a lot less access than others / Unsure

4. How do you feel you benefit financially from fisheries compared to others in your community?

   I benefited a lot more than others / I benefited more than others /
   I neither benefited or am harmed more than others / I am harmed more than others / I am harmed a lot more than others / Unsure

5. How does your participation in fisheries management activities compare to others' participation in fisheries management activities?

   I participate a lot more than others / I participate more than others /
   I participate the same as others / I participate less than others /
   I participate a lot less than others / Unsure

6. One a scale of 1 – 5 (1 being completely untrustworthy, and 5 being completely trustworthy), how trustworthy do you think your community is, meaning people will comply with rules?

   1 2 3 4 5

7. Are you also a seaweed (or fish) farmer? Yes / No

8. If so, how many hours per week do you spend on each activity (fishing and farming) on average?

   Hours a week spent fishing: _________
   Hours a week spent farming: _________

9. Would you give up fishing entirely if you could make more money farming?

   Yes/No