



Disparities in the impacts of co-management on fishers' livelihoods

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Received: 6 December 2022 / Accepted: 21 May 2023 / Published online: 30 June 2023
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Abstract

Natural resources are widely managed through collaborative governance arrangements (e.g., co-management) which often result in the uneven distribution of costs and benefits among fishers. Discrepancies in how a fisher is impacted by co-management relative to other fishers or others in the community (i.e., disparity) can negatively affect fishers' wellbeing, their support for management, and subsequently, ecological outcomes. Yet, disparities in the distribution of social impacts from co-management have rarely been assessed. We address this gap by examining disparities (losses and gains) in perceived livelihood impacts from co-management. Losses (or gains) occur when a fisher experiences a more negative (or positive) impact on their livelihood relative to other fishers or others in the community. We used data from interviews with 1191 fishers associated with 48 coral reef co-management arrangements across Kenya, Tanzania, Madagascar, Indonesia, and Papua New Guinea to examine how socioeconomic and institutional characteristics were associated with losses and gains from co-management. Overall, we found that more fishers perceived equality than disparities in the distribution of co-management impacts. Of those that perceived disparities, more fishers perceived losses than gains. We also found that disparities could be predicted by a range of socioeconomic characteristics, including distance to markets and wealth, and institutional characteristics of the co-management regime, such as gear, access, and area restrictions. This study provides insights on potential entry points that could be used by managers and policy-makers to promote equitable co-management of small-scale fisheries, such as the reduction of losses by increasing participation in decision-making processes, fostering conflict resolution mechanisms, prioritizing gear restrictions over area restrictions, and reducing poverty.

Keywords Inequality · Equity · Fisheries livelihoods · Socioeconomic impacts · Institutional design principles · Natural resource management

Introduction

Common-pool resources across the world—including forests, fisheries, and pastures—are commonly governed under co-management governance arrangements (Berkes 2009; Oldekop et al. 2016; Gelcich et al. 2019). Co-management

is intended to be a collaborative and participatory process often involving communities, governments, civil society, and research institutions (Berkes 2009), and aims to provide a degree of decision-making power to people who are affected by management decisions. By facilitating the incorporation of local values, needs, governance, and priorities, co-management is thought to lead to better outcomes for local people than more centralized governance approaches (Berkes 2009). Studies suggest that co-management can lead to both positive outcomes such as increased participation and empowerment (d'Armengol et al. 2018; Oldekop et al. 2016; Yang and Pomeroy 2017) and negative outcomes such as inequalities including unequal access to decision-making (Bene et al. 2009) and uneven distribution of costs and benefits among local people (Cinner et al. 2014; Gurney et al. 2015; Ward et al. 2018). However, a clear understanding of how positive and negative impacts are experienced and

Handled by Patrik J. G. Henriksson, Stockholm Resilience Centre, Sweden.

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perceived by the diverse members within communities is still lacking (Quimby and Levine 2018; Gibbes and Keys 2010).

Discrepancies on how an individual is impacted relative to others in the community (i.e., disparities) have important implications for social and ecological outcomes (Pascual et al. 2014; Hamann et al. 2018). When co-management costs fall on those who are most deprived, disparities can further harm the most vulnerable people, increasing poverty and deepening social inequalities (Adams et al. 2004; Persha and Andersson 2014). Perceived disparities can influence peoples' attitudes and their willingness to engage with management initiatives (Fabinyi et al. 2015; Hamann et al. 2018). In particular, if disparities are considered unfair,¹ management support and cooperation can be undermined, leading to social conflicts and non-compliance (Gurney et al. 2014), and ultimately, to hampering management success (Loomis and Ditton 1993; Pascual et al. 2014; Fabinyi et al. 2015). Indeed, scholarship on distributional equity from psychology suggests that preferences for equitable distributions are rooted in neurological and psychological processes, and are strongly related to attitudes, beliefs and behavior, including legitimacy and collective action (Dawes et al. 2007; Nishi et al. 2015; Tyler 2015). Importantly, subjective wellbeing has been shown to be strongly related to perceptions of (un)fair disparities (Wilkinson and Pickett 2009; Prilleltensky 2012).

Given the implications of distributional inequity on the social and ecological outcomes of co-management, disparities in socioeconomic impacts are a key consideration for co-management decision-makers. Depending on the context, decision-makers may be interested in promoting equality or even certain types of disparities. For instance, management strategies may be focused on promoting winners without increasing losers (i.e., making people better off without making anyone worse off) (Pareto 1906). In addition, strategies may be focused on managing subjective or perceived disparities, which are considered a stronger predictor of individual and social outcomes than objective measures of disparity (Nishi et al. 2015; Hauser and Norton 2017; Starmans et al. 2017).

¹ Following McClanahan et al. 2012, we use disparity to refer to discrepancies in perceived benefits (and/or costs) between an individual fisher and other fishers or the community more generally. The disparity metric in our analysis is measure of the distribution of livelihood impacts from co-management and has three categories: losses, equality, and gains. Equality and equity are often used interchangeably in the literature, yet they are distinct concepts (McDermott et al. 2013). Equality refers to the equal distribution of benefits and/or costs among individuals or groups (i.e., the absence of disparity), and is one potential distribution that could be considered equitable. Distributional equity refers to the fair distribution of benefits and/or costs among individuals or groups (McDermott et al. 2013).

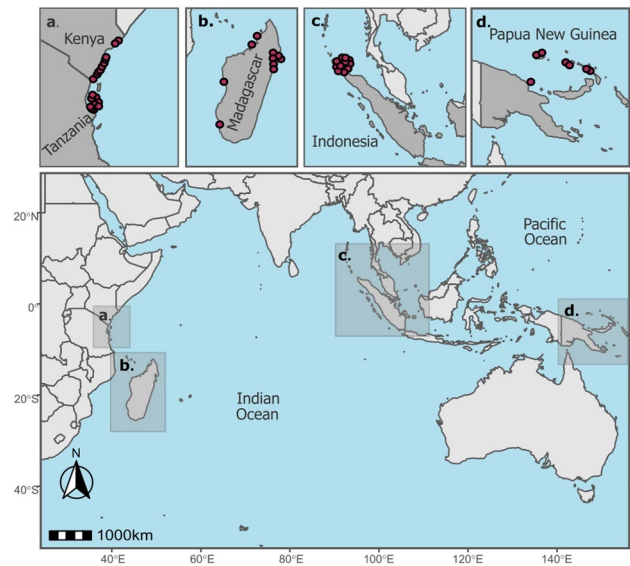


Fig. 1 Map with co-management sites in **a** Kenya and Tanzania, **b** Madagascar, **c** Indonesia, and **d** Papua New Guinea. Approximate locations of co-management sites are indicated with red dots

According to the theory of relative deprivation, the perception of being a loser can negatively affect people's wellbeing (Crosby 1976; Smith et al. 2012). Therefore, in the context of co-management, promoting perceptions of not being a loser may be important for promoting subjective wellbeing, and support for management. In addition, understanding the social conditions associated with disparities in co-management outcomes is essential to informing targeted policies and practices that account for equity issues.

Despite the importance of understanding disparities in co-management, it remains unclear the degree to which co-management leads to disparities (i.e., objective disparity), the degree to which disparities are perceived (i.e., subjective disparity), and what socioeconomic and institutional characteristics are related to these disparities. Indeed, the literature on inequality and environmental management has largely focused on economic inequality (i.e., wealth or income) and its role as a driver of outcomes (Baland et al. 2007; Persha and Andersson 2014; Hamann et al. 2018), and on differential impacts among occupational or social groups (e.g., gender and religion) (Gurney et al. 2015; Ward et al. 2018; Gill et al. 2019).

In this paper, we build on this existing work by quantifying how specific socioeconomic and institutional characteristics relate to two types of disparities (subjective and objective) in livelihood impacts from coral reef co-management for 1191 fishers across 48 co-management arrangements in five Indo-Pacific countries (Figs. 1, 2). We used household surveys to elicit two forms of disparity based on five-point Likert-type rating scale about the impacts of co-management on: (1) the respondent's livelihood and (2) the

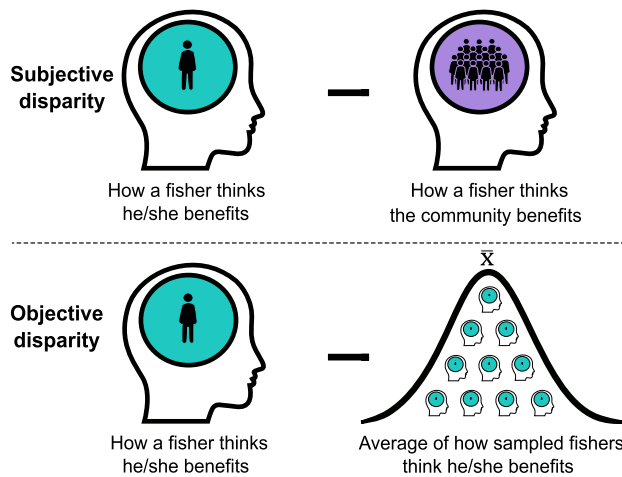


Fig. 2 Subjective and objective disparity metrics in our study. Subjective disparity refers to the level of impact that an individual fisher perceived to receive from co-management, minus the impact that individual fisher perceived the community receives. Objective disparity refers to the level of impact that an individual fisher respondent perceived to receive from co-management, minus the average of the impact perceived by all sampled fishers in the community. Each disparity metric was broken down into three categories: (a) losses (subjective disparity < 0 ; objective disparity < -0.5); (b) equality (subjective disparity $= 0$; objective disparity ≥ -0.5 and ≤ 0.5); (c) gains (subjective gain > 0 ; objective gain > 0.5)

wider community (Fig. 2). These surveys were also used in combination with key informant interviews to examine 17 socioeconomic and institutional conditions expected to be related to co-management outcomes.

Materials and methods

Study sites and sampling approach

We studied 48 independent coral reef fisheries co-management arrangements spanning five Indo-Pacific countries: Kenya, Tanzania, Papua New Guinea, Indonesia, and Madagascar (Fig. 1) (Cinner et al. 2012). We used purposive sampling to ensure variation in our predictor variables (i.e., different levels of market integration and population). To gather information and triangulate results in each study site, we employed a combination of household surveys, semi-structured interviews with community leaders, co-management organization leaders, and other key informants (knowledgeable fishers, elders, and other stakeholders), and analyses of secondary sources such as population censuses. In total, we conducted 1191 resource user interviews, 53 key informant interviews, 54 community leader interviews, and 51 organizational leader interviews. This study was part of a project focused on household heads, who were mostly men. This research was approved by the JCU Human Ethics Committee

(approval number H3020). Prior informed oral consent from participants was obtained. Written consent was not obtained due to low literacy rates.

Disparity metric (response variables)

We asked fishers to indicate: (1) the degree to which they perceived co-management had a positive, neutral, or negative impact on their livelihoods (individual impact). Livelihood was conceptualized and explained as a broad concept of wellbeing (not solely referring to employment) (Allison and Ellis 2001); and (2) the degree to which they perceived co-management had a positive, neutral, negative impact on the broader community (community impact). Both responses were on a 5-point Likert-type scale, 1 being very negative impact on livelihoods, 5 very positive impact, and 3 being neither positive nor negative. From these questions, we created two metrics of disparity, which we refer to as subjective and objective disparity (Fig. 2):

Subjective disparity was calculated by subtracting a respondent's score for community impact from their score for individual impact. Subjective disparity thus captures whether the respondent self-identifies as a winner or loser (i.e., perceived relative position of the individual within the community), which may affect their perceptions, attitudes, and behavior (e.g., relative deprivation) (Crosby 1976).

Objective disparity was calculated by subtracting the community's mean individual impact from each respondents' individual impact score. Objective disparity is thus the relative position of the respondent among sampled fishers (i.e., level of impact a fisher perceives to have received relative to other fishers in their community). Although it may not necessarily be perceived by respondents, research has shown that objective disparity matters for people's wellbeing (Townsend 1987; Wilkinson and Pickett 2009). The uneven allocation of costs and benefits may increase existing inequalities and levels of poverty and lead to social conflict and a wide range of governance problems (Persha and Andersson 2014).

Thus, our subjective metric considers how a fisher thinks the community benefits, while the objective measure integrates perceptions of sampled fishers (Fig. 2). We broke down subjective and objective disparity metrics into three categories each (losses, equality, gains). Values equal to zero (or between 0.5 and -0.5 in the case of objective disparity metric) were categorized as equality, values below zero (or below 0.5) were categorized as losses, and values above zero (or 0.5) were categorized as gains. Losses occur when a fisher experiences a more negative impact relative to the rest of the community (or fishers in the case of objective

disparity), gains occur when a fisher experiences a more positive impact relative to the rest of the community (or fishers), while equality occurs when a fisher experiences same impacts relative to the rest of the community (or fishers). Hence, we obtained four response variables, which related to whether fisher experienced or perceived an equality outcome versus an: (1) objective gain; (2) objective loss; (3) subjective gain; and (4) subjective loss. For example, a subjective gain would be when a fisher perceives that he or she benefits more than he or she perceives the community benefits. An objective gain refers to when a fisher's perception of the impact to their livelihood is higher than the average of all sampled fishers' perceptions from that community.

Socioeconomic and institutional characteristics (predictor variables)

We examined the relationship between disparities and 17 socioeconomic and institutional characteristics, which were selected based on institutional analysis theory (Ostrom 2009) and their relevance to this specific context according to co-management theory and research (Cinner et al. 2012; Ward et al. 2018; Gurney et al. 2019; Epstein et al. 2021) (SI Appendix, Table S1).

We examined eight individual-level and two community-level socioeconomic characteristics (SI Appendix, Table S1) which can influence whether people engage in collective resource management (Ostrom 2009; Ward et al. 2018; Epstein et al. 2021) and how cost and benefits are distributed (Gurney et al. 2015; Gill et al. 2019). Socioeconomic characteristics, such as gender, migrant status, wealth, and education, shape hierarchical structures that privilege certain individuals (e.g., wealthy and highly educated people) while marginalizing others (e.g., women and migrant) who are often excluded from decision-making processes and bear the costs of management (Persha and Andersson 2014; McClanahan and Abunge 2016; Gustavsson et al. 2021). In addition, participation in community events can increase social capital and promote management equity (Diedrich et al. 2017), but also exacerbate inequalities as those individuals with more connections may have more ability to influence decisions and benefit from co-management (Smith 2012). Fishery dependency, operationalized here as primary marine livelihood and occupational diversity, can also influence how fishers benefit from co-management (Cinner et al. 2012; Aaron MacNeil and Cinner 2013). For instance, highly dependent fishers may be more vulnerable to restrictions than those with lower dependency and experience higher negative impacts from co-management (McClanahan et al. 2009). Finally, trust in leaders may influence perceived benefits and disparity because fishers who trust leaders may perceive that management is effective (Jones et al. 2017) and that leaders take into account their interests and do what is

right and fair (Ruano-Chamorro et al. 2022). At the community level, proximity to markets may positively impact local livelihoods by providing access to resources and economic opportunities (Bene et al. 2010), although it may crowd out intrinsic incentives (Cinner et al. 2021). In addition, large population size can diminish or enhance collective action (Poteete and Ostrom 2004) and thus the delivery of equitable livelihood outcomes to local communities.

We examined seven key characteristics that were informed by Ostrom's eight design principles for devolved commons management (Ostrom 1990). Institutional characteristics are key to understanding the likelihood of collective action and, thus, the possibility of achieving ecological and social benefits (Ostrom 1990) and can influence how users receive and perceive benefits and costs (Cinner et al. 2012). Clear defined boundaries and operational rules can exclude certain people or social groups, negatively impacting their livelihoods while benefiting others, leading to unequal distribution of impacts in the community. The operational rules considered in this study include access restrictions (i.e., restricted or prohibited access to fishing grounds to non-members), area restrictions (i.e., prohibition of fishing in certain areas) and gear restrictions (i.e., prohibition of certain gears). Participation in resource management decision-making is key to achieve procedural equity (Ruano-Chamorro et al. 2022) and good governance (Lockwood 2010). Specifically, active participation of local users in decision-making processes can promote procedural fairness (Ruano-Chamorro et al. 2022) and, thus, equitable distribution of outcomes. Graduated sanctions promote compliance by punishing severe or repeated rule violations (Ostrom 1990) and can increase the likelihood of obtaining both benefits and costs from co-management (Cinner et al. 2012), while the presence of effective mechanisms to solve conflicts in co-management arrangements is essential to promote equity (Gurney et al. 2019; Ruano-Chamorro et al. 2022). A more detailed description of institutional and socioeconomic characteristics that can influence social outcomes in co-management arrangements is provided in SI Appendix, Table S1.

Analyses

We conducted four mixed effect binomial logistic regression models, including site as random effect, to quantify the relationship between the predictor variables and the likelihood of an equality outcome vs subjective loss (model 1), subjective gains (model 2), objective losses (model 3), and objective gains (model 4). For example, in model 1, we examined what differentiates those experiencing subjective losses from those experiencing subjective equality. Similarly, in model 2, we examined what differentiates those experiencing subjective gains from those

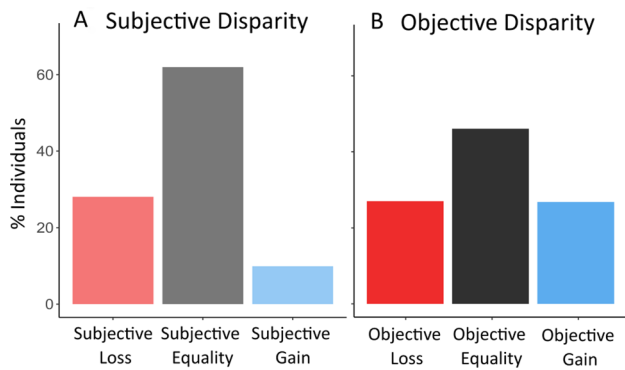


Fig. 3 Distribution of subjective and objective disparity metrics. **A** Percent of individual fishers who perceived more negative impacts from co-management relative to the community (red); the same impacts than the community (grey); and more positive impacts than the community (blue). **B** Percent of individual fishers who perceived more negative impacts from co-management relative to sampled fishers (red); the same impacts relative to sampled fishers (black); and more positive impacts relative to sampled fishers (red)

experiencing subjective equality, and so on. We followed an information theoretic approach to model selection (Grueber et al. 2011) (SI Appendix).

Results

Equality was the most frequent category of the objective and subjective disparity metric (i.e., losses, equality, and gains) and comprised the majority of outcomes in our subjective, but not our objective metric (Fig. 3). In other words, fishers generally perceived more equality (i.e., fishers felt they were benefiting the same as the rest of the community) than what was measured in more objective terms (Fig. 3). The frequency of objective losses and gains was similar (Fig. 3B), while the frequency for subjective losses was higher than the frequency of subjective gains (Fig. 3A), meaning that fishers were more likely to see themselves as losers than as winners relative to sampled fishers.

Although objective and subjective disparities were related (Chi square = 178.59, $df=4$, p value < 2.22 e-16), there were substantial variations in fishers' objective compared to their subjective disparity (Fig. 4). Many fishers perceived subjective equality when experiencing objective gains ($n=203$) and objective losses ($n=102$) (Fig. 4). Furthermore, it was more common for a fisher to perceive subjective losses when they experienced objective losses than for a fisher to perceive subjective gains when experiencing objective gains (i.e., 56% of the fishers experimenting objective losses perceived subjective losses, while only 16% of fishers experiencing objective gains perceived objective gains) (Fig. 4).

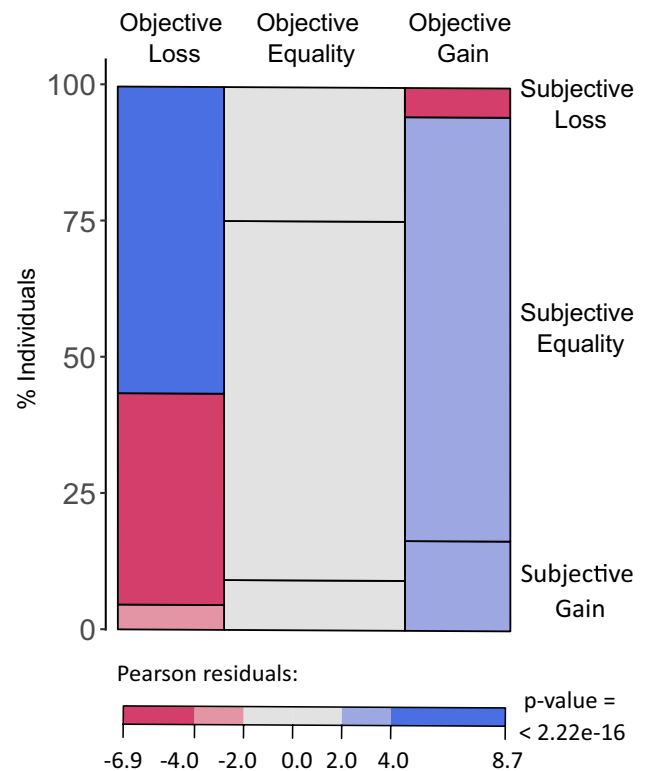


Fig. 4 Mosaic plot and percentage of fishers experiencing combinations of objective and subjective disparity categories (losses, equality, gains). The widths of the columns indicate the percentage of the number of observations in each objective disparity category, and the widths of the rows indicate the percentage of the number of observations in each subjective disparity category (e.g., 56% of fishers experienced both objective and subjective losses, and 78% of fishers who experienced objective gains perceived subjective equality). Chi-square test and Pearson residuals are shown. Blue indicates that the observed value is higher than expected than if the data were random; red indicates that the observed value is lower than expected than if the data were random

Relationships between institutional and socioeconomic characteristics and disparities

We used four binomial mixed-effects models to examine how the likelihood of an equality response versus each of the four different types of losses and gains were related to seven institutional and 10 socioeconomic characteristics (SI Appendix, Table S1) that have been previously shown to be important in shaping co-management outcomes (Ostrom 2009; Cinner et al. 2012; Ward et al. 2018; Gurney et al. 2019; Epstein et al. 2021). We found four socioeconomic characteristics and five institutional characteristics were significantly related to disparities (Fig. 5). We also found that overall, losses were more likely to be influenced by these characteristics as opposed to gains.

Socioeconomic characteristics were related to three of our response variables (subjective losses, subjective gains, and

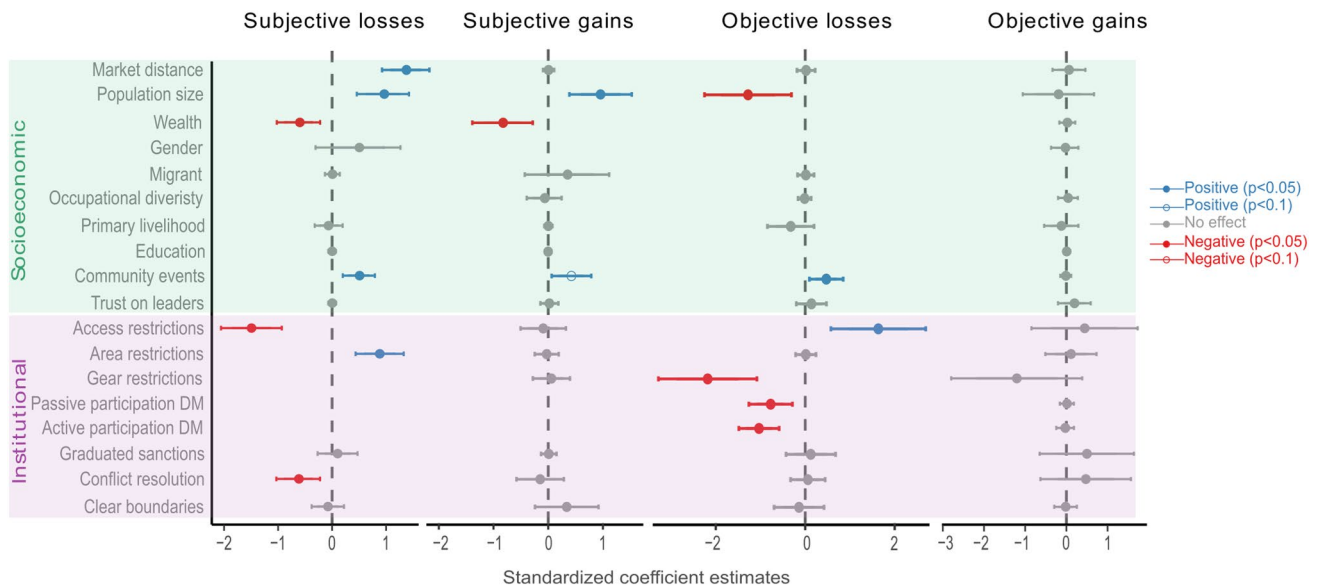


Fig. 5 Relationship between socioeconomic and institutional characteristics and subjective and objective disparity metrics. Relationships are indicated with the model-averaged standardized coefficient estimates of binomial logistic mixed effect models. Community is

objective losses). Population size and participation in community events were the only socioeconomic characteristics related to both subjective and objective disparity (Fig. 5). In communities with large population size, fishers were more likely to see themselves as winners and losers relative to the rest of the community (i.e., experience subjective losses and gains), and were less likely to experience objective losses. Fishers who participated in community events were more likely to experience subjective gains and subjective losses, and more likely to experience objective losses. Wealth was both negatively related to subjective losses and gains, and thus, wealthier fishers were less likely to perceive disparities (both losses and gains). In addition, distance to markets was positively related to subjective losses. In other words, fishers living in communities with lower market access (i.e., farther from markets) were more likely to see themselves as losers.

Institutional characteristics were related to two of our response variables (subjective losses and objective losses) (Fig. 5). Rules relating to access, gear, and area restrictions had a different relationship with the two types of disparities. Specifically, fishers in sites with access restrictions were less likely to perceive subjective losses but more likely to experience objective losses; fishers in sites with area restrictions were more likely to perceive subjective losses, while fishers in sites with gear restrictions were less likely to experience objective losses (Fig. 5). In other words, fishers affected by access restrictions were more likely to perceive being equally impacted by co-management relative to the community, although fishers

included as a random effect in the models. Error bars indicate 95% confidence interval. Effect sizes have been standardized by subtracting their mean and dividing by two times their standard deviation

were more likely to experience negative impacts from access restrictions than other fishers in objective terms. In contrast, fishers in communities with area restrictions were more likely to see themselves as losers, while in communities with gear restrictions, fishers were less likely to experience objective losses relative to other fishers. Two additional institutional characteristics were related to different types of disparities. Participation in the decision-making process was negatively related to objective losses (Fig. 5), suggesting that higher levels of participation in decision-making reduces objective losses (or promotes equality). Finally, the presence of effective conflict resolution mechanisms was negatively related to subjective losses (Fig. 5).

Discussion

Together, our study revealed three key results with important implications for co-management. First, fishers can overestimate equal outcomes, and when they do perceive disparities, losses are more likely to be perceived than gains. Second, losses and gains were related to distinct socioeconomic and institutional characteristics, with some characteristics related to only losses, and others to both gains and losses. Our third key result is that socioeconomic and institutional characteristics tend to be related to subjective or objective disparity.

Subjective and objective disparity

Fishers perceived higher levels of equality (i.e., subjective equality) than indicated by the objective disparity measure (i.e., objective equality). In other words, fishers may be perceiving that everyone in the community is similarly impacted by co-management, even though co-management actually impacts some fishers more than others. Other studies have shown that co-management can be perceived as acceptable and fair even when it impacts some groups (e.g., women) more negatively than others (Kleiber et al. 2018; Lau et al. 2021). This may be because fishers perceive the decision-making process of their respective co-management arrangements as fair, which may lead to perceptions of equity or equality in co-management impacts (Gustavsson et al. 2021) regardless of the actual distribution (Tyler 2015). In cases where disparities were perceived, we found that fishers perceived more than twice as many losses than gains. This result may be indicative of the concept of loss aversion, which refers to the cognitive bias that people have towards perceiving that losses hurt twice as much as the satisfaction of an equivalent gain (Kahneman and Tversky 1979). Indeed, we found that fishers perceived more subjective losses when they experienced objective losses compared to their perception of subjective gains when they were experiencing objective gains. If they perceive these losses as unfair, fishers may be experiencing relative deprivation (Crosby 1976; Smith et al. 2012). This feeling of being worse off than others can lead to frustration, anxiety, dissatisfaction, anger, or resentment and promote social conflicts, distrust, and anti-social behavior (Crosby 1976; Wilkinson and Pickett 2009; Smith et al. 2012). In a co-management context, relative deprivation may lead to unethical and inefficient management interventions because it can negatively affect people's wellbeing, reduce support for co-management (Gelcich et al. 2007; Wangel and Blomkvist 2013), and ultimately lead to management failure. For instance, fishers in Texas felt relative deprivation because fishing regulations only affected them and not fishers who fish in other bays, which caused opposition towards fishing regulations (Loomis and Ditton 1993).

How socioeconomic and institutional characteristics are related to disparities: losses and gains

Our second key finding is that losses and gains were related to distinct socioeconomic and institutional characteristics, with some characteristics more likely to be related to only losses (e.g., distance to markets, gear and area restrictions), and others more likely to be related to both gains and losses (e.g., population size and wealth). These findings can help identify individuals and contexts in which undesirable outcomes of co-management are more likely to result, which

could then be targeted with additional support. In addition, if further investigations reveal that the relationships between these socioeconomic and institutional characteristics are causal, these characteristics could be used as levers for change.

Losses were less likely to occur where there was participation in decision-making, conflict resolution mechanisms, gear restrictions, absence of area restrictions, and in communities near markets. Participation in decision-making and effective conflict resolution mechanisms have been shown to promote perceptions of procedural equity (i.e., fair decision-making process) (Ruano-Chamorro et al. 2022), which in turn can lead to perceptions of distributional equity. Gear restrictions in this context may reduce objective losses because coral reef fishers often use multiple gears, or alternatively gear restrictions may be viewed as a means to reduce competition from fishers using other gears. As a result, fishers may be less vulnerable to gear restrictions than to other restrictions, such as area restrictions. Consistent with our results, other studies have found that fishers often have more positive perceptions of gear than area restrictions (McClanahan et al. 2012; Barley Kincaid et al. 2014; McClanahan and Abunge 2016).

Our finding that perceived losses were less likely in communities close to markets could be due to a number of mechanisms. Market proximity may reduce dependency on middlemen, potentially leading to higher bargaining power and earnings (Maire et al. 2020; Rojas et al. 2021). Alternatively, the relationship between market proximity and perceived losses could be due to an increase in fishers' preferences for equality. Indeed, research from human evolutionary biology suggests that market integration gives rise to prosocial norms, including a preference for distributional equality, which can facilitate mutually beneficial exchanges among strangers who do not have established social relationships (e.g., kinship and reciprocity) (Henrich et al. 2010). Conversely, other studies have found that market engagement can reduce preferences for equal or pro-poor distribution of conservation benefits (Martin et al. 2019; Cinner et al. 2021; Gurney et al. 2021) and lead to an unequal distribution of market benefits among fishers (Ferguson 2021). Indeed, the influence of markets on human preferences and behavior and, thus, conservation and management outcomes continues to be debated (Maire et al. 2020; Cinner et al. 2021). It is likely that the relationship is complex, being dependent on the social-ecological context, and potentially non-linear (Epstein et al. 2021).

Both gains and losses were more likely to be experienced and/or perceived when fishers were poorer, more involved in community events, and lived in communities with a larger population. Previous research has also shown that poorer fishers are more likely to perceive both negative and positive impacts (e.g., fisheries displacement and higher catch)

from marine protected areas in Kenya (Cinner et al. 2014). One possible explanation is that poorer people are more vulnerable (Cinner et al. 2009), which means that any change to their livelihoods has a greater impact than on wealthy people. Further, concerns about scarcity can influence cognitive processes (Shah et al. 2018), leading people to be more psychologically sensitive to the impacts (both positive and negative) of co-management. With regard to the positive relationship we found between involvement in community events and the experience of both gains and losses, increased connectedness through these events could be exacerbating disparities and benefiting certain groups over others, as well as making disparities within the community more visible (Ballet et al. 2007; Cook 2014). Lastly, the relationship between population size and management outcomes is complex, context-dependent (Poteete and Ostrom 2004), may be non-linear (Aaron MacNeil and Cinner 2013), interacts with other factors (Aaron MacNeil and Cinner 2013), and is generally unclear. Therefore, further examination is required to better understand the mechanisms through which population size shapes co-management disparities.

How socioeconomic and institutional characteristics are related to disparities: objective and subjective

Our third key finding is that socioeconomic and institutional characteristics tend to relate to either subjective or objective disparity, with just three characteristics associated with both types of metrics. For instance, conflict resolution was only related to subjective disparity and participation in decision-making was only related to objective disparity. Conflict resolution mechanisms may provide tangible ways of solving problems within the community and reduce fishers' perceptions of being a loser. Members of a community in Papua New Guinea regularly engage in collective reasoning of what is fair and unfair during meetings, which facilitates a shared perception of equity within the community (Lau et al. 2021). A similar process may occur through effective conflict resolution mechanisms, thus reducing the likelihood that fishers perceive that they are being more negatively impacted than other members of the community. On the other hand, fishers involved in decision-making, and thus possibly able to satisfy their needs for procedural equity and self-determination (Decaro and Stokes 2013), may tend to perceive similar impacts from co-management (i.e., objective equality). The presence of access restrictions was negatively related to subjective losses and positively related to objective losses. The likelihood that fishers experience losses relative to other fishers (i.e., objective losses) may be increased because certain groups (e.g., clans) within the community may hold different access rights (Lau et al. 2021) and impact fishers' livelihoods unevenly. In addition, access rights embedded in customary governance systems may be seen as legitimate

(Osei-tutu et al. 2021) and lead to perceptions of equality (i.e., low subjective losses).

Therefore, the conditions related to a fisher receiving more losses or gains than other fishers are not always the same conditions that relate to the same fisher seeing themselves as a loser or a winner relative to the community they belong to. In essence, socioeconomic and institutional characteristics may have different influences on how fishers' livelihoods are affected relative to other fishers (i.e., objective disparity), and on how fishers' livelihoods are affected relative to how fishers perceive the community to be affected (i.e., subjective disparity). These findings provide entry points for managing for either subjective or objective disparities. For example, to foster objective equality, managers may promote participation in decision-making and implement gear restrictions rather than access restrictions. Alternatively, while objective equality is likely a frequent goal in co-management, promoting subjective equality or perceptions of being a winner might be an equally valid goal given the influence of fairness perceptions on attitudes, behaviors, and wellbeing. Thus, our study provides guidance on the different strategies that could be implemented depending on the outcome of interest.

Limitations and future research

Our study takes an important first step in evaluating different types of disparity in co-management, and exploring how these outcomes are related to key socioeconomic and institutional characteristics, but has some limitations that could be addressed in future studies. First, while our study provides some evidence of the direction and magnitude of the relationship between disparities and the examined socioeconomic and institutional characteristics, it is not designed to establish whether those relationships are causal. Future research could assess the causal effect of potential drivers of equity, such as those suggested in this study, through impact evaluation, which involves focusing on design over methods and the use of counterfactuals (Ferraro and Hanauer 2014). A second limitation is that this study does not compare co-managed sites with 'control' sites that are not under co-management arrangements. Future studies could include different management arrangements (e.g., co-management, open access, and state-led) to better understand the relationship between co-management and equity. A third limitation is that our study assessed disparity measures based on perceptions but not on quantitative objective indicators (e.g., livelihood income and expenditure). Co-management can result in disparities in material benefits which can further harm marginalized groups and may not be captured by disparities measurements based on equity perceptions. Therefore, future studies could additionally measure disparities in material benefits and other non-perception-based indicators

of wellbeing (Kaplan-Hallam and Bennett 2018) to provide a more complete understanding of the disparities that exist in a certain context.

A fourth key limitation of our study is that we examined distributional equality and not distributional equity. Distributional equality involves distributing benefits and/or costs equally among people. Although equality is often equated with equity, a fair distribution of benefits or costs can follow other distributions or principles. Indeed, social justice theory identifies three major distributional justice principles: need, equality, and proportionality (Deutsch 1975). Which of these principles is considered fair can vary according to the situation at hand, including the socio-cultural context and the nature of the benefit (Martin et al. 2019; Gurney et al. 2021). For example, in Fiji, distributing material benefits arising from a co-managed marine protected area according to customary rights (a proportionality distributional justice principle) was perceived as fairer than distributing benefits equally, according to need, or proportionally to opportunity costs associated with displaced fishing effort (Gurney et al. 2021). Equity or fairness is a powerful human motivator, and it has a strong influence on feelings and behaviors. Given it is often equity and fairness, rather than equality, that people care about and which, therefore, influences behavior (Starmans et al. 2017), research is needed to evaluate if the disparities we identified are perceived as fair or not. In addition, future studies could assess whether the socioeconomic and institutional characteristics included in this study are also related to equity perceptions.

Conclusion

Co-management has positive and negative impacts on people's livelihoods which are often unevenly distributed. These disparities or uneven distributions of co-management impacts have both ethical and instrumental implications for environmental management. Therefore, understanding what co-management disparities exist and the conditions under which disparities are likely to occur is critical for promoting equitable and effective management. Here, we provide some of the first evidence on how disparities are experienced in objective and subjective terms, and how they are related to key socioeconomic and institutional characteristics. In our analysis of 1191 fishers across 48 co-management arrangements in five Indo-Pacific countries, we found that objective and subjective equality were more prevalent than disparities (losses and gains), and it was more common for a fisher to perceive losses than gains. We also found that disparities were related to a variety of socioeconomic (e.g., distance to markets, population size, and wealth) and institutional (e.g., area restrictions and conflict resolution mechanisms) characteristics.

These findings suggest that different strategies can be implemented to promote or reduce the different kinds of disparities we examined (i.e., objective versus subjective disparities, and losses versus gains). However, there are two key aspects to consider when implementing these strategies to ensure equitable and effective management. First, it is critical to unravel whether equality or different types of disparities are considered equitable or fair by local fishers, because it is often not equality that concerns people, but rather equity. Second, given that disparities can have consequences for other social and ecological aspects of the system, it is critical to understand the trade-offs of managing disparities. For example, our study suggests that improving market access for small-scale fishers may promote equality and reduce losses. However, market engagement can pose risks to small-scale fisheries, e.g., it can lead to overexploitation (Cinner et al. 2016), a reduction in preferences for distributional equality (Gurney et al. 2021), or may crowd out critical aspects of pro-environmental behavior (Cinner et al. 2021), including willingness to engage in collective action (Gurney et al. 2016).

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s11625-023-01361-w>.

Acknowledgements We thank the communities and leaders for their time and willingness to participate in this research. We acknowledge support from the Australian Research Council Centre of Excellence for Coral Reef Studies, James Cook University. This work was supported by grants from the Australian Research Council, including through a Centre of Excellence Grant (CE140100020), Future Fellowship Grant to J.C. (FT160100047), and Discovery Early Career Research Fellowship Grants to G.G.G. (DE210101918) and M.L.B. (DE190101583). SG acknowledges ANID/PIA BASAL FB0002, ANID—Millennium Science Initiative Program—ICN 2019_015, and FONDECYT 1230982. We acknowledge Melanie A. Hamel for her contribution to the initial data analysis and the initial data collectors Andrew Wamukota, Narriman Jiddawi, Ando Rabearisoa, Rachel Lahari and John Kuange.

Author contributions CRC: conceptualization, analysis, writing—original draft preparation, writing, reviewing, and editing. GGG: conceptualization, writing, reviewing, editing, and supervision. MLB: conceptualization, methodology, analysis, writing, reviewing, and editing. SG: writing, reviewing and editing. JEC: conceptualization, resources, methodology, analysis, writing, reviewing, editing and supervision. All the authors reviewed have approved the final version.

Funding Open Access funding enabled and organized by CAUL and its Member Institutions.

Data accessibility statement The data has been deposited on Research Data JCU and it is available at <https://doi.org/10.25903/ypbj-zf68>. The code can be accessed at https://github.com/cristinaruanochamorro/RuanoChamorroetal_2023_Disparity_Comanagement.

Declarations

Conflict of interest We declare no conflict of interest with this work.

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