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Sea Cucumber Moratorium and Livelihood Diversity in Papua New Guinea

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Abstract

Livelihood diversity factors including: flexibility within fisheries; geographical mobility; reallocation of displaced fishing effort into the broader economy; and the non-material benefits that fisheries provide; form an important component of research into overfishing solutions. We use two small scale fisheries related socio-economic surveys of communities in the Tigak Islands of Papua New Guinea. The first conducted five years before a ban on the harvesting of sea cucumbers was imposed and the second from the present day, five years after the initiation of the ban – with the objectives of exploring changes in household fishing strategies (types and numbers of species targeted) and to identify any important socioeconomic factors that help explain those changes. Fishing's contribution to total household income has increased significantly, with the percentage of female residents living in a household now positively and significantly associated with fishing income. The average number of species categories targeted per household increased insignificantly, while households with more women are significantly less likely to target more species than households with more men. Moreover, customary management practices contribute to this difference. Together, these results show that households are not worse off financially five years after the ban on sea cucumber harvesting; and that gendered seascape use has implications for the role of livelihood diversity as a marine policy tool.

Keywords: Customary marine tenure, Fisheries moratorium, Gender in fisheries, Livelihood diversity, Small scale fisheries

Introduction

The conservation and management of sea cucumbers is vital if they are to fulfill their important ecological role in marine ecosystems (Purcell 2010). They are also of great social and economic value to many coastal communities and have provided livelihoods in the Indo-Pacific for centuries (Anderson *et al.* 2011; Conand 1994; Hamel *et al.* 2001; Kinch *et al.* 2008a; Kinch *et al.* 2008b). However, regional assessments have revealed that population declines from overfishing have occurred in 81% of global sea cucumber fisheries (Anderson *et al.* 2011). Furthermore, moratoria on fishing or exports are now in place in 39% of these fisheries (Eriksson *et al.* 2012; Purcell *et al.* 2013; Robinson, and Lovatelli 2015). The moratorium on fishing of sea cucumbers in Papua New Guinea was implemented in September 2009.

Much conservation effort has been invested into the design and implementation of management systems for sea cucumbers and other small scale fisheries (SSFs) in developing countries (Andrew *et al.* 2007; Aswani *et al.* 2015; FAO 2013; Purcell 2010; Purcell, Lovatelli, and Pakoa 2014). Many of the prescriptions applied to SSFs adopt an ecosystem approach to fisheries management (EAFM). EAFM emphasizes stakeholder participation as compared to a classical biological (stock assessment) approach to fisheries management (FAO 2003; Garcia *et al.* 2003; Pomeroy, 2015; Purcell, Lovatelli, and Pakoa 2014). As such, understanding local socioeconomic concerns and limitations of SSFs is crucial (Aswani *et al.* 2015) as they not only impact but are also impacted by fisheries management measures. For example, social and economic factors can act as drivers of overfishing (Cinner 2009; Cinner, and McClanahan 2006; Cinner *et al.* 2011; Cinner *et al.* 2009a; Cinner *et al.* 2009b; Pomeroy, and Andrew 2011); as is

the case when poverty levels are high and governance is weak (Cinner 2011). Secondly, management interventions that are geared only to reducing dependence on fisheries can disrupt livelihoods, supply chains, and post-harvest processing skills (Purcell, and Pomeroy 2015). There is therefore, a general consensus that management approaches should safeguard social and economic interests (Allison, and Ellis 2001; FAO 1995; Pomeroy 2011; Purcell 2010; Purcell, and Pomeroy 2015). One such approach, in terms of moving away from the routine use of moratoria in SSFs (Purcell, and Pomeroy 2015), has been to utilise aquaculture as a livelihood diversification strategy for live coral reef organisms (Bell *et al.* 2008; Pomeroy, Parks, and Balboa 2006) and for sea cucumber fisheries (Bell, Purcell, and Nash 2008; Eriksson *et al.* 2012;). However, aquaculture approaches should not be viewed as a substitute for better sea cucumber management (Pomeroy, 2015), but instead can act as a complement to existing natural fisheries. Farm production systems for sandfish (*H.scabra*), which are a species of sea cucumber, are currently being trialled in Papua New Guinea (Hair *et al.* 2016).

The consensus that management strategies should safeguard social and economic interests has stimulated a number of thematic areas of social science research for better SSFs marine policy. These areas include combining customary management practices with contemporary management science to develop hybrid fisheries management systems (Ruddle, Hviding, and Johannes 1992; Aswani 2005; Aswani, and Ruddle 2013). Customary management practices are informed by indigenous ecological knowledge and culturally embedded in customary marine tenure (CMT) arrangements (Bennett 2012; Cinner, and Aswani 2007; Hyndman 1993). Examples of CMT arrangements (Carrier 1981; Carrier, and Carrier 1989; Cinner, and Aswani

2007; Otto 1998) that are formally recognized in Papua New Guinea's constitution (Hyndman 1993) include: 1) territorial access rights to communal fishing grounds, which are generally based on residency; 2) individual ownership rights for some types of fishing methods or gear, which are often inherited; and 3) individual access rights to particular species, which can be gender based. Gender in aquaculture and fisheries is not generally considered in marine policy prescriptions (Choo, and Williams 2014; Gopal *et al.* 2014; Williams *et al.* 2012), however, it would be advantageous to do so, as individual access rights to particular species implies that benefits and barriers exist which can create a fishing flexibility difference between men and women. For example, SSFs literature illustrates a common contrast between men's and women's fishing activities (Kleiber, Harris, and Vincent 2015; Purcell *et al.* 2016). This is evidenced by a greater representation of males in non-gleaning fisheries further out to sea, whilst women primarily participate in gleaning activities for hand collected species close to shore (Chapman 1987; Kleiber, Harris, and Vincent 2015). It is important to recognize however, that this gendered seascape use pattern is not representative of all SSFs and changes over time (Kleiber, Harris, and Vincent 2015; Purcell *et al.* 2016).

CMT arrangements are localized and can differ considerably within the same geographical context (Aswani 1999). Firstly, by way of an increase in the intensity with which communal territorial access rights can be enforced; which mainly occurs in response to the advent of population growth, commercialised fisheries and increased competition for resources (Aswani 2005; Carrier, and Carrier, 1989; Cinner, and Aswani 2007; Otto 1997). Secondly, in terms of the way that these communal rights can be eroded by socioeconomic drivers such as demographic

changes, urbanisation, socioeconomic development, technological innovations and commoditisation of fisheries (Brewer *et al.* 2009; Cinner 2005; Cinner, and Aswani 2007; Ruddle 1996, 1998). The strength of CMT arrangements therefore, is related to context specific socioeconomic conditions (Cinner, and Aswani 2007). Subsequently, a potential link may exist between the highly flexible and autonomous character traits of CMT arrangements (Cinner *et al.* 2012b; Hyndman 1993) and changing seascape use patterns in SSFs.

A second thematic area of social science research is exploring the role of livelihood diversity as a policy tool for overfishing (Allison, and Ellis 2001; Cinner 2014). Livelihood diversification encompasses the idea that people employ a range of strategies to meet their socioeconomic needs. In SSFs, livelihood diversity factors such as reallocation of displaced fishing effort into the broader economy; fishing flexibility; and geographical mobility (Allison, and Ellis 2001) are important components of research into overfishing. However, current findings do not always support the idea that diversification strategies based on economic assumptions will lead to reduced fishing pressure (Cinner 2014; Monnereau, and Pollnac 2012; Pollnac, Pomeroy, and Harkes 2001). It is becoming increasingly recognized that the non-material benefits provided by SSFs can keep people in a declining fishery (Cinner 2014; Cinner, Marnane, and McClanahan 2005; Pollnac, Pomeroy, and Harkes 2001). These types of benefits include cultural or personal identity (Cinner 2014). In addition, research in CMT lends support to the notion that this cultural practice falls within the concepts of individual identity construction (Bennett 2012; Otto 1998). Identity is often described as a cultural benefit with multiple and intertwined values, in terms of the way that nature accrues meaning and significance for people (Chan,

Satterfield, and Goldstein 2012; Chan *et al.* 2011; Kenter *et al.* 2015). Multiple and intertwined values can be described as being relational from the perspective of gender based access rights to particular species. Relational values are defined as the values associated with relationships, both interpersonal and as articulated by social norms (Chan *et al.* 2016). Moreover, relational cultural values influence and are influenced by localized cultural practices (Church *et al.* 2014), such as CMT. Research in the non-material benefits that form part of individual CMT arrangements therefore, can help to better shape our understanding about livelihood diversity as a marine policy tool.

The overriding aim of this paper is to assess household responses to the sea cucumber moratorium, in terms of changes to household fishing strategies (types and numbers of species targeted). The purpose of which is not to establish causality but to identify any important social and economic factors that can help to explain fisher responses. As such, this paper explores heterogeneity in fishers and their fishing practices; thereby contributing, in a complementary way, to the development of sandfish farming in Papua New Guinea. Specifically, the research objectives are to:

1. Determine changes to household income in order to identify any reallocation of fishing effort to the broader economy.
2. Identify any changes to fishing pressure on each individual type of species, by determining the change in the proportion (percentage) of households targeting each species category. Test the change for significance.

3. Determine the change in the average number of species targeted per household, as a proxy for fishing flexibility, and test the change for significance.
4. Determine if the enforcement of territorial access rights (cultural practice with non-material benefits) is a significant precondition for households that responded by targeting a larger number of species.

Methods

Study area

Socioeconomic data were collected from households in the Tigak Islands of New Ireland Province, Papua New Guinea. The Tigak Islands (Figure 1) are located within the Tigak Rural Local Level Government area and are spread over the two electoral wards of Nonovaul and Enang. Varying degrees of remoteness exist with the Nonovaul Ward being closest to the town of Kavieng and its central market. Enang Ward has communities located up to approximately 30 km by boat from Kavieng. The result of this is that fishers in Enang often utilize alternative points of sale such as their local community store and/or travelling fish buyers (NFA 2005). These alternative points of sale generally offer lower prices as compared to prices received in town.

Figure 1 here

The islands contain a variety of seascapes including coral reefs, sea grass meadows, large lagoons and numerous passages. All households participate in some form of fishing, not only for

subsistence but also as an income earning activity (NFA 2005). As such, people are highly dependent on coastal marine resources. Some households also participate in a small variety of non-fishing income streams including: selling fuel; providing boat taxi services; acting as fish buyers; and selling market vegetables. Communities have well-defined territorial user rights over their fishing grounds, which form part of marine tenure arrangements. These user rights potentially have implications for geographical mobility, in terms of being able to fish in more productive fishing grounds belonging to other communities.

Data

The sea cucumber moratorium was implemented in September 2009. Five years prior, in 2004, sixty households participated in a small scale fisheries related socioeconomic survey. This survey formed part of the Coastal Fisheries Management and Development Project that was being conducted by the National Fisheries Authority. The survey was focused at the electoral ward level as these are the administrative divisions used in Papua New Guinea. The sampling framework used a random sampling design (rather than a repeated measures approach) (NFA 2005) and therefore data collected during the post moratorium survey was not constrained by lost samples. Furthermore, the 2004 survey employed an equal sampling effort with thirty households per electoral ward being selected by enumerators. However, some data were missing meaning that four observations were dropped during data cleaning. The 2004 survey instrument collected information on a large variety of socioeconomic factors including data on household demographics, species targeted, fishing methods used and whether or not households enforced territorial fishing rights (NFA 2005). However, no data were collected on

sea cucumbers, or any other species, in terms of their contribution to household fishing income.

The 2004 survey allowed respondents to report their fishing activities in terms of either species categories targeted or fishing methods used. The reason for this was that some households targeted particular species or groups of organisms, while others took whatever species were captured using a particular fishing method. A list of targeted species therefore, was derived by the authors from both the species categories and fishing method responses. As there were a large number of species categories in this list we pooled a variety of them under the label of “mixed fish”. The purpose of which was to define a simple species portfolio for analysis (Table 1). Species category descriptions, as described in the 2004 survey, that were pooled together include: reef fish; lutjanids; lethrinids; serranids; siganids; mullet; scarids; acanthurids; haemulids; wrasses; goatfish; milkfish; and triggerfish (NFA 2005). All of these species categories can be found within sea grass habitats and/or the flats, crests and slopes of fringing reef (Di Carlo, and McKenzie 2011; Nagelkerken *et al.* 2002; Unsworth, Bell, and Smith 2007). In this way and as part of the data cleaning process, we were able to geographically separate “mixed fish” from other groups of finfish generally caught further out to sea; and therefore negate some of the noise surrounding the 2004 data.

Table 1 here

The post moratorium survey was conducted in 2014. The questions in this survey instrument replicated the pre moratorium questionnaire, except for the way that respondents reported their fishing activities. To this end, the species portfolio list (Table 1) was incorporated into the survey design. The 2014 survey also adopted a random sampling design that was focused at the electoral ward level. A sample size of 98 households, for two-tailed *t* tests and *z* tests, was determined using a power of 0.80 and an alpha of 0.05 (Acock 2012). Due to missing data however, three observations were dropped during data cleaning. Sampling effort was apportioned between the two electoral wards on the basis of 2011 Census data (National Statistical Office 2011). A potential limitation of the post moratorium data is that we did not identify the percentage of the sampled households in 2014 that correspond with the same households sampled in 2004. However, approximately one in five households were systematically surveyed, key informants interviewed, focus group discussions undertaken and the lead author also participated in fishing activities to verify the accuracy of household responses. These activities provided an opportunity to gain a clearer understanding of coastal resource use and livelihood diversity in terms of household responses to the sea cucumber fishery collapse.

Analysis

We employ descriptive statistics to determine changes in a variety of household socioeconomic factors including total monthly income, contribution of fishing to household income, changes to the proportion of households targeting each individual species category and a change to the average number of species targeted by per household. The purpose of which is to identify

significant explanatory variables for our econometric model. We used a pooled-variance t test for a given level of significance, $\alpha = 0.05$, in a two-tailed test to determine whether there were significant differences in total monthly income and the importance of monthly fishing income between 2004 and 2014. The assumption of normality was violated so both data sets were normalized using a square root transformation, after 2004 incomes had been adjusted for inflation using local CPI figures (National Statistical Office, 2013). Discrete variables in the summary table are reported using proportions. A two sample proportion z test, $\alpha = 0.05$, was used to assess the changes for significance. A two-tailed Wilcoxon rank sum test was used to test for difference between 2004 and 2014 in the number of species categories targeted by households. The Wilcoxon test was preferred over the pooled-variance t test because of the small sample sizes and the fact that the dependent count variables, for both years, are not normally distributed. Measuring strength and direction of associations between variables of interest was performed using Pearson's correlation, unless they did not satisfy the assumption of normality. In these cases Spearman's correlation was employed.

A widely employed approach for investigating the determinants of household decisions, particularly within the context of farmers adopting new agricultural technologies in developing countries, is through the use of count data models such as the Poisson/Negative binomial types (Mariano, Villano, and Fleming 2012; Rahelizatovo, and Gillespie 2004; Ramirez, and Schultz 2000; Sharma, Bailey, and Fraser 2011). These models can also be applied to the analysis of household fishing portfolios. For example, and has been used in this study, a portfolio of species are counted to assess changes in the number of species targeted per household

(dependent variable) between 2004 and 2014. Count data models are limited in that they treat each target species as being of equal importance. However, as we are also interested in explaining the likelihood of fishers targeting more species, the Poisson is the fundamental probability distribution to be used and not the logistic or normal distribution (Long, and Freese 2006; Mariano, Villano, and Fleming 2012). 15 explanatory variables were fitted to both the 2004 and 2014 models for the purpose of calculating percentage change coefficients (percentage change in expected count for a unit increase in one explanatory variable). 13 of these variables were selected from Table 2. Two additional variables were also included in the models. The first to account for households targeting hand collected species closer to shore. The second variable incorporates access to the central market in Kavieng in terms of whether or not households were located in the Enang electoral ward. Hypothesis tests for over-dispersion ($\alpha = 0$) were conducted to examine whether the Poisson or unrestricted negative binomial model was more appropriate to use.

Finally, and in response to the findings generated by the Poisson model, we constructed cumulative percentage polygons to compare the proportions of households (in terms of gender and the enforcement of territorial access rights) that lay below the average number of total species targeted. A two sample proportion z test, $\alpha = 0.05$, was used to assess changes for significance. The statistical package Stata v14 was used for all analysis.

Results

Descriptive statistics

Changes to socioeconomic conditions are presented in Table 2 along with their levels of significance. Households are not worse off financially but, fishing's contribution to household income has changed significantly ($p = 0.019$). Households have increased their number of fishing trips per week significantly ($p = 0.000$), while there has been a significant ($p = 0.034$) reduction in the number of hours per fishing trip. The number of canoes owned per household has risen significantly ($p = 0.001$) and this reconciles with a reduction in the proportion of households owning a powered motor boat. In general, households are now applying significantly more fishing pressure to hand collected species. The average number of species targeted per household has increased insignificantly from 3.1 in 2004 up to 3.7 in 2014. A number of significant changes have also occurred within the "household characteristics" grouping. The average number of residents per household has significantly ($p = 0.021$) increased from 5.5 in 2004 up to 6.4 in 2014. The number of children attending school from each household has increased significantly. The most likely reason for this increase is that in 2014 an earlier change in legislation meant that attending school was free whilst in 2004 parents were required to pay school fees. Awareness of fishing rules increased significantly ($p = 0.000$) between 2004 and 2014, although it is important to note that this does not necessarily mean that regulations are being complied with or that the effectiveness of governance has improved (personal observation). Finally, the proportion of households enforcing territorial access rights to communal fishing grounds has increased significantly ($p = 0.000$) from 28.9% in 2004 up to 86.8% in 2014.

Table 2 here

A summary of associations between variables of interest is presented in Table 3.

Table 3 here

Figure 2 presents the distributions of the number of species targeted per household in 2004 and 2014, indicating some degree of fishing flexibility within the study area. In 2004 the most species targeted by any one household is 6; the median number of species targeted is 3 with 31% of the sample belonging to the 50th percentile, while 39% of the sample is below the median value. 19 households targeted two species while 8 households targeted four. In 2014 and with no access to sea cucumbers, 8 households targeted all available species. The median number of species targeted by each household was again 3 with 28% of the sample belonging to the 50th percentile and 33% of the sample below the median value. Approximately 15% of households preferred to fish for one species category and 9% adopted six categories.

Figure 2 here

2004 and 2014 Poisson models

Results indicate that in 2004 none of the explanatory variables are significant determinants for increasing expected species target rates (Table 4). In addition, all household income factors are insignificant predictors in both 2004 and 2014. Being a household that employs hand collecting

activities significantly ($p = 0.000$) increases the expected number of species targeted by 147%; holding all other variables constant. The importance of owning a dingy with an outboard motor is insignificant as a determinant with target expectations decreasing from 25.4% in 2004, down to 8.3% in 2014. Results suggest that in 2014 the “household characteristics” group of variables contain a number of important non-material preconditions. The percentage of females living in a house significantly ($p = 0.018$) decreases target expectations by 1%. Access to Kavieng market ($p = 0.031$) and enforcement of communal territorial access rights ($p = 0.046$) are also significant household preconditions for increasing expected target rates by 54% and 33% respectively.

Table 4 here

Cumulative percentage polygons

Figure 3 compares the proportions of households (in terms of gender and the enforcement of territorial access rights) that lay below the average number of total species targeted. The purpose of which is to provide some insight into the changing relationships (Table 3) between two explanatory variables (gender majority and communal territorial access rights) and the dependent variable (number of species targeted).

Figure 3 here

As can be seen, households enforcing communal territorial access rights in 2004 targeted between one and four species, with approximately 71% of these households targeting below the average of 3.1 (Table 2). Approximately 53% of households containing more women targeted less than 3.1 species, while approximately 81% of households with more men were targeting below the average. In 2014 at least one household from each of these three categories targeted the entire available species portfolio. Approximately 67% of households enforcing access rights targeted less than the average of 3.7 species (Table 2) which was an insignificant decrease down from 71% in 2004. 79% of households with more women now target below the average which is an insignificant increase up from 53% in 2004. The proportion of households with more men that target below the average however, has decreased significantly ($p = 0.013$) down to 56% from 81% in 2004.

Discussion

Understanding local social and economic benefits (and barriers), is an important component of developing livelihood diversification strategies. As such this section focuses on links driven by fisher responses to the collapsed sea cucumber fishery. Two key links are presented. The first is the connection between the increase in fishing's contribution to household income and an increase in fishing pressure on hand collected species closer to shore. The second is the connection between increased enforcement of communal territorial access rights and an increase in the number of species targeted per household. Moreover, these two connections share some common household responses, from the perspective of CMT arrangements, and a flexibility difference in the number of species targeted between men and women. A brief

summary is then provided in terms of key livelihood diversity factors that have potential implications for the development of sea cucumber aquaculture in the study area.

The increase in fishing's contribution to household income between 2004 and 2014 is a significant response. In addition, findings indicate that households' previously targeting sea cucumbers have responded by significantly increasing fishing pressure on other hand collected species located closer to shore. The connection between these two responses could be higher market values (McClanahan 2010), particularly for crabs and tropical lobsters which are certainly in demand by resorts in the study area (Personal observation). All nine species categories however, except for mixed fish, exhibit negative relationships with fishing's contribution to income. Negating therefore, improved market conditions as a potential connection. Instead, we found that the percentage of female residents in a household was the only significantly positive association with fishing's contribution to income. This suggests that either female majority households are more dependent on fishing as a source of income than households with more men; or that women are fishing harder than men to maintain household income levels. Given the SSFs context of the study area, it is likely that all households are highly dependent on fishing for both subsistence and as a source of income. Therefore, a likely explanation contributing to the connection between fishing's contribution to income and the increased pressure on hand collected species closer to shore can be found in the response that women are fishing harder than men. This response by women as a household survival strategy, in terms of responding to a loss of income, is not unique to SSFs. Lingam (2005) summarizes a number of complementary case studies at the household level. Her findings highlight areas of

concern about the cumulative gender implications of economic reconstruction policy that was undertaken during the 1980s and 1990s. One such issue is that women shoulder the burden of household survival, not just in terms of domestic tasks but also in terms of intensifying their working day to maximize earnings (Lingam 2005).

We also found that both fishing's contribution to income and majority female households, are significantly and negatively associated with the average number of species targeted per household. As such, this connection between fishing's contribution to income and the additional fishing pressure on hand collected species is likely to be interrelated with the connection between increased enforcement of communal territorial access rights and an increase in the number of species targeted per household.

The increase in the proportion of households enforcing communal territorial access rights to fishing grounds between 2004 and 2014 is a significant response to the collapsed sea cucumber fishery. Additionally, findings indicate that the average number of species categories targeted per household has increased. Though insignificant, this response indicates that a degree of fishing flexibility exists in the Tigak Islands. Furthermore, being a household that enforces territorial rights is a significant determinant for increasing the expected number of species targeted. One of the drivers strengthening the exclusivity of communal fishing grounds is population growth (Cinner, and Aswani 2007). As such, a potential explanation connecting high levels of territorial enforcement with species target rates can be found when considering population growth in the light of geographical mobility. As exclusivity levels rise due to

population growth, owning a powered boat to travel to more distant and productive fishing areas is likely to become a moot point for many people. The reason being, that these fishing areas will be owned by other communities who will likely enforce their territorial rights. As is evidenced in other areas of Papua New Guinea, high levels of exclusivity can give rise to conflict among fishers (Cinner 2005). Therefore, in order to avoid conflict households would need to consider increasing the number of species that they target, as a fishing strategy, from within their own fishing grounds.

As mentioned above, we found that fishing's contribution to income and majority female households are both significantly and negatively associated with the average number of species targeted. While the income association with average species targeted does not translate as a significant household precondition for decreasing expected target rates, the percentage of females living in a house does. Simplistically put, women have responded to the collapsed sea cucumber fishery by fishing harder to maintain income levels and, they are achieving this by targeting less species than men. This may imply that women are continuing to target their preferred species on the basis of non-material benefits, such as identity and ecological knowledge. Alternatively, it may also imply that the individual species access rights of CMT arrangements are forming a barrier in terms of the particular species that they can target. The connection between the exclusivity of communal fishing grounds and decreasing expected targets rates for majority female households however, is more likely to be driven by a combination of both of these alternatives from the perspective of non-material relational values (Chan *et al.* 2016). For example, interpersonal relationships between women are created

through the individual identity benefits that they derive from cultural ecosystem services and the shared ecological knowledge benefits that inform CMT arrangements. Moreover, these interpersonal relationships are articulated by societal norms in the form of customary management practices which may determine who can harvest particular species (Cinner, and Aswani 2007). Relational values therefore, are being materialized through a change in gendered seascape use patterns. Changes in these patterns suggest a fishing flexibility difference between men and women in the Tigak Islands. Men are targeting more species than women in 2014 whereas they were targeting less species than women in 2004. Moreover, the change in target rates for men was significant while the change for women was not. This relationship between high levels of enforcement of communal fishing boundaries and the flexibility difference between men and women also explains, in part, the importance of hand collecting activities as a household precondition for increasing expected target rates.

We have presented two key links that appear to have been driven by fisher responses to the collapsed sea cucumber fishery. These two connections identify some livelihood diversity factors that have potential implications for the development of sea cucumber aquaculture in Papua New Guinea. The remaining paragraphs in this section explore these factors and their implications for decision makers.

We found that there has been little reallocation of fishing income into the broader economy. In fact monthly income generated from other livelihoods such as cash crops, fuel sales, boat taxi services and acting as fish buyers has decreased. This confirms a high level of dependence on

marine resources. As such better management strategies in terms of moving away from the routine use of moratoria is required (Pomeroy 2015; Purcell, and Pomeroy 2015). Sea cucumber aquaculture is an appropriate management strategy in terms of safeguarding the social and economic interests of fishers. However, a number of constraints are associated with the development of sandfish farming in other countries. These include inadequate regulations and weak enforcement which are facilitating poaching and a new pattern of global resource extraction (Eriksson *et al.* 2012; Eriksson *et al.* 2015a; Eriksson *et al.* 2015b). In order to achieve conservation objectives and commercial sustainability therefore, it is suggested that decision makers in Papua New Guinea address the enforcement of sea cucumber regulations before farming is introduced (Eriksson *et al.* 2012).

Geographical mobility is a diversification factor that has implications from a number of perspectives for isolated coastal and island communities in Papua New Guinea. Results suggest that a lack of mobility (from the perspective of communal territorial fishing boundaries) influences fishing strategies in terms of the types and numbers of species targeted by households. However, a lack of mobility (from the perspective of fewer households owning powered dinghies) can also contribute to adverse market conditions by restricting access to the central market in Kavieng, where better prices are received for fishing catch. Lower prices for fishing catch can be reconciled with women working harder and men targeting more species categories in order to maintain household income levels. The reduction in the proportion of households owning powered dinghies therefore, appears to have influenced household responses since 2004. One potential reason for the reduction in the number of households

owning motor boats is the relatively high fuel prices in the study area due to its isolation (Personal observation). Developing aquaculture policies that minimize this type of exogenous pressure is therefore needed (Cinner, and McClanahan 2006).

A flexibility difference exists between men and women. This difference is being driven, in part, by the individual species access rights of CMT arrangements. Species access rights benefits are intertwined with indigenous ecological knowledge and identity; thereby influencing the way that people prefer to interact with nature. In addition, it is becoming increasingly recognized that these types of non-material benefits can keep people in a declining fishery (Cinner 2014). Therefore, if the sea cucumber aquaculture initiative is to achieve fishery sustainability objectives as a diversification strategy, then management policy must encompass peoples' cultural values and practices.

Conclusion

Aquaculture development in SSFs now forms part of strategic marine policy in terms of sea cucumber fishery sustainability and broader food security objectives. However, aquaculture initiatives need to safeguard not only peoples' economic interests, but also the values that they have for the cultural benefits that ecosystems provide. Our analysis shows that households are not worse off financially five years after the ban on sea cucumber harvesting. In addition, women have responded to the collapsed sea cucumber fishery by fishing harder to maintain income levels and that they are achieving this by targeting less species than men. We have argued therefore, that a flexibility difference exists between men and women in the Tigak

Islands. Furthermore, we have presented a case that this difference is due in part to the individual species access rights of CMT arrangements. Species access rights benefits have relational cultural values that are being materialized in gendered seascape use patterns. As such, we suggest that the individual aspects of CMT are complementary to communal territorial rights, in terms of household responses to collapsing fisheries. Further research into the importance placed by fishers on gendered seascape use therefore, is likely to better shape our understanding about the implications that it has for aquaculture as a marine policy tool.

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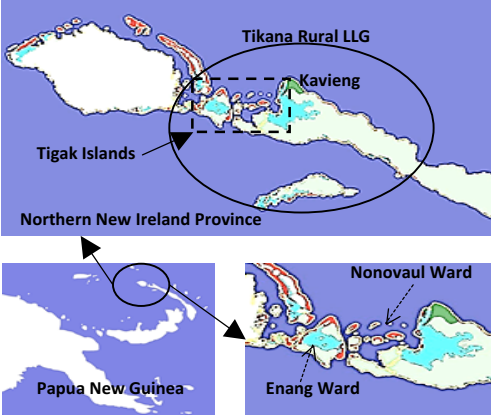


Figure 1. The Tigak Islands in northern New Ireland Province of Papua New Guinea (NFA 2005).

Table 1. Species categories portfolio.

Categories	Definition
Mixed fish	Including species of Lutjanidae; Lethrinidae; Serranidae; Siganidae; Mugilidae; Scaridae; Acanthuridae; Haemulidae; Labridae; Mullidae; Chanidae; and Balistidae located within mangrove-sea grass-fringing reef habitats (using hand lines, nets and spear guns).
Deep water fish	Mainly Lutjanidae, Lethrinidae, Serranidae species, but, located further out to sea away from fringing reefs (using hand line or spear guns).
Sea cucumber	2004 only, located within sea grass-fringing reef habitats (hand collected; some species dived for in deeper areas on reef slopes and in lagoons).
Pelagic fish	Mackerel and tuna – Scombridae, Barracuda – Sphyraenidae, rainbow runner and scads – Carangidae (trolling).
Crabs	Generally mud crabs (<i>Scylla serrata</i>) located in mangrove habitats (hand collected).
Trochus	<i>Trochus maculatus</i> found in sea grass-fringing reef habitats (hand collected).
Shellfish	A variety of bivalve mollusk species located within mangrove-sea grass habitats (hand collected).
Lobsters	Generally the ornate rock lobster (<i>Panulirus ornatus</i>) found on the crest and front of fringing reef habitat (spear gun).
Clams	Tridacnidae species found within fringing reef habitat including lagoons (hand collected).

Table 2. Changes in socioeconomic conditions in the Tigak Islands.

Household socioeconomic conditions	2004 (n = 56)		2014 (n = 95)		Significance of change
	Mean	Median	Mean	Median	
<i>Household income</i>					
Total monthly income (PGK)	551	473	609	510	0.186
Monthly fishing income (PGK)	293	198	400	320	0.002
Contribution of fishing (%)	61	67	73	78	0.019
Contribution of market vegetables (%)	30	20	11	0	0.000
Contribution of betel nut (%)	0	0	12	3	0.000
Contribution of other income (%)	10	0	5	0	0.114
<i>Household fishing strategies</i>					
Number of fishing trips per week	1.9	1	3.3	3	0.000
Number of hours per fishing trip	4.2	4	3.6	3	0.034
Number of canoes owned	1.3	1	1.9	2	0.001
Owns a dingy with outboard motor (%)	32.8	-	19.4	-	0.061
Targets mixed fish (%)	98.3	-	91.9	-	0.092
Targets deep snappers (%)	62.8	-	41.9	-	0.012
Targets sea cucumbers (%)	45.7	-	-	-	-
Targets pelagic fish (%)	25.5	-	19.4	-	0.374
Targets crabs (%)	22.1	-	46.0	-	0.003
Targets trochus (%)	20.4	-	32.7	-	0.097
Targets shellfish (%)	13.6	-	40.9	-	0.001
Targets tropical lobster (%)	11.9	-	38.8	-	0.001
Targets clams (%)	7.8	-	58.2	-	0.000
Average number of species targeted	3.1	3	3.7	3	0.188
<i>Household characteristics</i>					
Age of household head	41	40	47	45	0.005
Education level of head	7	6	8	7	0.009
Number of residents	5.5	5	6.4	6	0.021
Number of children at school	0.2	0	2	2	0.000
Females living in house (%)	49.1	-	49.5	-	0.018
Extended family living in house (%)	27.2	-	39.8	-	0.107
Household heads are migrants (%)	17.9	-	20.4	-	0.701
Aware of fishing rules (%)	25.5	-	63.3	-	0.000
Enforcing territorial access rights (%)	28.9	-	86.8	-	0.000

Table 3. Associations between variables of interest.

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- Fishing's contribution to household income is positively and significantly ($p = 0.018$) associated with the number of female residents per household.
 - Fishing's contribution to household income is negatively and significantly ($p = 0.001$) associated with the number of species targeted.
 - The percentage of female residents is negatively and significantly ($p = 0.002$) associated with the number of species targeted.
 - Hand collected species are negatively associated with fishing's contribution to income. Crabs ($p = 0.043$) and clams ($p = 0.019$) are significant, shellfish and trochus are not.
 - All nine species categories, except for mixed fish, exhibit negative relationships with fishing's contribution to income.
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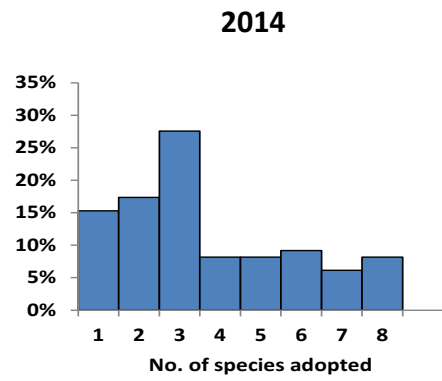
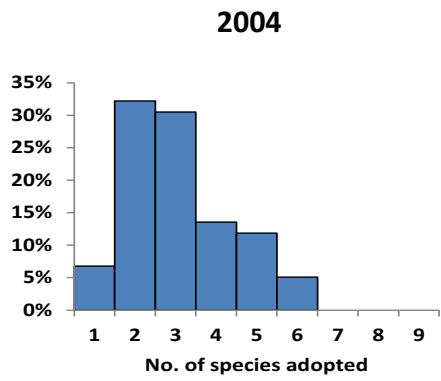


Figure 2. Frequency distribution of total species targeted by household proportion.

Table 4. Percentage change coefficients of the Poisson models.

Dependent variable: number of species targeted.	2004		2014	
	Coeff.	p-value	Coeff.	p-value
<i>Household income</i>				
Monthly fishing income (PGK)	-0.7	0.764	-0.6	0.574
Contribution of market vegetables (%)	-0.3	0.561	-0.1	0.712
Contribution of other income (%)	-0.3	0.703	0.5	0.115
<i>Household fishing strategies</i>				
Number of fishing trips per week	-4.4	0.607	5.6	0.382
Number of hours per fishing trip	2.8	0.733	-0.7	0.886
Number of canoes owned	5.7	0.805	-6.2	0.356
Owns a dingy with outboard motor (%)	25.4	0.323	8.3	0.608
Targets species collected by hand (%)	56.7	0.112	146.7	0.000
<i>Household characteristics</i>				
Age of household head	-0.7	0.492	-0.8	0.097
Education level of head	-0.1	0.990	1.4	0.489
Number of residents	1.6	0.753	-3.2	0.234
Females living in house (%)	0.0	0.980	-0.9	0.018
Aware of fishing rules (%)	1.0	0.981	44.4	0.008
Enforcing territorial access rights (%)	-4.8	0.897	53.9	0.046
Located in Enang Ward (%)	13.9	0.735	32.5	0.031
<i>Log likelihood function</i>	-52.489		-146.464	
<i>Prob[ChiSq_d > value]</i>	0.815		0.000	
<i>McFadden pseudo R²</i>	0.088		0.212	

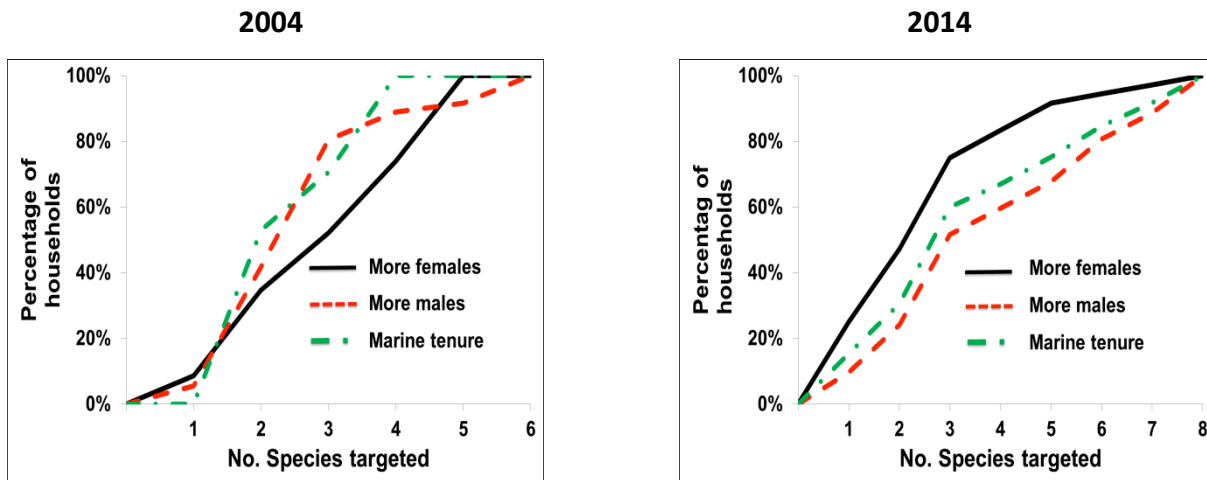


Figure 3. Cumulative percentage polygons for number of species targeted, household gender majority and enforcement of territorial access rights.