

Locally managed marine areas: Implications for socio-economic impacts in Kadavu, Fiji

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ABSTRACT

Marine protected areas (MPAs) are a widely used marine conservation tool designed to preserve marine biodiversity and improve fisheries management. Although the environmental benefits of MPAs are well established, evaluating the social and economic impacts of MPAs is challenging. In this paper we quantitatively identify the economic and social differences between communities based on whether or not the community has a tabu area in their local fishing ground. This is an area permanently closed to fishing within a locally managed marine area (LMMA), a form of MPA in the Pacific region. To do this we analyse survey data at both the household and village level in Kadavu, an administrative province of Fiji. We find there are differences in economic activity and diet between the communities but little difference in overall income and wealth. Our study shows that villages with an active tabu area have more positive social outcomes in terms of perceptions of LMMAs. However, there are some notable negative social outcomes as well. In particular, we find that households not engaged in commercial fishing perceive conflict around the management of marine resources. We also find that households engaged in commercial fishing believe penalties for violating LMMA rules are high. Together, these results could potentially impede the adoption of LMMAs and tabu areas. Overall, our survey results do not indicate that tabu areas are detrimental or beneficial on the whole, either economically and socially.

1. Introduction

1.1. Marine protected areas and locally managed marine areas

Marine protected areas (MPAs) are a widely used marine conservation tool designed to preserve marine biodiversity and improve fisheries management. It is generally accepted that MPAs are effective at accomplishing these tasks and even have positive spill-over effects on adjacent areas [1–4], especially when the MPA enforces a complete restriction on extractive use [5,6]. Given the adverse impacts of marine biodiversity loss [7], projected increases in biodiversity loss [8], the importance of sustaining fishery stocks [6], and the commitment of nations to Aichi Target 11 of the Convention on Biological Diversity [9], MPAs are likely to increase in number and size.

The need to conserve marine biodiversity and preserve fisheries is acute in Fiji, where the national economy and citizens' well-being are directly tied to marine resources; fishing and aquaculture alone accounted for 1.6% of Fiji's national GDP in 2016 [10]. To achieve marine conservation goals, the Fijian government makes wide use of MPAs, mostly in the form of locally managed marine areas (LMMAs). An LMMA is an "area of nearshore waters being actively managed by local

communities or resource-owning groups, or being collaboratively managed by resident communities with local government and/or partner organisations" [11]. An LMMA differs from a typical MPA in that LMMAs "are characterised by local ownership and/or control", whereas other forms of MPA are usually "designated by levels of management via a top-down approach" [11]. An LMMA, in the South Pacific context, is rooted in traditional and customary fisheries management [12–14] and is designed to gain support and active engagement from the local community, with the latter being a key condition for the successful and lasting implementation of MPAs.

This approach to marine conservation in Fiji is widespread. For example, Fiji's LMMA network exceeds 10,000 square kilometres and covers over 22% of all inshore fishing areas [14]. These LMMAs have been observed to obtain positive environmental impacts typical of MPAs, with increased biodiversity, restored habitat, and increased fish size and abundance [15,16]. As with MPAs generally, the socio-economic impacts are less well understood, although positive social impacts have been found to arise from community involvement in the design and management of the MPA [17].

LMMAs across Fiji have a range of objectives that reflect community goals with differing rules and practices designed to meet these objectives

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[11]. A common characteristic of LMMAs, however, is the inclusion of one or more permanent, well-defined sections in which no extractive use of resources may occur [14]. These areas are typically known as *no-take* or *tabu* areas and account for nearly 600 square kilometres of Fiji's LMMA network. The use of the word "tabu" to describe these areas comes from the traditional name of a customary management tool in which a section(s) of fishing ground is closed for a period of time (e.g. following the death of an important individual in the community).

Although the environmental benefits of MPAs and LMMAs are well established, evaluating their social and economic impacts is challenging. These impacts are often unclear due to uncertainty surrounding the economic costs and benefits for both extractive and non-extractive users [18] and the non-uniformity of social impacts on different individuals and groups in the local community [19,20]. While the social impacts of MPAs and LMMAs are mixed [19–23], it has been consistently found that the effectiveness and longevity of MPAs and LMMAs rely on support from the local community. Such support is often obtained through stakeholder inclusion in the design process [24–26].

Many existing studies on the social and economic impacts of MPAs and LMMAs draw conclusions based on qualitative analysis of a modest number of semi-structured interviews. In contrast, we use a rigorous statistical framework to analyse extensive household- and community-level survey data to compare social and economic measures for communities with and without tabu areas. Specifically, we focus on income derived from a variety of sources, household wealth, diet, community resilience, and attitudes towards LMMAs. The collected data and derived results will be of use for both future research and policy design. In terms of future research, the establishment of baseline data will allow for causal implications of LMMAs to be discovered. In terms of policy design, understanding the current state of affairs in Kadavu is beneficial for maintaining and extending its own LMMA network. In addition, understanding the socio-economic factors correlated with tabu areas will signal which of these factors are important to consider when implementing or extending a tabu area, allowing for the implementation of more effective and efficient fisheries management elsewhere.

The following subsection of the introduction provides a brief overview of the administrative province of Kadavu. The methods section is divided into two subsections, one detailing the methods used to collect the data and the other detailing the models used to derive the results. The results section is divided into five subsections: a subsection detailing descriptive statistics of the data; results relating to economic activity; results relating to household diet; results relating to general household attitudes; and results relating to household attitudes specifically concerning LMMAs. The discussion, conclusions, and acknowledgments sections follow.

1.2. Kadavu, Fiji

The administrative province of Kadavu consists of many islands that form a volcanic archipelago. It is situated south of the largest and most populated Fijian island, Viti Levu (Fig. 1). The main island in the province, Kadavu, is the third largest island in Fiji and covers an area of approximately 430 square kilometres [27]. The province has 75 villages spread across nine districts – Nabukelevu, Nacea, Nakaseleka, Ono, Ravitaki, Sanima, Tavuki, Yale, and Yawe – with a total population of 10,167 in 2007 [28]. Infrastructure in the province is underdeveloped, with Kadavu having limited roading, limited electric power, and no proper sewerage system [29].

Most transport in the province is by motorboat, which is costly. Some core services are provided in the province, including schooling, limited law enforcement, a postal service, and banking. The majority of economic activity in Kadavu is based on agriculture and fisheries, largely undertaken at a subsistence level. Any trade that does happen typically occurs within and between villages in the province, although some goods are sold to wholesalers or exported to Viti Levu. The major cash crop for the province is *yaqona*, from which *kava* is made. Kava is a

ceremonial drink that is also popularly consumed outside of ceremony [30]. Tourism is a small but growing sector [31], driven by the prevalence of reefs that are popular for snorkelling and diving, particularly the Great Astrolabe reef in the Ono district [32].

2. Methods

2.1. Survey methods

The survey sample was drawn from 34 villages (45% of all villages in the province) across Kadavu's nine districts (Table 1 and Fig. 2). Villages were selected according to both the availability of baseline fisheries data and geographical spread. Within each village, the *turanga ni koro* (village headman) was asked to provide basic information on the composition of the village and the state of the nearby fisheries and marine protected areas. Table 1 summarizes this information.

Within each village, at least 10 households were surveyed, for a total of 346 households. These households included 1576 individual members, or over 15% of the provincial population in 2007. Households were nominated by the *turanga ni koro* to broadly represent both the socio-economic strata within the village and a range of income generation activities carried out within the village. If a household was not available, it was revisited at a later time. Households and villages were each modestly compensated in recognition of respondents' time and effort.

The survey was administered by staff from the University of the South Pacific in July 2016. The survey questionnaire included detailed questions on household demographics, agriculture (particularly *yaqona*), livestock and bees, non-timber forest products, fishing and gleaning, wages and other income, durables and wealth, diet and food security, natural disasters, fisheries management, and community resilience. The survey was administered electronically on tablet computers using version 2.51 of SurveyCTO [33] to facilitate complex branching (thereby reducing the overall duration) and to reduce data-entry errors. The survey took 50 min, on average, to complete.

The section on community resilience includes and extends questions adapted from Aalbersberg [34] and from Gawith et al. [35] in their work on the role of community resilience in mitigating damage from natural disasters. Households were asked for their level of agreement on a scale of 0–10, with 0 being strongly disagree and 10 being strongly agree, on 42 statements related to beliefs about the village, the environment, and LMMAs. Table 2 shows a subset of these 42 statements used in the analysis. Each statement is accompanied by a key for identifying the statements in subsequent results tables. These statements relate to attitudes towards the village, the environment and LMMAs.

2.2. Empirical models

To understand the economic differences between villages with an active tabu area and those without, we analysed household-level survey data along with village-level survey data to evaluate household income and wealth, the probability of households engaging in specific income-generating activities, and household diet. Tobit [36] and probit models with the following forms were used:

$$Y^* = f(HD, HS, AT) + \varepsilon, \text{ where } Y = \begin{cases} Y^* & \text{if } Y^* > 0 \\ 0 & \text{if } Y^* \leq 0 \end{cases}$$

$$\Pr(C) = f(HD, HS, AT)$$

where *HD* denotes household demographics, *HS* denotes household size, and *AT* denotes presence of an active tabu area. The response variable *Y*

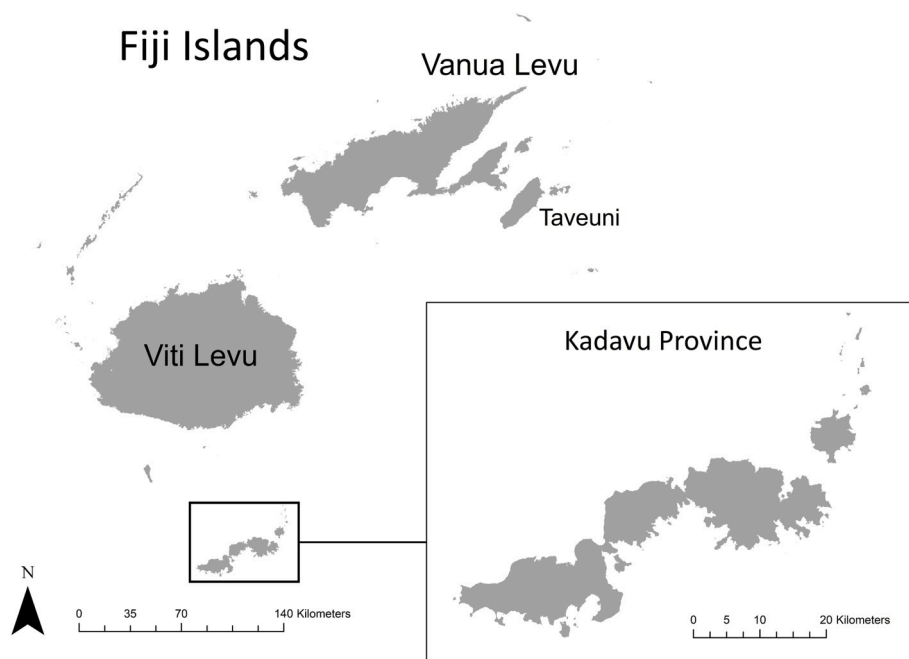


Fig. 1. Map of Fiji Islands and Kadavu province [45].

Table 1
Basic village information.

Village	District	Number of <i>mataqali</i> ^a	Number of households	Number of tabu areas	Combined tabu area (acres)
Daviqe	Nabukelevu	3	60	1	4
Kabariki	Nabukelevu	3	35	2	2.5
Levuka	Nabukelevu	4	35	1	4
Nasau	Nabukelevu	3	48	1	3
Daku	Nacea	2	18	2	20
Dravuvalu	Nacea	5	45	0	0
Jioma	Nacea	7	47	2	12
Kadavu	Nacea	6	55	1	25
Nacamoto	Nacea	3	34	0	0
Soso	Nacea	4	34	2	8
Lawaki	Nakaseleke	3	25	1	1
Nakagasele	Nakaseleke	2	13	1	2
Nukuvou	Nakaseleke	4	13	0	0
Buliya	Ono	2	52	0	0
Dravuni	Ono	2	32	0	0
Nabouvalu	Ono	3	23	0	0
Narikoso	Ono	5	22	0	0
Vabea	Ono	4	27	0	0
Matanuku	Ravitaki	4	20	1	1
Muani	Ravitaki	3	43	1	6
Nasegai	Ravitaki	4	55	1	2.5
Ravitaki	Ravitaki	7	59	1	3
Drue	Sanima	4	34	2	1.5
Naivakarauniniu	Sanima	4	16	1	17
Cevai	Tavuki	2	13	1	1
Galoa	Tavuki	4	43	1	2
Namuana	Tavuki	3	46	2	6
Solodamu	Tavuki	3	23	1	1.5
Tavuki	Tavuki	4	26	1	4
Waisomo	Tavuki	5	20	0	0
Rakiraki	Yale	4	32	1	0.25
Naloutu	Yawe	7	35	1	7
Naqalotu	Yawe	2	38	1	2
Natokolau	Yawe	2	12	1	3

^a Fijian clan or landowning unit.

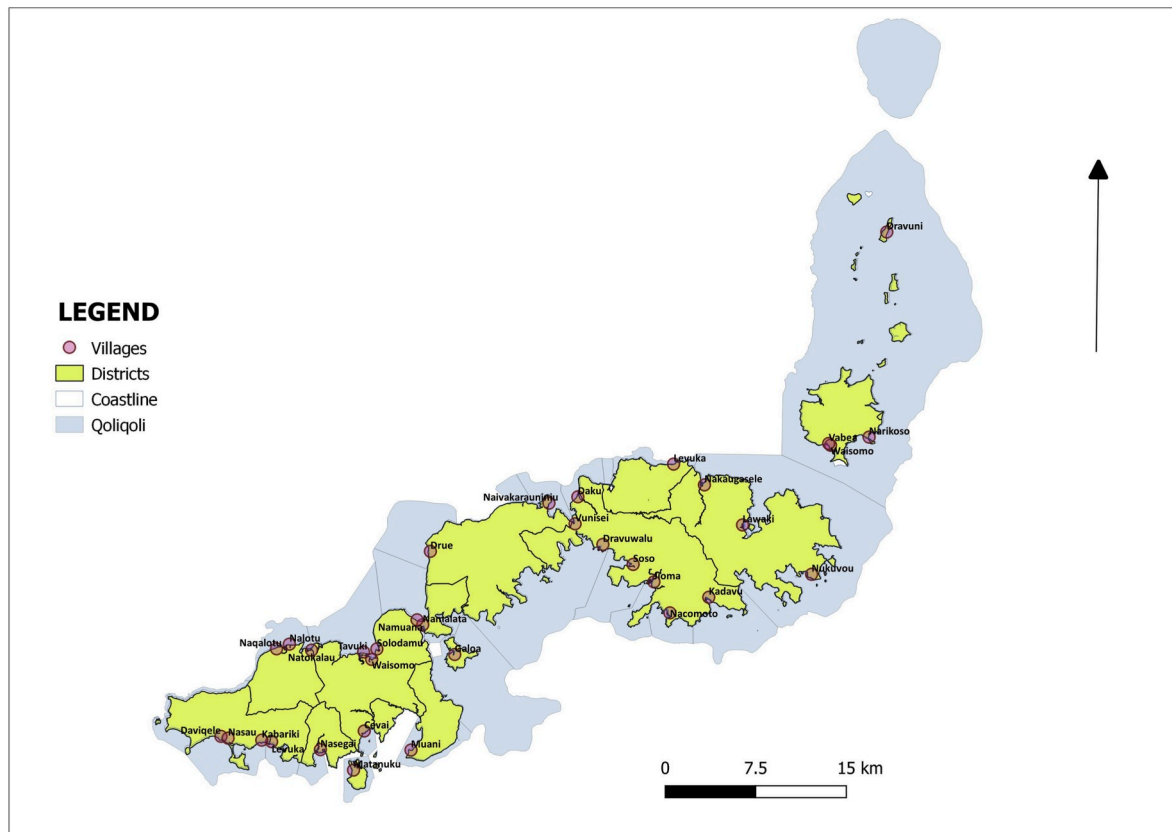


Fig. 2. Map of surveyed villages in Kadavu province.

includes fishing income, income from yaqona sales, overall income, remittances, and wealth, all of which have been transformed by the natural logarithm to account for strong positive skewness.¹ The response variable *C* includes dummy variables indicating whether a household engaged in raising cash crops, engaged in fishing for cash income, and recently consumed an easily grown crop, fish, meat, kava, or a general protein source (either meat, fish, eggs, legumes or nuts, or dairy products). We defined easily grown crops to be taro, kumara, other root vegetables, leafy green vegetables, other vegetables, and potatoes. Cassava was omitted due to its status as the ubiquitous food of the region; 80% of all households had cassava recently. The inclusion of meat attempts to identify a substitution effect of tabu areas, while inclusion of a general protein source is a conservative attempt to identify differences in levels of protein consumption.

Household demographics include head of household’s age, average household age, maximum household member level of education (measured in years of schooling), and head of household’s gender. Following Jolliffe [37]; household education is measured as the maximum education of any household member.

Household size is simply the number of household members. Presence of an active tabu is a dummy variable indicating whether the household is in a village with an active tabu area. Income, remittances, and wealth are measured in Fijian dollars, reported at an annual level. The variable of interest here is *AT*, with all others included as control variables.

To understand the relationship between particular household characteristics and household attitudes (see Table 2), we used tobit models of the following form:

$$Y^* = f(HD, HS, EA, ATF) + \epsilon, \text{ where } Y = \begin{cases} Y^* & \text{if } Y^* > 0 \text{ and } Y^* < 10 \\ 10 & \text{if } Y^* \geq 10 \\ 0 & \text{if } Y^* \leq 0 \end{cases}$$

where *HD* and *HS*, as previously defined, are household demographics and household size, respectively. *EA* denotes economic variables and *ATF* denotes dummy variables for engagement in commercial fishing, presence of an active tabu area, and an interaction between them. The economic variables include whether a household engaged in commercial cropping and the natural log of household wealth. The variables of interest are contained in *ATF*, with all others included as control variables. The interaction between an active tabu area and engagement in commercial fishing is to account for the differing relationship that fishing and non-fishing households have with tabu areas.

Due to the sampling structure, errors are clustered at the village level [38,39]. In all regressions, the marginal effects are evaluated at the means of the explanatory variables unless otherwise stated. The marginal effects for the probit models are intuitive; it is the increase in probability brought about by a one-unit change (or discrete change from the base level) of the explanatory variable. In the case of the tobit models, multiple marginal effects are available. Here we were interested in the marginal effects of the explanatory variables on the censored outcome. Referring to the above forms, this would be the marginal effect on *Y* rather than *Y**, giving the change in level of agreement on the 11-point scale.

Using these models, we can establish differences between households in villages that do or do not have an active tabu area, but we cannot establish any causal conclusions on the effect of an active tabu area. Regressions were performed using Stata 15 [40], and we considered results to be statistically significant when significant at the 10% level.

¹ Many respondents responded ‘zero’ for these variables. Therefore, these variables were incremented by one before being transformed so that variables originally at zero were mapped to zero.

Table 2
Community resilience and fisheries management questions.

Results table key	Survey questions on attitudes towards the village, the environment, and LMMAs
Att 1	People in this village/community work together to solve problems.
Att 2	People in this village/community have clear roles and responsibilities for carrying out tasks.
Att 3	The village/community holds meetings to deal with issues in the village/community.
Att 4	Women are involved in making important decisions in the village/community.
Att 5	Young people are NOT involved in making important decisions in the village/community.
Att 6	The leadership of this village is NOT effective.
Att 7	I can rely on groups in this village/community for assistance when times are difficult.
Att 8	The environmental attitude of people in this community is positive.
Att 9	There is conflict within the community for marine resources.
LMMA 1	There is a high degree of consensus about the policies of the Locally Managed Marine Area (LMMA).
LMMA 2	The institutions governing the Locally Managed Marine Area (LMMA) are credible.
LMMA 3	Community members understand Locally Managed Marine Area (LMMA) rules.
LMMA 4	Community members agree with Locally Managed Marine Area (LMMA) rules.
LMMA 5	Community members comply with Locally Managed Marine Area (LMMA) rules.
LMMA 6	Community members respect those who enforce Locally Managed Marine Area (LMMA) rules.
LMMA 7	Those who enforce Locally Managed Marine Area (LMMA) rules are credible.
LMMA 8	Penalties for breaking Locally Managed Marine Area (LMMA) rules are high.
LMMA 9	Local values are compatible with the goals of the Locally Managed Marine Area (LMMA).

Note: Some statements are asked in the negative to avoid respondents blindly agreeing with all statements. Att designates attitudinal measures.

3. Results

The differences between households with and without tabu areas in terms of economic activity, diet, community attitudes and resilience are outlined below. Descriptive statistics are outlined in Table 3 and regression results in Tables 4–9.

3.1. Descriptive statistics

Median household demographics are similar between households

Table 3
Descriptive statistics for the households surveyed in Kadavu.

	No active tabu			Has active tabu		
	Median	Lower quartile	Upper quartile	Median	Lower quartile	Upper quartile
Head of household's age (years)	47.5	38	59	48	37	59
Average household age (years)	28.7	21.3	38	29.3	21.2	40.5
Highest household education (years)	12	11	12	12	11	14
Household size	3	2	4	3.5	2	5
Income (FJ\$)	6850	2600	13,800	4598	1800	9950
Fishing income (FJ\$) ^a	1590	675	9500	720	240	1877
Yaqona income (FJ\$)	600	0	2750	1422	140	3500
Remittances (FJ\$)	0	0	500	200	0	600
Wealth (FJ\$)	1928	858	23,638	3583	1555	9501
			Percentage			Percentage
Female head of household			5.60%			10.50%
Engages in commercial cropping			58.90%			81.30%
Engages in commercial fishing			34.40%			24.60%
Observations			90			256

^a Fishing income medians were restricted to households engaged in commercial fishing as the median values among all households was 0. This leaves fishing income artificially high relative to the other categories.

with and without an active tabu area (Table 3). Median incomes, remittances and wealth, however, differ between the groups. Households with no active tabu have a higher median fishing income and a lower median yaqona income than households with an active tabu, an unsurprising result since it is expected that households substitute yaqona production for fishing in the presence of an active tabu. Median overall income is lower and median wealth is higher in villages with no active tabu. As expected, the proportion of households engaged in commercial fishing is higher where there is no active tabu, whereas the proportion of households engaged in commercial cropping is higher where there is an active tabu.

As a precursor to our main results, we emphasise that we cannot establish the causal effect of tabu areas given the limitations of our data. In particular, our main findings are at risk of suffering from reverse causality, whereby the implementation of a tabu area occurred because of some difference in one of the response variables, rather than the implementation of a tabu area causing the difference to precipitate. Hence, we focus on whether or not differences exist and leave claims of causal implications aside.

3.2. Economic activity

Using the rich, multivariate regression framework described above, Table 4 shows that there is a statistically positive correlation between the presence of a tabu area and income from yaqona sales (i.e., yaqona incomes are statistically higher among households in villages with active tabu areas). Differences in yaqona incomes and remittances for the average household are statistically significant, with both being higher for average households in the presence of an active tabu area. Note that a significant marginal effect should not imply a causal impact of an active tabu area either here or among the remaining results; instead, it simply indicates that the difference between average households is statistically significant. An insignificant coefficient but a significant marginal effect for remittances indicates that the correlation between an active tabu area and remittances is stronger for the average household, but not notable for households further from the average. The probability that a household engages in commercial cropping is statistically higher in areas with an active tabu; this probability is 23.5% points higher for the average household. There is no significant difference in the probability that a household engages in commercial fishing between households with and without an active tabu area.

Table 4
Household economic indicators (tobit model) and commercial activity (probit model).

	ln(Income)	ln(Fishing Income)	ln(Yaqona Income)	ln(Remittances)	ln(Wealth)	Pr(Cropping) ^a	Pr(Fishing) ^a
Demographics ^b	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Has active tabu	-0.156 (-0.86)	-2.215 (-1.37)	2.334* (1.73)	1.755 (1.59)	0.253 (0.72)	0.702** (2.13)	-0.253 (-1.17)
Constant	7.589*** (9.80)	6.688* (1.78)	4.148* (1.67)	-4.753* (-1.86)	5.200*** (7.17)	0.324 (0.52)	0.615 (1.03)
Marginal effects at means							
Has active tabu	-0.156 (-0.86)	-0.796 (-1.34)	1.877* (1.92)	1.126* (1.74)	0.253 (0.72)	0.235* (1.87)	-0.0852 (-1.17)
Observations	346	346	346	346	346	346	346

t and z statistics in parentheses.

*p < 0.10, **p < 0.05, ***p < 0.010.

^a Refers to the probability of engaging in commercial cropping or commercial fishing.

^b Demographic control variables include head of household’s age, average household age, highest household education, head of household gender, and household size; “Yes” indicates that these variables were included in the regression.

Table 5
Household diets (probit model).

	Pr(Grown crop)	Pr(Protein source)	Pr(Fish)	Pr(Meat)	Pr(Kava)
Demographics ^a	Yes	Yes	Yes	Yes	Yes
Has active tabu	0.810*** (3.09)	-0.435 (-1.54)	-0.476* (-1.69)	0.0660 (0.25)	0.216 (1.07)
Constant	0.161 (0.25)	0.996* (1.79)	0.453 (0.96)	-0.898 (-1.58)	-0.243 (-0.46)
Marginal effects at means					
Has active tabu	0.197** (2.50)	-0.106* (-1.73)	-0.164* (-1.85)	0.0174 (0.25)	0.0855 (1.07)
Observations	346	346	346	346	346

z statistics in parentheses.

*p < 0.10, **p < 0.05, ***p < 0.010.

^a Demographic control variables include head of household’s age, average household age, highest household education, head of household gender, and household size; “Yes” indicates that these variables were included in the regression.

3.3. Household diet

The probabilities of consuming easily grown crops and consuming fish have significant coefficients and significant marginal effects where there is an active tabu area (Table 5). In villages with an active tabu area, the probability of consuming an easily grown crop is higher by 19.7% points and the probability of consuming fish is lower by 16.4% points. Active tabu areas have no significant coefficients for the probability that a household consumes a protein source, meat, or kava. The

Table 6
Household village and environmental attitudes (tobit model).

	Att 1	Att 2	Att 3	Att 4	Att 5	Att 6	Att 7	Att 8	Att 9
Demographics ^a	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Commercially crops	1.047** (2.01)	0.281 (0.57)	0.676 (0.94)	0.669 (1.05)	-0.102 (-0.09)	-0.469 (-0.45)	1.182 (1.58)	-0.0163 (-0.03)	0.189 (0.20)
Commercially fishes	0.973 (1.00)	-0.259 (-0.22)	0.319 (0.29)	1.288* (1.89)	-2.849*** (-3.12)	0.167 (0.12)	-0.148 (-0.13)	0.221 (0.14)	0.117 (0.13)
Has active tabu area	0.814 (1.08)	0.420 (0.64)	1.597* (1.86)	-0.0255 (-0.04)	-0.375 (-0.29)	0.871 (0.77)	0.438 (0.47)	0.736 (0.67)	2.388*** (2.66)
Commercially fishes & has active tabu	0.428 (0.38)	1.715 (1.27)	0.194 (0.15)	-1.520 (-1.53)	2.519 (1.64)	-3.663** (-2.02)	1.666 (1.07)	1.451 (0.88)	-1.757 (-1.52)
ATF F-statistic	1.192	3.803*	1.543	2.437	1.668	2.112	2.841*	2.865*	0.282
p-value	0.276	0.0520	0.215	0.119	0.197	0.147	0.0928	0.0914	0.596
Observations	346	346	346	346	346	346	346	346	346

t statistics in parentheses.

*p < 0.10, **p < 0.05, ***p < 0.010.

^a Demographic control variables include head of household’s age, average household age, highest household education, head of household gender, household size, and the natural log of household wealth; “Yes” indicates that these variables were included in the regression.

marginal effect of having an active tabu area is significant for the probability of consuming a protein source, indicating that where there is an active tabu, the average household has a lower probability of consuming a protein source of 10.6% points. Like remittances, this suggests that the correlation between active tabu areas and protein consumption is stronger for the average household relative to households further from the average.

3.4. Household attitudes

Community resilience results are outlined in Tables 6 and 7 (the definitions of the variables are listed in Table 2). We include a joint interaction variable “Commercially fishes & has active tabu” to define the joint effect of being a household engaged in commercial fishing where there is an active tabu area. A Wald test assesses the statistical difference (labelled as ATF F-statistic and associated p-value) in level of agreement between fishing households with no active tabu area and fishing households with an active tabu area. Table 7 shows the calculated marginal effects of an active tabu area with respect to average non-commercial fishing and commercial fishing households. Fig. 3 shows the distribution of responses among households for community resilience.

Among commercial fishing households, those with active tabu areas have higher levels of agreement with the following statements: “People in this village/community have clear roles and responsibilities for carrying out tasks” (Att 2); “I can rely on groups in this village/community for assistance when times are difficult” (Att 7); and “The environmental attitude of people in this community is positive” (Att 8) (Table 6, ATF F-statistic). For the average commercial fishing household, agreement with these statements is about one point higher on the scale of agreement when in the presence of an active tabu area (Table 7). These results

Table 7
Marginal effects of active tabu areas on household village and environmental attitudes (tobit model).

	Att 1	Att 2	Att 3	Att 4	Att 5	Att 6	Att 7	Att 8	Att 9
Doesn't commercially fish	0.426 (1.06)	0.232 (0.62)	0.613* (1.76)	-0.0144 (-0.04)	-0.186 (-0.28)	0.446 (0.77)	0.226 (0.47)	0.463 (0.64)	1.234*** (2.70)
Commercially fishes	0.496 (1.01)	1.037* (1.75)	0.624 (1.11)	-0.798 (-1.61)	0.953 (1.30)	-1.271 (-1.43)	1.017* (1.72)	1.163 (1.48)	0.307 (0.53)
Observations	346	346	346	346	346	346	346	346	346

Marginal effects; *t* statistics in parentheses.

p* < 0.10, *p* < 0.05, ****p* < 0.010.

Table 8
Household attitudes toward locally managed marine areas (tobit results).

	LMMA 1	LMMA 2	LMMA 3	LMMA 4	LMMA 5	LMMA 6	LMMA 7	LMMA 8	LMMA 9
Demographics ^a	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Commercially crops	-0.961 (-0.71)	-0.311 (-0.29)	-0.559 (-0.54)	-0.493 (-0.50)	-0.569 (-0.58)	-0.735 (-0.77)	-0.475 (-0.51)	-3.580** (-2.51)	-0.560 (-0.53)
Commercially fishes	2.635** (2.35)	1.558 (1.53)	1.599 (1.53)	1.449 (1.44)	1.372 (1.14)	1.658** (2.38)	1.708** (1.98)	-3.529** (-2.55)	2.077* (1.71)
Has active tabu area	5.430** (2.48)	3.178* (1.81)	3.407** (2.09)	3.614** (2.06)	2.202 (1.23)	3.342** (2.41)	1.307 (0.80)	-0.646 (-0.32)	2.633 (1.47)
Commercially fishes & has active tabu	0.166 (0.12)	-1.080 (-0.76)	-0.0852 (-0.07)	0.204 (0.18)	0.327 (0.20)	-1.083 (-0.94)	-1.600 (-1.14)	6.953*** (3.61)	-0.367 (-0.28)
ATF <i>F</i> -statistic	7.795***	1.762	4.384**	6.198**	2.514	3.092*	0.0340	11.88***	1.459
<i>p</i> -value	0.00554	0.185	0.0370	0.0133	0.114	0.0796	0.854	0.000638	0.228
Observations	346	346	346	346	346	346	346	346	346

t statistics in parentheses.

p* < 0.10, *p* < 0.05, ****p* < 0.010.

^a Demographic control variables include head of household's age, average household age, highest household education, head of household gender, household size, and the natural log of household wealth; "Yes" indicates that these variables were included in the regression.

Table 9
Marginal effects of active tabu areas on household attitudes toward LMMAs (tobit model).

	LMMA 1	LMMA 2	LMMA 3	LMMA 4	LMMA 5	LMMA 6	LMMA 7	LMMA 8	LMMA 9
Doesn't commercially fish	2.576** (2.40)	1.864* (1.83)	2.129** (2.07)	2.168** (2.00)	1.376 (1.24)	2.279** (2.48)	0.855 (0.81)	-0.275 (-0.31)	1.572 (1.44)
Commercially fishes	1.900** (2.48)	1.139 (1.35)	1.685* (1.90)	1.796** (2.27)	1.388 (1.61)	1.414* (1.77)	-0.182 (-0.18)	2.628*** (3.70)	1.021 (1.10)
Observations	346	346	346	346	346	346	346	346	346

Marginal effects; *t* statistics in parentheses.

p* < 0.10, *p* < 0.05, ****p* < 0.010.

suggest that among commercial fishing households, those with active tabu areas believe their communities are better organised, more reliable, and view the environment more positively. The marginal effect of an active tabu area is not significant for Att 8, suggesting a weaker correlation with active tabu areas for the average commercial fishing household (Table 7). Across households the responses to Att 2 and Att 8 were consistent, with most households agreeing or strongly agreeing. Responses to Att 7 were more heterogeneous, however, with nearly 10% of respondents strongly disagreeing and nearly 40% of respondents strongly agreeing (Fig. 3).

For households in villages with no tabu area, those that commercially fish have significantly higher agreement with "Women are involved in making important decisions in the village/community" (Att 4), and have significantly lower levels of agreement with "Young people are NOT involved in making important decisions in the village/community" (Att 5) than those that do not commercially fish (Table 6). This finding implies that, among households with no tabu area, commercial fishing households believe their communities are more inclusive; among households with a tabu area, we see no difference between commercial fishing and non-commercial fishing households. The responses to Att 5 were more varied than for Att 4, with 12% of respondents strongly agreeing and 41% strongly disagreeing (Fig. 3).

Households in villages with active tabu areas have significantly greater agreement with "The village/community holds meetings to deal with issues in the village/community" (Att 3) and "There is conflict within the community for marine resources" (Att 9) (Table 6). As the ATF *F*-statistics are insignificant for Att 3 and Att 9, this difference is only present among non-commercial fishing households (Table 6). This result suggests that non-commercial fishing households with tabu areas believe their communities are more collaborative when dealing with issues but also perceive greater challenges around their marine resources, relative to non-commercial fishing households without a tabu area. That this perception of increased conflict is not present for commercial fishing households could indicate a failure of engagement with non-commercial fishing households about tabu areas. Of all the community resilience statements, responses to Att 3 were the most consistent, with over 60% of respondents strongly agreeing. Responses to Att 9 were more varied, with most households believing there was no conflict within the community around the management of marine resources, but with others disagreeing (Fig. 3).

Commercial cropping households have higher levels of agreement with "People in this village/community work together to solve problems" (Att 1). One interpretation of this is that there is more collaboration between those who farm as opposed to those who do not. This

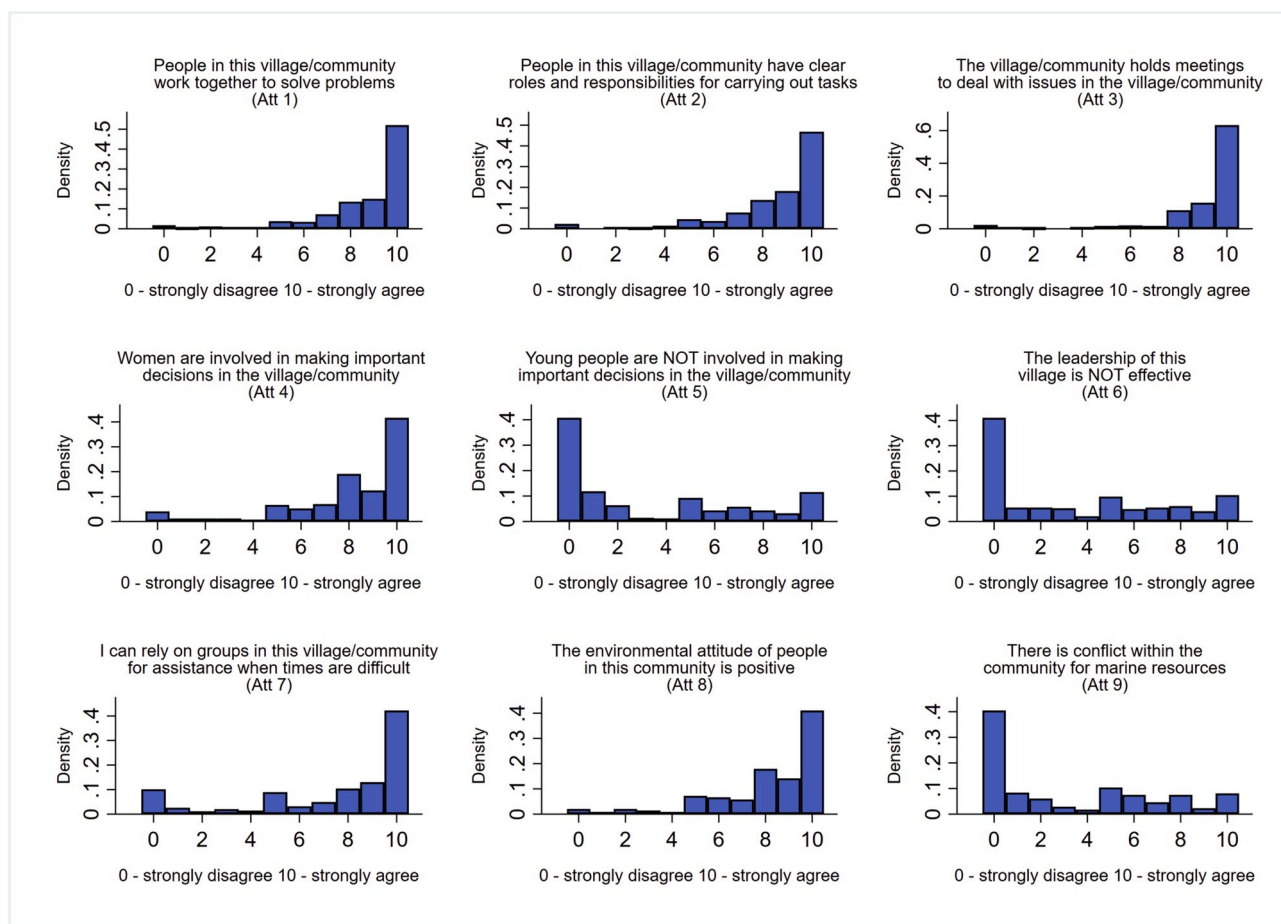


Fig. 3. Distribution of household attitudes toward the village and the environment.

result could be related to households helping each other to address challenges like controlling weeds and pests.

3.5. Household attitudes toward LMMAs

Household attitudes towards LMMAs are outlined in Table 8, with Table 9 showing the calculated marginal effect of an active tabu area with respect to commercial fishing and non-commercial fishing households. Fig. 4 shows the distribution of responses to each statement. The ATF F-statistic, as above, is to ascertain whether there is a statistical difference between households that commercially fish in villages with and without active tabu areas.

Households with an active tabu area have statistically higher agreement with the statements “There is a high degree of consensus about the policies of the LMMA” (LMMA 1) and “Community members respect those who enforce LMMA rules” (LMMA 6). Agreement with these statements for the average household is anywhere from 1.4 to 2.6 points higher when in the presence of an active tabu area, with the greatest differences for non-commercial fishing households (Table 9). Among households with no active tabu area, those engaged in commercial fishing also have higher agreement with these statements (Table 8). Responses to LMMA 1 are consistent, with nearly 60% of respondents in strong agreement and 78% of all respondents agreeing or strongly agreeing. Responses to LMMA 6 were less consistent, with a small but noticeable number of households strongly disagreeing with the statement (Fig. 4).

Households in villages with an active tabu area have statistically higher levels of agreement with the statements “Community members understand LMMA rules” (LMMA 3) and “Community members agree

with LMMA rules” (LMMA 4) for both those that do and do not commercially fish. Average households in villages with active tabu areas have higher levels of agreement with LMMA 3 and LMMA 4 by 1.7–2.2 points on the scale of agreement (Table 9). This finding suggests that households in villages with active tabu areas generally view LMMA rules more favourably. For non-commercial fishing households, those with active tabu areas have statistically higher agreement for the statement “The institutions governing the LMMA are credible” (LMMA 2) (Table 8), relative to those with no active tabu areas. The average non-commercial fishing household has a level of agreement that is 1.9 points higher when in the presence of an active tabu area (Table 9). This finding implies that non-commercial fishing households with active tabu areas believe LMMA governance is more credible relative to non-commercial fishing households with no active tabu areas. Household responses to LMMA 2, LMMA 3 and LMMA 4 were relatively consistent (Fig. 4).

Households located in villages with no active tabu areas and who commercially fish have significantly higher agreement with “Those who enforce LMMA rules are credible” (LMMA 7) and “Local values are compatible with the goals of the LMMA” (LMMA 9) relative to households that do not fish commercially (Table 8). For households in villages with active tabu areas, only LMMA 9 has statistically higher levels of agreement among households who fish commercially.² This finding suggests that commercial fishing households have more positive views of LMMA goals and that, among households with no active tabu areas, commercial fishing households believe LMMA enforcers to be more

² This result is not present in the tables but is determined by a Wald test similar to the ATF F-statistic.

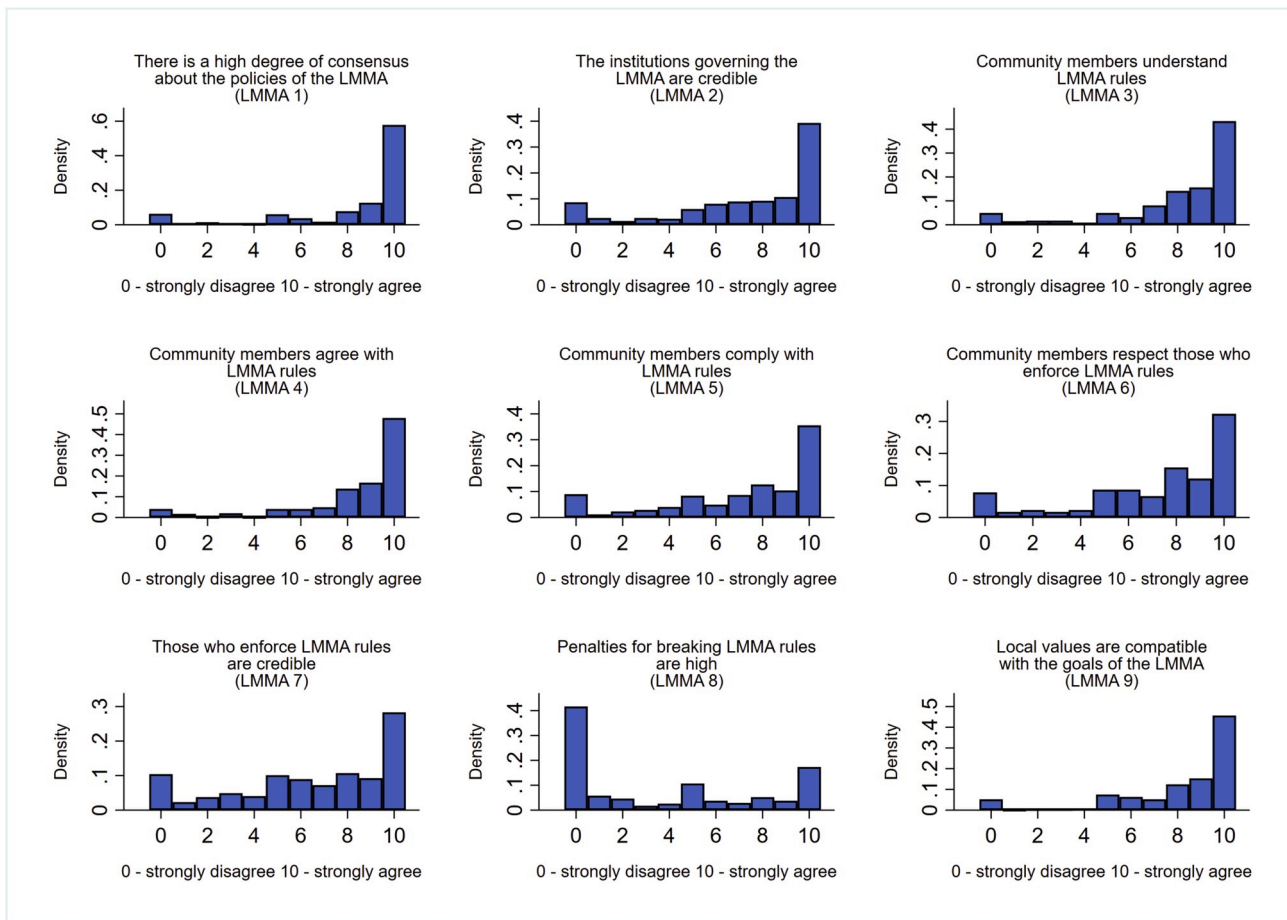


Fig. 4. Distribution of household attitudes towards LMMAs.

credible, with this difference in belief disappearing for households in villages with active tabu areas. Household responses to LMMA 7 were highly variable, while the responses to LMMA 9 were quite homogeneous (Fig. 4).

Overall, households that commercially fished and cropped have statistically lower levels of agreement with the statement “Penalties for breaking LMMA rules are high” (LMMA 8). However, households located in villages with active tabu areas and who fish commercially believed that the penalties were high. It is not surprising that those who would be most impacted by the penalty would believe the penalty was high (Table 8). Average commercial fishing households have levels of agreement that are 2.6 points higher for LMMA 8 when in the presence of an active tabu area (Table 9). The household responses were highly variable for LMMA 8, with 42% of respondents strongly disagreeing and 16% strongly agreeing (Fig. 4). There were no significant relationships for “Community members comply with LMMA rules” (LMMA 5) (Table 8).

4. Discussion

Establishing MPAs that do not allow extractive use increases marine biodiversity and replenishes fisheries [41]. Given the important link between the socio-economic impacts of an MPA and its effectiveness and longevity, understanding the socio-economic differences between Kadavu villages with and without active tabu areas can help shed light on the effectiveness of tabu areas and, more broadly, their implementation within an LMMA context.

As noted earlier, our findings are not of a causal nature but are instead correlative. Hence, we remain open to reverse causality and

assume that it may underlie observed differences among households with and without tabu areas.

We find that households in villages with an active tabu area disproportionately engage in other commercial activities; for Kadavu, this activity is yaqona production. The engagement in other commercial activities can be beneficial from the village perspective; the village wide impact of natural disasters can often be mitigated by having diverse income streams. We also find that overall levels of income and wealth do not differ between households with and without active tabu areas. The finding regarding engagement in other commercial activities is consistent with that of Leisher et al. [23]; who found that villages with active tabu areas had higher levels of non-fishing income. However, Leisher et al. also found that higher overall levels of income and wealth were associated with households with an active tabu area, whereas we find no statistical difference in wealth or overall income between households in villages with and without active tabu areas. In the villages studied by Leisher et al., the close proximity to Suva (Fiji’s capital city) provided a number of alternative income opportunities. In Kadavu, there is no large metropolitan area and therefore limited alternative income sources. An implication of this finding is that tabu areas appear to present fewer constraints in the presence of alternative income sources, especially those that are not restricted by the tabu and increase in line with marine conservation such as tourism and research.

The absence of a relationship between active tabu areas and commercial fishing activity and fishing income is somewhat surprising. *A priori*, we expect more commercial fishing in villages without active tabu areas. This result may be driven by the noted spill-over impacts of tabu areas [42,43]: even though fishing can no longer occur in a section of the fishing ground, the spill-over impact may increase fishing yield in the

rest of the fishing ground. Both the probability of households commercially fishing and fishing incomes are similar to those villages without a tabu area. These findings are relevant when deciding to implement a tabu area in a community that relies heavily on commercial fishing; if tabu areas do not degrade fishing incomes, then conservation objectives can be achieved in conjunction with the village not suffering severe economic consequences.

Households located in villages with active tabu areas consume greater amounts of easily grown crops and consume less fish. This finding runs counter to those of Leisher et al. [23] and Aswani and Furusawa [44]; who found higher fish consumption in villages with active tabu areas. However, this result may stem from reverse causality; that is, it is possible that villages that consume less fish are more likely to implement active tabu areas given the relatively lower impact these tabu areas would have on villager diets as opposed to the implementation of active tabu areas causing a village to consume less fish.

Commercial fishing households in villages with active tabu areas believe that they have greater clarity around roles and responsibilities, feel that their communities could be relied upon to help in times of need, and have more positive views of the environment. From these findings, a possible inference is that villages with better organisation, social safety nets and appreciation of the environment are more likely to implement tabu areas. If such relationships exist, increasing uptake of tabu areas could be achieved by helping communities define roles and responsibilities more clearly, extend their social safety nets, and increase environmental awareness.

Households that are located in villages with an active tabu area but do not fish commercially report that their communities hold more meetings to deal with issues and that there is greater conflict within their communities for marine resources. Since households that commercially fish do not perceive greater conflict, it could be that non-commercial fishing households simply perceive a greater conflict when there is an active tabu area rather than the conflict for marine resources actually being greater. It would also be expected that managing an active tabu area is likely to require more village meetings. Given that such discussions focus on a resource that impacts commercial fisherman, their perception of the number of meetings is likely to differ from those whose livelihoods are not dependent on the resource. The perception of increased conflict within the community for marine resources aligns with the work of Bennett and Dearden [21]; who found similar perceptions of inter-community conflict within marine reserves. This result could have implications for the ongoing management of marine resources and community harmony; too much time spent managing the resource may lead households to push for the tabu status to be removed. Additionally, explaining to non-commercial fishing households why implementing and maintaining a tabu area neither indicates nor leads to increased conflict could help achieve greater uptake and sustainability of tabu areas.

All households in villages with active tabu areas believe that their communities are in greater agreement and have a better understanding of LMMA policies and rules. They also believe that their communities have more respect for those enforcing LMMA rules. These findings suggest that active tabu areas are not detrimental to the communities' understanding and agreement with the LMMA, supporting the notion that having tabu areas is unlikely to damage the success and longevity of the LMMA.

The existence of a positive relationship between commercial fishing households and the belief that local values are compatible with LMMA goals could be born out of local stakeholder engagement that is central to the LMMA philosophy. It would be expected for commercial fishing households to be heavily involved in deciding what the goals of the LMMA are, more so than non-commercial fishing households. This relationship would support the notion that engaging the local community in the functioning and design of their LMMA is essential for uptake and sustainability of the LMMA.

We find a striking difference in perceptions of the severity of

penalties for breaking LMMA rules among households who fish commercially. Commercial fishing households in villages with active tabu areas consider penalties to be high, whereas commercial fishing households in villages without an active tabu area do not.

5. Conclusions

MPAs (and LMMAs) are an important marine conservation tool. While there is evidence of the benefits of MPAs on marine resources, there is less information on the socio-economic impacts of MPAs. In particular, both the statistical framework and the quality and breadth of collected data have been lacking in this area, especially with reference to the social outcomes of imposing bans on extractive use in certain areas.

Our research quantitatively explores the socio-economic differences between communities with and without active tabu areas in their LMMA in the province of Kadavu in Fiji. We find there are differences in economic activity and diet between the communities but little difference in overall income and wealth. Our study shows that villages with an active tabu area have more positive social outcomes around perceptions of LMMAs. However, there are some notable negative social outcomes as well. In particular, we find that households not engaged in commercial fishing perceive conflict around the management of marine resources. We also find that households engaged in commercial fishing believe penalties for violating LMMA rules are high. Together, these results could impede the adoption of LMMAs and tabu areas.

Our survey results indicate that tabu areas are neither detrimental nor beneficial from an economic or social perspective. We cannot establish any causal implications, however, because we have no data on villages before they implemented tabu areas. Determining the causal impacts of tabu areas would be useful and is a potential area for further research. Indeed, our survey data could provide the comprehensive baseline data needed to look at causal relationships for those villages that establish an LMMA in the future.

Our analysis is only able to look at the presence or absence of a tabu area: we are not able to explore any links between tabu size and socio-economic outcomes. We are similarly unable to analyse other types of tabu area, such as rotational or periodic fishing bans. These additional aspects could provide some valuable insights into potential trade-offs that may arise with size and type of a tabu area. An analysis on tabu failure is also a worthwhile venture given the importance of maintaining no take areas for restocking but is also not possible with our available data. The potential findings of such analyses could aid in the design of LMMAs to best suit community needs while also meeting conservation goals.

An important relationship for future consideration is that between the presence of a tabu area and health outcomes of villagers. Although touched upon here through the correlation between probability of consuming different sources of food and presence of a tabu area, we again cannot establish any causal effects. In addition, our survey questions were not detailed enough relative to diet and health for us to say anything meaningful about this relationship. In any case, future work that extends on our questions around diet and health could, in conjunction with our current data, allow for a better exploration of this topic.

The use of MPAs, and more specifically LMMAs, is likely to increase given the greater recognition of marine resource degradation, the need for greater marine conservation, and the perceived and demonstrated benefits of the LMMA model. Often the burden of such marine conservation falls on developing communities, the villages of Kadavu being a prime example. It is therefore important to determine whether these marine conservation tools impose undue harm, confer lasting benefits, or land somewhere in the middle. The findings presented here should help to answer this question.

CRedit authorship contribution statement

Thomas Robertson: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing. **Suzie Greenhalgh:** Conceptualization, Investigation, Writing - review & editing, Supervision, Project administration, Funding acquisition. **Isoa Korovulavula:** Supervision, Project administration, Funding acquisition. **Tomasi Tikoibua:** Investigation. **Pio Radikedike:** Investigation. **Philip Stahlmann-Brown:** Conceptualization, Methodology, Investigation, Writing - review & editing, Supervision, Project administration.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.marpol.2020.103950>.

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