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Article

Assessing Indicators and Limitations of Food Security Objectives in Coral Reef Restoration

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Abstract

Coral reef restoration is often presented as a marine conservation solution that provides 'win-win' outcomes. However, most studies on reef restoration have focused on the biological success, while little is known about whether social objectives are ever achieved. This study investigates a reef restoration initiative in the Spermonde archipelago, Indonesia, where food security was initially presented as an intended social outcome. We utilised an ethnographic mixed-methods approach to investigate: 1) perceived sociocultural benefits of coral restoration to the local community; 2) impacts of reef restoration on local food security; and 3) local sociocultural barriers and limitations of reef restoration as a mechanism for improving food security. We found fish contributed to food security primarily as an income source to purchase food. Local people mainly valued nearby reefs for storm protection. Furthermore, most fishers are organised through patron-client systems that target pelagic species; therefore they currently have minimal dependency on adjacent reefs. However, fishing restrictions linked to the restoration programme still negatively impacted both pelagic fishers and a small population of reef-based fishers—indirectly by damaging reciprocal fishing relations with neighbouring islands and directly by limiting access to local reefs. Complex social and trade networks associated with patron-client networks present potential barriers for transitioning to reef-based fisheries and eradicating the use of destructive fishing gear, therefore limiting access to potential food security benefits generated from reef restoration. These findings show that the relationship between coral restoration and food security is tenuous and cannot be assumed. These findings also demonstrate that social dynamics surrounding community-based conservation initiatives are complex and context-dependent, and such details must be considered when designing marine habitat restoration initiatives.

Keywords: development, sustainability, Indonesia, COREMAP, marine protected areas, coral reef restoration, food security

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INTRODUCTION

With anthropogenic stressors on the rise, coral cover is rapidly declining across the globe (De'ath et al. 2012). The decline of coral reefs and their ecosystem services has led to a rise in advocacy for and implementation of intervention strategies designed to conserve and restore remaining reefs (Anthony et al. 2017). Coral restoration in particular has gained recent

popularity as a supplementary conservation strategy (Gardner et al. 2003). Coral restoration is the process of assisting coral ecosystem recovery from disturbances to a state where their structure and function is self-sustaining (Suding 2011).

Despite its growing popularity, coral restoration is still in its infancy; and there are few established indicators of measuring effectiveness— a knowledge gap for which practitioners have been criticised (Hein et al. 2017). To date, success is predominantly evaluated by changes in ecological function, although most coral restoration programmes have socio-economic and/or sociocultural objectives explicitly included. Moreover, local stakeholders have been found to perceive greater value in sociocultural benefits rather than ecological ones (Hein et al. 2019). sociocultural benefits are related to the ecosystem services provided by coral reefs, including food security, alternative livelihoods, increased educational opportunities, stewardship building, maintenance of well-being, cultural identity, place attachment, aesthetics, and pride in resource conditions (Kittinger et al. 2012; Frey and Berkes 2014; Hesley et al. 2017; Muir et al. 2017; Hein et al. 2019). Ensuring that restoration efforts result in locally perceived sociocultural benefits is critical to the long term support and success of restoration programmes. Successfully providing such benefits is often linked to improved community support and project design—invaluable attributes of well-managed and successful conservation programmes (Mahajan and Daw 2016; Trialfhianty and Suadi 2017). Previous studies have also demonstrated that programmes that do not acknowledge the importance of sociocultural benefits often fail at achieving conservation objectives (West 2006; Waylen et al. 2010).

This study examines a coral restoration initiative in the Spermonde islands of Indonesia, where food security was presented as an intended social outcome. We evaluated, 1) perceived sociocultural benefits of coral restoration in the local community; 2) local values concerning coral reef ecosystems; 3) impacts of coral restoration on local food security; and 4) sociocultural barriers and limitations of coral restoration as a mechanism for improving local food security.

We draw on concepts from natural-cultural systems analysis to highlight power relations, cultural beliefs, and values in human environment systems—factors that have previously been identified as strongly influential on food security outcomes of marine conservation programmes (Kamat and Kinshella 2018) and are often ignored when other interdisciplinary approaches such as social-ecological systems are applied (Dacks et al. 2019; Cote and Nightingale 2011). A natural-cultural framework integrates complex histories of gender, race, class, sexuality, and national identity that shape local ideas of nature and the natural (Subramaniam 2014). Furthermore, this framework aims to acknowledge external linkages and drivers that occur at different scales. Berkes (2002) emphasises that local resource commons and management systems are embedded in and affected by regional, national and global influences, and that failure to recognise these linkages is a central reason for some unsuccessful natural resource management interventions and the persistence of resource degradation.

Our study highlights the importance of understanding the locally-perceived sociocultural benefits of coral reefs and coral restoration and the social complexities of realising these benefits in small island communities prior to establishing project goals. We also provide ethnographic evidence of social and political barriers to improved food security through coral restoration within the Spermonde context. Furthermore, our findings suggest that coral restoration initiatives within this specific context may actually lead to further food insecurity. In the sections that follow, we present some contextual background and key concepts followed by a description of the study site and the methodology used to gather and analyse the data.

BACKGROUND

Sociocultural indicators and food security

Initiatives that adopt culturally-grounded indicators based on local ecological and sociocultural factors and their interrelationships may lead to more effective local action and improved human and ecosystem resilience (Sterling et al. 2017b). However, developing locally-appropriate indicators has proven to be a major challenge for resource managers, policymakers and scientists alike (Breslow et al. 2017). To develop culturally-grounded sociocultural indicators, conservation or natural resource management programmes must begin with and build on local cultural perspectives, including values, knowledge, and needs; and develop an understanding of the feedbacks between ecosystems and human well-being (Fabinyi et al. 2017; Sterling et al. 2017b). Few studies have focused on developing and testing locally-appropriate sociocultural indicators, and often evaluate social factors through easily-quantifiable socio-economic indicators such as material assets or social capital that may be inadequate or inappropriate for a particular local context (Dacks et al. 2019). Adoption of inappropriate or inadequate indicators may result in irrelevant or disruptive actions on the local scale (Jupiter 2017; Sterling et al. 2017a). In this article we focus on how food security is a particularly difficult domain to measure and evaluate within the context of marine conservation (Kamat 2014).

The relationship between food security and coral restoration remains tenuous, yet restoration programmes, along with many marine conservation programmes, identify improved food security as an intended social outcome. Food security is inherently complex with a range of mediating factors; however, the most agreed upon definition is: 1) availability of consistent and sufficient quantities of food; 2) access to appropriate and sufficient food; and 3) consumption or appropriate use of basic nutrition and food preparation (World Food Programme 2009). Given this complexity, ethnographic, culturally-grounded information is necessary to evaluate food security at local scales (Barrett 2010).

To the best of our knowledge, no previous studies have evaluated the effect coral restoration has on the food security of local communities, but other studies have looked at the impacts of marine protected areas (MPAs). Coral restoration is typically implemented as a supplementary strategy for MPAs, and like coral restoration, MPA's are often intended to increase fish

biomass, leading to greater local fishing yields adjacent to MPAs and therefore improved local food security. Marine resources contribute to food security directly, as an important source of animal protein and micro-nutrients, and indirectly, by providing livelihoods and income that enables fishers to purchase food (Barrett 2010; Foale et al. 2013). Some studies found that MPAs led to improved food security and nutrition (Aswani and Weiant 2004; Aswani and Furusawa 2007). In other cases, MPAs were found to have negligible effects (Gjertsen 2005; Darling 2014), or even adverse effects on household food security (Neumann 2006; Mundy et al. 2014; Moshy et al. 2015). These divergent findings point to the significance of the socio-economic, regional, and ethnographic context where MPAs are established and the local context of food security (Kamat and Kinshella 2018). Contextual factors, therefore, affect how MPAs, and by extension coral restoration sites, influence food security, and such factors should be considered when assessing success.

Case study context

This study took place in the Spermonde archipelago of Indonesia, located in the centre of the Coral Triangle, a region known to have the highest coral and fish diversity on earth (Sanciangco et al. 2013). The Spermondes are composed of approximately 180 coral islands and are located approximately 60 km off the coast of Makassar, the capital city of South Sulawesi (Figure 1). Fifty-four of these islands are densely populated. Island residents rely upon fishing as the dominant livelihood with an estimated 6,500 fishing households in the region (Pet-Soede et al. 1999). Most fishers are employed through a patron-client fishery system, locally termed "*pa'gai*." Similar patron-client systems are widespread throughout the Spermonde and are characterised as hierarchical wage-labour systems where *pungawwa* (*pungawwa*=patrons) provide fishing gear, boats, access to markets, and loans to their *sawi* (*sawi*=fisher/crew) (Ferse et al. 2012; Ferse et al. 2014). Locally-caught fish are the primary animal protein in these communities and most other foods are imported from mainland Sulawesi.

Starting in the late 1960s, this region experienced rapid economic growth through the introduction of commercial fishing operations. Under the New Order regime in Indonesia, agricultural and fishing practices transitioned from providing resources for local consumption to producing commodities that could be sold at a global scale.[1] Within the Spermonde context, this transition was characterised by the adoption of more selective and destructive fishing practices and gear types, resulting in a less diverse fishery, depletion of select commercial species, degradation of coral, and a wage-labour system, wherein fishers worked to support a global economy, in which they gained minimal economic benefit (Gorris 2016). Similar to case studies in northern Sulawesi, Borneo, and mainland Malaysia where small-scale farming was replaced by plantation-style wage labour cocoa and rubber farming, the introduction of capitalist-driven, industrialised resource exploitation practices to the Spermonde resulted in the deepening of inequality and poverty in local communities and the degradation of local marine environments (Scott 1985, 1999; Tsing 1993; Dove 2011; Li 2014).

To address some of these local social and environmental problems stemming from rapid development in the region, various social development and conservation programmes were established. Most notably, the Coral Reef Rehabilitation and Management Project (COREMAP) was designed and implemented as a programme aimed at achieving both conservation and development objectives. COREMAP, implemented through the Ministry of Marine Affairs and Fisheries of Indonesia, is the largest MPA programme in Indonesia and is one component of Indonesia's execution of the regional Coral Triangle Initiative (Glaser et al. 2010). In the Spermonde islands, efforts were focused on establishing community-based initiatives, such as locally-managed MPA's, grant-supported alternative livelihoods, and coastal resilience infrastructure. Despite extensive efforts, many COREMAP-established MPA's remain unenforced, alternative livelihoods poorly adopted, and other management strategies typically neglected once COREMAP representatives left the host communities (Glaser et al. 2010; Ferse et al. 2014). Ultimately, the greatest barriers to achieving targeted marine conservation and development goals stemmed from challenges linked to lack of equitable collaboration and engagement with local communities and the inability to incorporate existing trade and social networks into conservation management strategies (Radjawali 2012).

The coral restoration programme we document here began in July 2017, posed as a dual conservation and development initiative designed by a large multinational corporation that sources resources within Indonesia. The programme is part of a larger company-wide sustainability initiative. At the time of its inception, the publicly-stated objectives of the coral restoration programme were to conserve and restore the biodiversity of local coral reefs, while simultaneously improving the food security of the local community through increased fishing yields and improved marine management.[2] The programme employs a community-based model where community members are paid to partake in the coral transplantation process and to guard the restoration site. Community members tie coral fragments to hexagonal-shaped steel structures, termed 'spiders', that are then deployed by trained divers to designated restoration sites around the island. On average, deployment events occur once per month during the dry season, employing around 36 local men and deploying 550 spiders in areas 1,000 sq. m over a 3-day period. Those who participated mainly did so as a supplementary source of income for 1-3 days per month. On average, compensation is comparable to a typical day's wage as a fisherman in the community (USD5-7). Two coral guards are also employed by the company to enforce the MPA that was designated by COREMAP and fishing restrictions on destructive gear.

MATERIALS AND METHODS

Community data collection and sampling

Our team is conducting an ongoing study of the programme and local village, hereafter referred to as the 'restoration

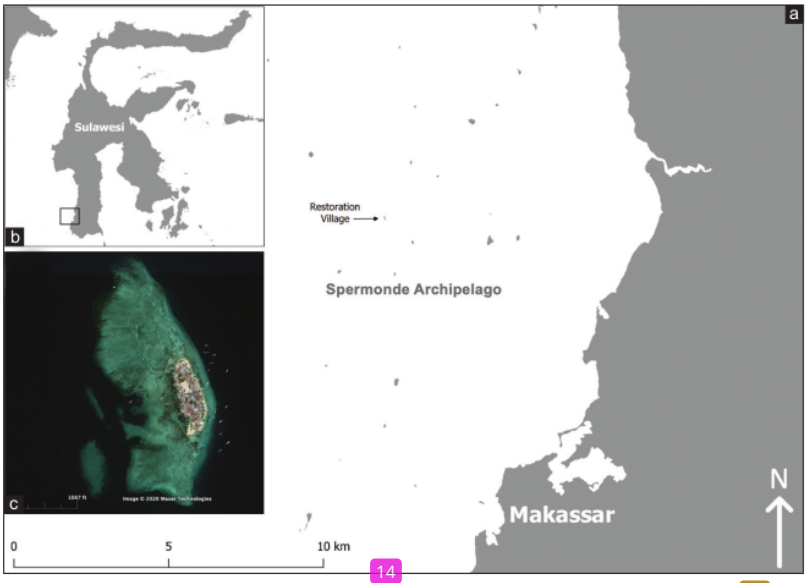

Figure 1

(a) Map of the Spermonde Archipelago in South Sulawesi, showing the Restoration Village and the city of Makassar (b) Regional map of Indonesia indicating the location of the Spermonde archipelago (c) Aerial image of the Restoration Village (Source: GoogleEarth)

village'. What is described here is based on data collected between December 2016 and July 2018. All 185 households in the restoration village were surveyed using a mixed-methods ethnographic approach. Prior to participation, respondents were informed of the purpose of the study and their informed consent to participate was obtained. Initial 'pre-treatment' baseline surveys were conducted in a census style to capture community-wide perceptions of the coral restoration initiative and environmental knowledge on coral reef ecosystems and to determine the level of pre-project food security in the community (N=185). These surveys were implemented by graduate students from Hassanudin University (UNHAS) over a 2-week period in December 2016. Follow-up household surveys examined potential temporal changes in food security factors mid-project implementation (N=87). These surveys were conducted via a random stratified sampling method based on demographic and socio-economic data collected through the baseline survey (Bernard 2011). Sampling subgroups were divided by gender and occupation (i.e., fishing vs non-fishing households). Additionally, qualitative data—about socioeconomic context, dependency on local marine resources, and perceptions of benefits and drawbacks of coral restoration and other conservation initiatives—was collected through semi-structured interviews with key informants, including government officials, community leaders, and local fishers (N=17). Additional respondents were then identified through a snowball sampling design (Johnson 2005).

Follow-up surveys and interviews were conducted by the first author with assistance from a professional translator. Data were collected over two 2-month field trips through the months of May and July of 2017 and 2018, and one 1-month field trip over January 2017. Field trips were conducted primarily during the early months of the dry season during the Ramadan holiday. Many households travel to other parts of Indonesia for extended fishing trips throughout the year but return to the island for Ramadan; therefore surveying during this time ensured the greatest community representation. This sampling strategy, while useful, partially limited our ability to capture seasonal variabilities. We addressed this particular limitation by conducting the shorter field trip during the wet season to capture seasonal variability in key aspects of local perceptions. Results from either method were triangulated, both between seasonal samples and between qualitative and quantitative results, to validate findings (Bernard 2011). Prior to the commencement of social data collection, Institutional Review Board approval was obtained for all research questions administered. Additionally, this research was part of a larger restoration study approved both by local and regional governments and implemented in conjunction with the requirements of the local collaborating university, Hassanudin University. Local colleagues were also trained in Human Subjects Research Best Practices in accordance with IRB requirements.

Fisheries surveys and sampling

Fisheries landings data from the restoration village was collected from December 2016 to October 2017. Fishers were opportunistically selected at all times of the day as they return to the island from fishing. Prior to participation, they were informed of the purpose of the study and their

informed consent to participate was obtained. If more than one fisher or boat was returning from fishing at the same time, enumerators randomly selected who to approach. Surveys were implemented by two research technicians from Hassanudin University who collected data for 6-10 days each month of the sampling period. Total length (cm) of each fish in the catch (or mantle length for squid) was recorded and identified to the species level. Enumerators were trained on fish identification by an experienced fisheries scientist before going into the field. Where fish species were not easily identified, photographs were taken to identify and confirm correct identification. The enumerators also asked the fishers about: 1) fishing gear used; 2) fishing effort or duration of the fishing trip; 3) location of the catch; 4) the boat type and length (m); and 5) who is the owner of the boat or fishing operation. If fishers could not identify the location of their catch by pointing to a position on a map, their catches were not recorded (< 5%). Catches from multiple locations or multiple gear types from a single fisher were separated accordingly by enumerators when collecting data.

Food security indicators

We examined 1) the 'pre-treatment' state of food security across the restoration village community to determine appropriate indicators of food security change related to coral restoration; 2) the relationship between local reefs and the community; and 3) if and how coral restoration may influence food security (Table 1). We measured food security and food security responses across four domains: Nutrition, Wealth, Access, and Fishery Attributes. These were designed using the UN World Food Programme's definition (2009) stated previously. Similar indicators have been used in previous studies of food security and marine conservation (e.g., Darling 2014). Based on the particular ethnographic context, we also incorporated predictive variables such as those listed under the Wealth and Access Domains as these indicators were identified as linked to access to food and overall food security. 'Fishery Attributes' is not typically used when evaluating food security, however it is an important aspect of food security for this project, given that we sought to understand interactions between coral restoration, the reefs' ability to support fishery species, and local food security (i.e., dependence of demersal vs pelagic fisheries).

Data analysis

Data on food security indicators was analysed using SPSS statistical software. For each of the four food security domains, we evaluated indicators across locally-relevant demographic variables (i.e., gender, occupation, marital status, age, and household size). Statistical tests were used to assess any existing food security disparities and to determine appropriate measures of food security. Qualitative data derived through semi-structured interviews and participant observation were analysed through thematic indexing and discourse analysis of specific narratives about historical and contemporary reef relationships and food security. Fisheries effort and catch composition were split into demersal (coral reef fish) and pelagic functional groupings based on dominant habitat (Froese and Pauly 2018). Comparisons were made between metrics of fishing effort as well as the mean (±SE) total length (cm) of fish species in the catch as compared to length at first maturity (Lmat). Values for Lmat were obtained from Fishbase (Froese and Pauly 2018) and when genus-level identification was the finest resolution (e.g., Loligo sp.), the mean of all species' Lmat was used.

Limitations

Given the duration of this study, we were unable to assess the long-term impacts that coral restoration may have on fish abundance in local reefs and how this may affect local food security through increased fishing yields. Resampling the fishery attributes after the coral restoration project has matured would provide insight into the possible temporal shifts in catch and fisher dynamics. This study's dominant purpose was to identify the current drivers of food security within this particular context and to identify institutional, social, and/or cultural barriers to food security benefits that are either pre-existing or created through the introduction of the restoration programme. Although we do not quantify the changes in food security within the community, we identify predictive variables that strongly influence food security and discuss how these variables are impacted by the restoration intervention. Further studies using techniques such as detailed dietary recall at various intervals, could provide finer-grained insights about the impact of marine resource health and availability on local food security.

RESULTS

Nutrition domain

Wealth was identified as the primary driver of nutrition indicators in the restoration village. Wealthier households had greater access to important dietary staples such as rice and water. Rice is the primary staple of the community and water is a mediating factor of food security in the community because it is necessary to prepare most cooked meals, including rice. This finding aligns with the specific context of the restoration village where minimal food production occurs on the island and food products are mainly purchased and imported from mainland Sulawesi. Nutrition was evaluated through perceived sufficient access to overall food, individual food groups, and diet diversity. 85.4% (N=157) of households reported that they had enough food overall; and of the households that perceived insufficient access to food, 42.9% (N=21) reported that their families would sometimes go hungry. Fish was found to be the most available food group (94.2%, N=156).

Sufficient access to food overall and individual food groups was evaluated across demographic variables and wealth variables through Chi-square analyses and Mann-Whitney U tests (Appendix I). According to Guttman Scale analysis, the

Table 1
Food security and food security response variables and measures

Food security domains	Indicator	Description
Nutrition	Overall household food security	"Do you and your family have enough food?" 1—Yes 0—No
	Individual food group security	Perceived access to individual essential food groups (i.e., meat, fish, vegetables, fruit, nuts, rice, tuber crops) 1—Yes 0—No
	Diet diversity	Cumulative sum of food groups that households have regular access (Continuous from 0 to 11)
Wealth	Material style of life	Cumulative sum of various household items present in a household (Continuous from 0 to 22) Socio-economic subgroups based on MSL sum (Low=1-4, Mid=5-9, High=10-22)
	Income	"Do you have enough household income to meet your needs?" 1—Yes 0—No
Access	Direct interaction w/organisation	1—Yes 0—No
	Perceived barriers to involvement	Perception of indicator based on 7-point scale (1=strongly disagree to 7=strongly agree)
	Perceived impacts of coral restoration on fishing	
	Perceived impacts of coral restoration on access to fishing grounds	
Fishery attributes	Fishery operations characteristics	Boat type and length; Number of crew members; Distance to Market (Continuous Scale)
	Catch composition	Length-frequency and Species composition
	Effort	Gear type; Distance to fishing grounds; Length of trip

collected data on material style of life (MSL) household items scaled unidimensionally (COR=0.90; COS=0.18); therefore, we evaluated MSL indicators as a scaled sum variable (Guest 2000). Households that perceived their incomes sufficient to support their needs also perceived their overall food security to be more adequate than households that perceived their incomes insufficient to support their needs (93.46% vs 68.00%, x2=17.66, df=1, *p-value*<0.001, *N*=157). Furthermore, income positively correlated with access to rice, tea, and coffee (*p-value*<0.05, See Appendix I). MSL positively correlated with access to vegetables, fruit, eggs, tea and coffee (*p-value*<0.05, See Appendix I). Only households with dependents reported meat to be part of their diet (*p-value*<0.005, See Appendix I). Diet diversity was evaluated across demographic and income variables through Student's t-test and Pearson's correlation. Based on Student's t-test results, no significant relations were identified (Table 2). Diet diversity, however, was found to be positively correlated with the sum of MSL household items (r=0.22, df=103, *p-value*<0.05, *N*=105).

Wealth domain

MSL household items and perceived income adequacy were used as indicators of wealth. MSL was selected as an indicator of wealth because fishers' incomes were highly variable on a daily and seasonal basis, thus exact income data was unreliable. MSL is a widely used indicator of wealth, especially in small-scale fishing communities (Pollnac et al. 2001; García-Quijano et al. 2015). Furthermore, we found MSL and perceived income adequacy to be positively related. Households who perceived their incomes as sufficient to support their needs had significantly more MSL household items ($\bar{x}$=7.52 vs 5.67, t=3.925, df=132, *p-value*<0.001, *N*=134). By using these two indicators we aimed to account for both short-term and long-term asset accumulation. MSL items included household electronics (i.e., tv, mobile phone, fan) and basic food preparation appliances (i.e., stove, oven, refrigerator). The suitability of individual household items was validated through early interviews and participant observation.

Based on Student's t-tests of MSL sum variables across nominal demographic variables, households with male heads were found to have higher MSL sums than households with female heads (Table 3). Based on Chi-square analysis results, no significant relations were found between perceived income adequacy and demographic variables (Table 3). Through Pearson's correlation analysis we found that household size positively correlated with MSL sum where larger households had more MSL items (r=0.291, *p-value*<0.005, *N*=118); however MSL sum per capita negatively correlated with household size (r=-0.515,*p-value*<0.005), No relationship was found between MSL sum and age (r=-0.079, p-value>0.05, *N*=134). According to Student's t-test, no significant relationships were found between perceived income adequacy and household size or age (Age: Yes $\bar{x}$=46.48 vs No $\bar{x}$= 47.17, t=-0.29, df= 167, p-value>0.05; Household Size: Yes $\bar{x}$=5.38 vs No $\bar{x}$= 5.22, t=-0.49, df= 144, p-value>0.05). We also evaluated the relationship between individual appliances needed for basic food preparation (i.e., running water, indoor oven, and gas stove) and demographic variables (Appendix II). Chi-square analyses showed that households without dependents were found to be less likely to have indoor ovens than households with dependents (p <0.05 See Appendix II).

Access domain

Community members across socioeconomic scales (based on MSL sum) were found to have equal access to project participation

(Yes $\bar{x}$=6.57, No $\bar{x}$=6.91, t=-0.301; *p-value*>0.05). However, community members linked to the Village Head, either as one of his constituents or as one of his appointed government workers, viewed the project as more accessible compared to individuals who were more closely aligned with the losing candidate. Village Head constituents were less likely to agree with the statement: "There are barriers that may affect your involvement in the coral restoration project," than non-constituents (constituents: Mean=1.73 vs non-constituents=3.53, U=122.50, *p-value*<0.05; government workers: Mean=1.47 vs non-government workers=2.22, U=159.50, *p-value*<0.05). Village Head constituents also perceived that what the restoration company had provided for the community aligned with their expectations (constituents vs non-constituents: $\bar{x}$=5.96 vs 4.40, U=51.50, p-value<0.05; government workers vs non-government workers: $\bar{x}$=6.71 vs 5.10, U=42.50, *p-value*<0.05). The Village Head was a major proponent of the project and instrumental in bringing the programme to the island. Village Head constituents reported having interacted directly with the conservation group more than those who did not vote for the current village head. (93.33% vs 57.14% respectively, x2=6.39, df=2, p-value<0.05, *N*=47). These interactions mainly consisted of attending project meetings where community members could provide input on site locations and marine management decisions. Furthermore, they had higher rates of participation in coral transplantation days (47% vs 5% respectively, x2=12.70, df=1, *p-value*<0.001, *N*=52).[3]

Table 2
Diet diversity across demographic variables

	n	Mean	*t*	*df*
Gender				
Male	96	6.47	0.004	124
Female	30	6.47		
Marital status				
Married	118	6.43	-1.200	10.971
Single	8	7.00		
Occupation				
Fisher	81	6.40	-0.354	123
Non-fisher	44	6.55		
Dependents				
Children	107	6.39	-1.127	37.777
No children	16	6.81		

Note: None of the differences were statistically significant

In relation to fishing and fishing yields, the reef restoration programme was found to have a disproportionate negative impact on independent fishers than *sawi* (wage-labour fishers). In qualitative interviews, several independent fishers described how they perceived that they are now prohibited from fishing on the reef due to new fishing restrictions associated with the restoration initiative. Some fishers stated that they were now restricted from using a speargun, the primary gear type that they previously relied upon. Other fishers who used hand lines stated there fishing was restricted due to the restriction on damaging corals. They described how their lures sometimes snag corals and to retrieve their lures they would need to snap off coral fragments. They viewed that the restriction on damaging coral does not allow for this practice and therefore fishers would be required to cut and abandon lures-- an additional cost that they could not afford.

Fishery attributes domain

Data was collected for 77 days over the 10-month sampling period. A total of 91 boat captains were surveyed, and they took a combined 375 trips. We recorded data on 1,548 individual fishes and molluscs, comprising 60 species. Only 19% of recorded fishing trips were on the local reefs for demersal fish where they landed 299 fish (Figure 2). On these trips, the dominant boat length was between 6 m and 15 m, while many were also smaller canoes <5 m using predominantly handlines (89% of total demersal catch). These catches were dominated by *Sepia sp.*, or cuttlefish, which accounted for 170 individuals, followed by *Siganus guttatus*, a rabbitfish, and *Terapon jarbua*, a reef-associated grunt. The cuttlefish and rabbitfish were mostly caught at lengths above maturity (+3 cm and +5 cm, respectively), whereas the grunt was not (Figure 3).

Restoration village fishers most commonly utilised the pelagic fishery, using a combination of handlines and purse seines (58% and 40% of total pelagic catch respectively). These landings made up 81% of the restoration village fishers' trips (1,249 individual fish). *Loligo sp.*, or squid, was the most commonly exploited species in this fishery (*N*=310). This was followed by *Rastrelliger kanagurta*, *Sphyraena jello*, and *Selar boops*. The total lengths of these species varied and *Scomberomorus commerson* was the largest species landed.

Table 3
MSL sum and perceived income adequacy across nominal demographic variables

		MSL sum				Perceived income adequacy				
Demographic Variable		*n*	Mean	*t*	*df*	Yes (*n*)	No (*n*)	x^2	Phi	*df*
Gender	Male	99	7.22	2.45*	85.1	90	40	0.09	-0.02	1
	Female	35	6.14			26	13			
Marital Status	Married	124	6.94	0.05	132	106	50	0.26	0.04	1
	Single	10	6.9			9	3			
Occupation	Fisher	84	7.11	0.94	131	70	38	1.85	0.11	1
	Non-fisher	49	6.65			45	15			
Dependents	Children	117	6.91	0.065	130	100	45	0.13	-0.03	1
	No Children	15	6.87			13	7			

*P<0.05, **P<0.005

Loligo sp. were primarily landed at lengths just below maturity, or 12cm. The only other pelagic species landed below Lmat were *S. commerson* and *S. jello* (Figure 3).

Fishing for purely subsistence purposes was minimal in the restoration village and overall food security benefits come from the profits generated from local fishing economies that allow community members to purchase food imported from mainland Sulawesi. Fishers consume a small portion of their catches but the majority of fish landings are sold to local collectors who resell it in the international market in mainland Sulawesi. Thus, the fishery supports local captains and fishers, as well as middle-men (i.e., collectors and boat owners), who then distribute fin-fish and squid on to further destinations. Additionally, offshore pelagic habitats were found to be more important than coral reefs to local fishers for supporting fishery activities and livelihoods; 81% of the fisheries landings on the island came from pelagic habitats, and only 19% from the reef (N=1548).

Fishery surveys revealed that 63.9% of local fishers are employed through the patron-client *pa'gai* system. In the restoration village *pa'gai* boats are crewed by up to 15 men and fishing trips may extend for up to 20 days. These boats target pelagic resources such as squid and mackerel species using ring nets or large purse seines. About 36.1% of fishers fish independently; however, many fishers only fish independently on a seasonal basis and depend on participation in *pa'gai* fisheries during the rest of the year.

Local sociocultural perceptions on the role of reefs

We evaluated the benefits and values of reefs to the local community through qualitative open-ended questions on coral reef ecosystem service benefits. Respondents primarily identified coastal resilience and storm protection as the primary function and importance of their surrounding reef system. Many respondents discussed how reefs act as a barrier for 'big waves' and protected the island from storm surge. Some respondents even described how coral prevented erosion during large storm events by stabilising sediment. Few respondents discussed the value of reefs in terms of directly contributing to their livelihood and food security. Furthermore, when asked more broadly what the primary concerns for life on the island might be, food security was mentioned by only one respondent; whereas, frequent power outages (98 mentions) and lack of fresh drinking water (25 mentions) were the most frequently mentioned concerns raised by community members (N=140).

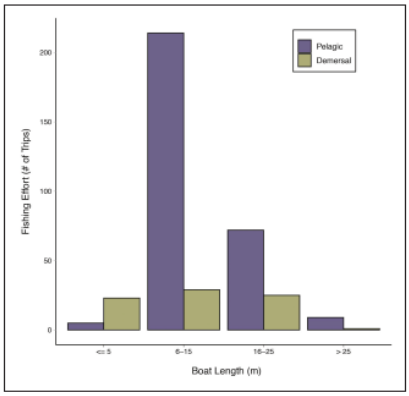

Figure 2
Boat size (m) used by fishers in the restoration village according to the type of fish targeted, or habitat (effort)

DISCUSSION

Patron-client fishery system as a barrier to improved food security

Our results indicate that food security in the community is more closely linked to overall wealth through access to regional cash markets that allow the accumulation of assets, rather than access to local food sources through subsistence fishing. Wealthier households were found to have greater food security in the community. Higher incomes allowed households to purchase food necessary to their diet. These findings align with previous studies on food security in other fishing communities. In Palawan households, fish primarily contributed to food security through its role as a main source of income used to buy other important foods (Fabinyi et al. 2017). Similarly, a study of Kenyan fishing communities found wealthier households had greater food security (Darling 2014).

Given the link between wealth and food security, the dominant *pa'gai* fishery system of the restoration village may be an existing contextual factor that could impede local fishers from improving their food security, as it operates as a patron-client system that inhibits fishers from achieving substantial financial autonomy. Most respondents who identified as a *sawi* (*pa'gai* fisher/crew-members) expressed that if abundance of fish increased on local reefs, they would want to utilise the resource; however, abundance was not necessarily the primary barrier to access. Many *sawi* respondents stated that they do not have the appropriate gear type and boats necessary to target coral reef fish nor the capital to transition to independent reef fishing. Moreover, many are reliant upon the loans provided through the patron-client *pa'gai* system.

Patron-client relations are widespread in rural production systems, like small-scale fisheries, especially in Southeast Asia (Kennedy and Firth 1946; Merlijn 1989; Ferse et al. 2012). *Pungawwa* are characterised as displaying strong reciprocal social ties with their *sawi* and often provide financial and personal support (Ferse et al. 2014). However, this support has been criticised as a mechanism that creates a poverty trap. To repay provided loans, *sawi* must sell their catches to their *pungawwa* at below market value and rarely regain their autonomy (Glaser et al. 2010). Patron-client systems are the dominant modes of fishery operations in the Spermonde, however, fisheries across the archipelago vary by target species and gear types. Although the pa'gai fishery in the restoration

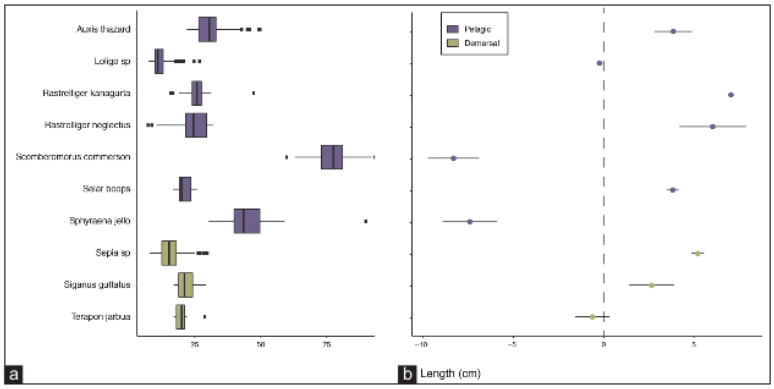

Figure 3

(a) Boxplot of the total length (cm) of top 10 species landed by restoration village fishers by habitat type; and (b) relationship between the mean (cm; ± SE) length and length at first maturity (Lmat) for each species

village, predominantly target pelagic species, fishers employed by patron-client-systems on other neighbouring islands target coral reef species. Pungawwa who support reef-based fisheries are the dominant source of illicit fishing gear. Furthermore, most of these *pungawwa* have the power to protect their fishers from prosecution for using destructive gear through relational ties with local governmental and military agencies (Glaser et al. 2010, 2015; Ferse et al. 2012).

The *pa'gai* system is a problematic system of power relations for the restoration project in two ways. Firstly, it is the primary mechanism that destructive fishing gears (i.e., cyanide and bombs) are made accessible to local fishers throughout the region, leading to the damage coral restoration aims to rectify. And secondly, its hierarchical patron-client system creates indentured work forces that prevent the improvement of economic conditions of fishers. These two distinct issues thus inhibit improved food security conditions from being realised. Restored ecosystems, the expected source of improved food security, may once again be damaged through ongoing use of destructive fishing gear; and individual *sawi*, financially bound to their *pungawwa*, are unable to improve their economic conditions, reflecting an inability to improve their food insecurity.

The adverse effects of coral restoration on livelihoods and social networks

The introduction of the restoration programme into the community has in itself led to adverse effects on food security for some community members. Independent reef fishers have been negatively impacted by the restoration initiative through fishing restrictions. They perceive that they have been denied access to local reefs resulting in a reduction of fishing yields and thus household food security. Moshy et al. (2015) identified similar consequences in fishing communities in Tanzania where fisher household food security declined because access to livelihood sources were denied due to the establishment of a marine reserve.

These restrictions are enforced by village head appointed coral guards who are also partially funded by the coral restoration project. Coral guards are responsible for enforcing the MPA and restrictions on prohibited gear types. Although these guards serve an important role as enforcement officers to legitimise and implement legal restrictions, they have been described by community members as poorly-trained and are enforcing restrictions that are not legally mandated by the local government or the restoration company. One respondent who previously was a COREMAP coral guard explained that the current coral guards were not trained on how to best engage with fishers. Under past conservation programmes, coral guards were supposedly trained to engage with fishers respectfully and to use these interactions to inform fishers of the degradation and harm caused by destructive fishing-- key characteristics to successful MPA enforcement (Hønneland 2000; Crawford et al. 2010).

Tactics enforced by current coral guards have damaged relationships in the local community and with neighbouring islands. Fishers from the restoration village and neighbouring islands have been restricted from fishing on the surrounding reef of the restoration village despite their historical use of the reef. This has resulted in damaged reciprocal relationships between the restoration village and neighbouring islands and indirect consequences for the food security and livelihood of some restoration village fishers. Since the restoration initiative, restoration village fishers have experienced restricted access to fishing grounds controlled by neighbouring islands as a means of protesting the restoration programme. Such inter- and intra-island reciprocal relationships are critical components of small island life in the Spermonde (Gorris 2016). These relations are essential for ensuring food security by providing access to important fishing grounds that support local livelihoods and well-being for some members of these island communities. Although the coral restoration initiative aims to improve food security, its problematic upset of existing relationships and exacerbation of existing inequities have resulted in the

inverse for some community members through the reduction of access to fishing grounds around the restoration village and other parts of the Spermonde.

Sociocultural dimensions of fish consumption

Some marine conservation initiatives in the Coral Triangle have been re-oriented to address conservation and food security issues simultaneously. Their agendas assume that coral reef species are a universally important dietary staple of local people in the Coral Triangle; however, numerous case studies and empirical reports have shown that consumption and livelihood dependence on non-demersal fish species (i.e., pelagic and aquaculture) are greater in some coastal and island communities across the Solomon Islands, the Philippines and Indonesia (Dey et al. 2005; FAO 2014; Needham et al. 2014; Albert et al. 2015; Roeger et al. 2016; Clifton and Foale 2017). Similarly, the restoration village community disproportionately fish and presumably consume pelagic species over coral reef species. Moreover, food security and fishing were rarely mentioned as benefits of coral reefs and coral restoration. Previous studies on the benefits of coral restoration had similar findings (Hein et al. 2019).

Pa'gai fishers target specific pelagic species because there is a demand for them in the global fish market. However, this taste preference is also evident within the local community. Multiple respondents expressed that the pelagic fish have a more desirable taste and smell compared to reef fish. Researchers surveying small island communities in other regions of the Coral Triangle have made similar taste preference observations in some, but not all areas, indicating a need for more systematic research on the topic (Richard Pollnac pers. comm. 2018). Studies in the USA also observed a commercial preference for pelagic species, based on form and taste (Boster and Johnson 1989).

During qualitative interviews independent reef fishers described increased abundance of parrotfish (*Scarinae*) since the installation of the coral spiders; however, they discussed that these increases have had no impact on their catches because they do not eat that type of fish. Many reef fishers from the island also described that they mainly target invertebrate species, such as squid, cuttlefish or octopus rather than demersal fish. At the time of this study, coral practitioners on the other hand strictly monitored longitudinal changes in fin-fish abundance along the reefs and not invertebrates. This gap between marine resources that are monitored by the project and marine resources that are valued and harvested by the local community, is a challenge to the effective evaluation of the most tangible impact of the restoration initiative on food security—changes in species abundance of target fisheries. Previous studies have highlighted the value of understanding culturally-valued species (and arrangements of species) and how this information can be utilised to adapt reef monitoring programmes (Foale et al. 2016; Dacks et al. 2019).

CONCLUSION

This study utilised a mixed methods ethnographic approach, to investigate: 1) potential impacts of reef restoration on local food security; and 2) sociocultural relationships that local people have with surrounding coral reefs, to inform locally-appropriate sociocultural indicators of reef restoration impacts. To the first point, our results caution against the assumption of a direct relationship between fish yields and community-wide food security. Instead, wealth and the ability to purchase foods to contribute to a diverse diet are dominant drivers. We emphasise that social dynamics surrounding community-based conservation initiatives are complex and context-dependent. Specifically, we illustrated how: 1) the patron-client *pa-gai* system may prevent community members from accessing potential food security benefits intended to result from coral restoration; 2) coral guards' enforcement tactics have damaged reciprocal fishing relations with neighbouring islands that may impact local fishers' yields, and have directly impacted local reef-based fishers access to historically important fishing grounds; and 3) the long-term success of coral restoration as an isolated solution may be ineffective in a region where destructive fishing practices are still widely utilised and protected by influential patrons. To the second point, we identified an important dichotomy in the perceived benefit of coral restoration by practitioners and the community. Food security was an assumed benefit of coral restoration by practitioners, while the majority of community members saw storm protection as the greatest value of coral reefs and restoration. Furthermore, the majority of the community have minimal livelihood and food security dependence on the reef, whether they are dominantly reliant upon pelagic fisheries as a source of income to buy other necessary dietary staples. Thus, we identified a discord between practitioners and the community that might hamper the long-term success of this initiative. This list of critical insights challenges key assumptions that initially drove the implementation of the intervention and suggests that the rationale underpinning the relationship between coral restoration and local food security is not as strong as it initially appeared. These findings echo studies of other marine conservation projects (Waylen et al. 2013; Bennett and Dearden 2014; Foale et al. 2016), as well as terrestrial conservation projects (Thapa Karki 2013; Nilsson et al. 2016), where local values and project objectives were misaligned. Future coral restoration initiatives must be cognizant of complex community dynamics, and for this we recommend community engagements throughout all stages. A culturally-grounded approach is necessary to develop social objectives for conservation that are locally-significant and that can better evaluate how existing social networks operate and may potentially conflict with conservation programme design. Moreover routine engagement with the community needs to be used to inform conservation practices that are adaptive to the social conditions of the community and to potential unintended consequences that may arise. Our approach of integrating well-established socio-economic indicators with ethnographic

sociocultural context has wide applicability to food security and conservation programmes globally. Future studies could focus more directly on how the implementation of sociocultural indicators affects the long term social and ecological success of conservation initiatives.

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NOTES

1. The New Order regime refers to President Suharto's regime (1966-1998). Coined by Suharto, the term was used to distinguish his rule from that of his predecessor, President Sukarno. The regime was characterised by anti-communist and pro-capitalism and development policies.
2. These initial goals were once publicly available on the company's website as an infographic. The project has since moved away from publicly stating any explicit social objectives for reef restoration.
3. Community leaders initially designed a participant selection system for build days, where each neighbourhood head selected build-day participants. Political alignment clearly influenced those who had access to participation and there was concern that local elites would have disproportionate access to benefits stemming from the initiative. This system was eventually abandoned as it was viewed by the community as highly exclusive and led to inter-community conflicts. Afterwards, the programme adopted an open participation process. This system was widely preferred by the community. Therefore, this quantitative data reflects the participation landscape during the initial programme participation design and likely would be different under the open process.

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Appendix I

Summary of results for food security indicators. Prompts were framed as whether respondents perceived that they and their families had sufficient access to the listed food groups (n=153). For all independent variables (excluding MSL sum) df=1

	MSL (Scaled sum)	Income Adequate (Y/N)	Gender (M\F)	Marital Status (Ma./Si.)	Dependents (Y\N)	Occupation (Fisher\ Non)
Overall Food Security	7.05; 6.19	94%; 68%	83%; 89%	84%;100%	85%; 88%	83%; 88%
	U=913.00	x^2=17.66**	x^2=1.00	x^2=2.12	x^2=0.17	x^2=1.01
Rice	6.83; 6.73	6[illegible]; 71%	88%; 95%	89%; 91%	88%; 94%	89%; 89%
	U=681.00	x^2=0.07	x^2=1.57	x^2=0.03	x^2=0.52	x^2=0.01
Water	6.95; 6.33	7[illegible]; 59%	75%; 82%	76%; 91%	76%; 76%	77%; 76%
	U=1,639.00	x^2=1.51	x^2=0.70	x^2=1.35	x^2=0.00	x^2=0.03
Vegetables	7.02; 6.07	69%; 65%	75%; 82%	76%; 82%	76%; 76%	79%; 75%
	U=1,734.50*	x^2=0.18	x^2=0.70	x^2=0.18	x^2=0.00	x^2=0.31
Meat	7.59; 6.67	7[illegible]; 66%	73%; 17%	22%; 18%	23%; 12%	30%; 16%
	U=1,448.50	x^2=1.51	x^2=0.53	x^2=0.08	x^2=1.07	x^2=3.71*
Snacks	6.99; 6.00	7[illegible]; 58%	85%; 84%	83%;100%	84%; 88%	86%; 84%
	U=1,253.50	x^2=1.20	x^2=0.01	x^2=2.15	x^2=0.23	x^2=0.15
Fruit	7.37; 6.41	7[illegible]; 65%	51%; 34%	47%; 45%	46%; 53%	44%; 48%
	U=2,567.50*	x^2=0.68	x^2=3.195	x^2=0.009	x^2=0.299	x^2=0.243
Tea	6.98; 5.69	6[illegible]; 63%	90%; 89%	89%; 100%	88%; 100%	91%; 89%
	U=1,009.50*	x^2=0.24	x^2=0.00	x^2=1.35	x^2=2.25	x^2=0.23
Milk	6.75; 6.31	68%; 58%	7[illegible]; 63%	72%; 75%	71%; 81%	72%; 73%
	U=1,285.50	x^2=1.18	x^2=2.13	x^2=0.03	x^2=0.80	x^2=0.01
Eggs	7.11; 5.74	7[illegible]; 56%	77%; 76%	77%; 82%	76%; 82%	79%; 76%
	U=1,840.50*	x^2=3.05	x^2=0.02	x^2=0.15	x^2=0.30	x^2=0.21
Fish	96.86; 5.40	6[illegible]; 67%	92%; 100%	94%; 100%	94%; 100%	96%; 93%
	U=427.50	x^2=0.00	x^2=2.97	x^2=0.73	x^2=1.06	x^2=0.80
Coffee	6.82; 5.07	7[illegible]; 50%	84%; 88%	84%; 100%	83%; 100%	87%; 84%
	U=992.50*	x^2=3.14	x^2=0.20	x^2=1.693	x^2=3.09	x^2=0.22

*P<0.05, **P<0.005

Appendix II

Summary of results of MSL wealth indicators (n=153). Prompts were framed as whether respondents owned various household items. Df=1 for all variables

	Gender (Male, Female)	Marital status (Married, Single)	Dependents (Yes, No)	Occupation (Fisher, Non-fisher)
Water	88%; 85%, x^2=0.345	86%; 100%, x^2=1.887	88%; 80%, x^2=1.029	85%; 89%, x^2=0.438
Electricity	73%; 87%, x^2=0.606	69%; 100%, x^2=5.169*	70%; 75%, x^2=0.185	73%; 71%, x^2=0.079
Water Heater	9%; 3%, x^2=1.63	6%; 17%, x^2=1.718	6%; 10%, x^2=0.591	13%; 4%, x^2=5.221*
Refrigerator/Freezer	17%; 10%, x^2=0.920	15%; 17%, x^2=0.023	14%; 15%, x^2=0.015	15%; 15%, x^2=0.001
Gas Stove	96%; 100%, x^2=1.558	97%; 92%, x^2=1.269	98%; 95%, x^2=0.628	97%; 97%, x^2=0.037
Electrical Stove	1%; 0%, x^2=0.309	1%; 0%, x^2=0.079	0%; 5%, x^2=7.144*	0%; 1%, x^2=0.575
Kerosene Stove	6%; 3%, x^2=0.796	5%; 17%, x^2=3.190	6%; 5%, x^2=0.012	3%; 7%, x^2=0.799
Outdoor Oven	1%; 5%, x^2=3.168	2%; 0%, x^2=0.240	1%; 5%, x^2=1.244	3%; 1%, x^2=1.213
Indoor Oven	21%; 21%, x^2=0.015	22%; 8%, x^2=1.305	19%; 40%, x^2=4.476*	25%; 19%, x^2=0.754
Boat	65%; 26%, x^2=18.461**	57%; 42%, x^2=1.07	57%; 45%, x^2=1.068	33%; 69%, x^2=19.375**

*P<0.05, **P<0.005

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