Mobilizing for change: Assessing Social adaptive capacity in Micronesian fishing communities

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1. Introduction

Across the Pacific Islands, fishing is critical to livelihood and food security for a majority of households, and is an important sociocultural activity with a rich history. Unfortunately, fishing communities, fisheries resources, and their associated habitats in Micronesia and across the broader region are threatened by climate change impacts, as well as human uses and natural hazards [1, 2] (IPCC 2019; Bell et al. 2013). Unsustainable fishing practices, such as nighttime spear fishing, are key drivers of the declining fisheries in Micronesia (Rhodes et al. 2015 and Rhodes et al 2018), and the lack of effective enforcement continues to compromise fisheries ecosystems and socio-economic resilience, particularly as it relates to climate change adaptation. Growing climate-related threats including increased sea surface temperature, sea-level rise, ocean acidification, changes in precipitation and storm patterns, repeating coral bleaching events, shifts in pelagic fisheries, changes in species composition, coastal erosion, and loss of habitats [3-9] (CPC/NOAA 2020; Cheung et al. 2013; Britten, Dowd, and Worm 2016; Free et al. 2019; Lehodey et al. 2013; Lehodey et al. 2014; Wongbusarakum et al. 2019), suggest that communities heavily reliant on fisheries resources for subsistence and income are profoundly vulnerable [10] (Bell et al. 2018). Already, fishing with existing methods is increasingly challenging and the decline in catch further impacts socio-cultural and economic conditions [1, 11] (IPCC 2019; Barnett and Waters 2016). In order to better manage fisheries and support community well-being and adaptation to changing climate, there is a need to advance understanding of not only relevant biophysical changes, but also the socioeconomic conditions and social adaptive capacity that affect fishing communities' well-being and resiliency.

Knowledge that informs climate adaptation planning and fisheries management often does not consider social adaptive capacity [12] (Maynard et al. 2015), or prioritize resilience indicators [13] (McClanahan et al. 2012). Ignoring social adaptive capacity means that key considerations such as local knowledge, institutional capacity, livelihood opportunities, and social capital are not incorporated into decisions influencing the ability to manage resources, mitigate risks, and build resilient communities and ecosystems. Further, there is limited guidance on which indicators are most important in assessing social adaptive capacity [14] (Engle 2011), and the relation of social adaptive capacity to climate impacts is particularly not well understood or documented [15, 16] (Cinner et al. 2018; Cinner et al. 2012).

This paper addresses these critical gaps by: 1) presenting the results of the development and testing of a methodology to collect social adaptive capacity data among selected small-scale fishing communities in Guam and the Federated States of Micronesia; and 2) discussing the findings related to climate adaptation policies and ecosystem approaches to fisheries management.

2. Social adaptive capacity

Social adaptive capacity is defined as the ability of an individual or community to cope with, prepare for, and adapt to disturbance and uncertain social-ecological conditions [17, 18] (Armitage 2005, Adger et al. 2005). As social adaptive capacity encompasses a wider range of

factors, it is thus more meaningful when contextualized at site-specific scales in engagement with local institutions [19-21] (Agrawal, McSweeney, and Perrin 2008; OECD 2009; Rahman and Hickey 2019). Prior research demonstrates that communities with reduced adaptive capacity have greater potential for environmental degradation [22] (Marshall 2010), increased economic hardship or missed development opportunities [23] (Allison et al. 2009), and decreased likelihood of resilience in the face of climate change [14] (Engle 2011). Building the capacity of fishing communities and households to adapt to climate change impacts will make them more resilient and less vulnerable to negative impacts on food security and declines in marine resource availability [10] (Bell et al. 2018). Recent research also highlights that social adaptive capacity directly affects the success of identifying strategies or subsequent management actions and policies essential to adapt to climate change [13, 24] (McClanahan et al. 2008; Cinner et al. 2013), and is necessary for prioritizing conservation investments to maximize desired social and ecological outcomes [25] (Mcleod, Margles, Wongbusarakum et al. 2015).

2.1 Indicators for social adaptive capacity

A review of the vulnerability and resilience methodologies and literature attempting to address social adaptive capacity, especially those developed for the Pacific region, suggested a significant opportunity to advance work on relevant indicators [2, 26, 13, 24, 25, 27, 28, 15] (Bell et al. 2013; Wongbusarakum and Loper 2011; McClanahan et al. 2012; Cinner et al. 2013; Mcleod, Margles, Wongbusarakum et al. 2015; Mcleod, Szuster, Hinkel et al. 2015; Whitney et al. 2017; Cinner et al. 2018). Indicators are defined as locally relevant factors or variables that are practical, valid, and reliable to establish baselines and to monitor changes. As some aspects of social adaptive capacity and related processes often cannot be measured directly, proxy indicators, or indirect indicators, are therefore used. In designing the survey questionnaire for this project, the four components of social adaptive capacity identified in Whitney et al. [28] (2017) were used as a guide to developing 5-point likert-style agreement statements in a survey. A study published during the survey implementation phase of this project, Cinner et al. [15] (2018), added a fifth component to this social adaptive capacity framework: Agency. While a quantitative continuous indicator of Agency is not derived in this study due to data limitations in constructing a reliable indicator based on the questionnaire developed with the Whitney et al. [28] (2017) framework, this concept is addressed through qualitative data and descriptive statistics. The five components of social adaptive capacity are described in Figure 1, and their interlinkages with social and biological conditions as well as fisheries management and policy are presented in Figure 2.

Figure 1: Interlocking and Interdependent Indicator Domains for Social Adaptive Capacity Adapted from Whitney et al. (2017). [26, 11, 15, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 15, 42, 43].

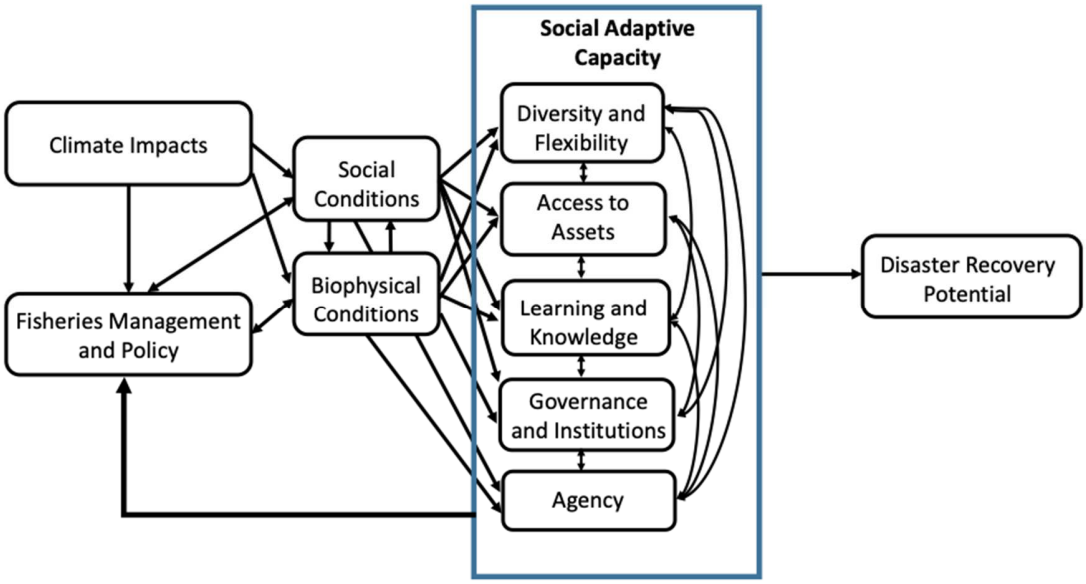


Figure 2: Interlinkages between social adaptive capacity with social and biophysical conditions as well as fisheries management and policy

Within these categories, a list of possible factors and variables were developed related to social adaptive capacity of fishing households across four study sites to inform the drafting of survey questions. The indicators and related variables were reviewed and refined with partners and community representatives to ensure that the study would not miss adaptive capacity concepts pertinent to the local context that can affect the effectiveness and sustainability of fishery management and climate change adaptation actions. The survey was finalized with the 46 five-point likert-style agreement statements mapped to each category of social adaptive capacity, as shown in Table 1. Descriptive statistics and data on the distribution of responses can be found in Table A.2 in Appendix A.

Table 1: Agreement Statements Mapped to Social Adaptive Capacity Categories

Diversity and Flexibility	Access to Assets	Learning and Knowledge	Governance and Institutions
My household is able to change fishing methods if necessary	Our coastal and marine environment recovers well after extreme environmental shocks/disasters	In my family, local and traditional knowledge for managing and sustaining fisheries are passed on from elders and parents to young people	Fisheries are managed sustainably under formal or traditional rules and regulations or other forms of protection
My household is able to move to different fishing sites if necessary	My household's income-generating activities are sustainable	My household is able to get information when we need to better cope with climate impacts on fisheries	There have been less fishing violations and illegal activities in the past 5 years
In the last 5 years my household has developed new ways to use coastal and marine resources	My household has access to land and sea resources that we can use or sale	Our community is aware of the causes and impacts of climate change	Fisheries management benefits my household
My household is willing to learn and do things differently in response to climate impacts and hazards	Marine and coastal systems my household's fisheries depend on are healthy	In the past, traditional knowledge and practices helped our community to successfully cope with climate events and impacts	Our fisheries management take climate change and its impact into consideration
My household can rely on ourselves in times of trouble	My household has friends, relatives, and other community groups who support us through difficult times	Today, traditional knowledge and practices are adequate to help us now successfully cope with climate risks and impacts	There is adequate coordination and cooperation within our community for fisheries management
My household would be willing to relocate our house away from the shoreline in order to be safer	Access to the reefs and sea is fair and equitable for all community members, including women	I know how changing climate may impact fisheries in the future	Members of my household participate in management planning and decision making related to resource management
My household uses traditional practices to help adapt to changing climate	The reefs and the ocean are a part of my life and my home	Personally I don't worry that climate change will have impact on our fisheries	Women are included in decisions regarding how to manage fisheries and natural resources
My household depends heavily on fisheries	Our community is able to access support from outside agencies or organizations that can help us effectively cope with climate change impacts	My children would like to be fishers	Negative impacts from climate hazards on the fisheries resources have increased in the past 5 years*
Migration is common in our community*	Our leaders can get support they need from outside in times of difficulty	My household members have knowledge and skills to use local land and sea resources to support our families	Our community has strong and effective leaders
I would like to do more to help sustain our fisheries	There are different groups (governments, NGOs, scientists/experts from different fields) working together to help us address impacts of climate change on our fisheries		Women's knowledge, experiences, and skills in fisheries are recognized and respected in our community
Fishing is important for my household It is a part of who we are	Our leaders can provide us with the resources we need to adapt to climate change		Crime is common in our community*
I would be willing to stop fishing for a different way of living that is more secure			I am content with the social status of my family in the village
Our community members work well with each other in times of natural disasters or difficulties			
Our community responds and recovers well from extreme environmental shocks/disasters			

* These statements were flipped when developing scales for the social adaptive capacity categories so that the directionality of all of the social adaptive capacity statements was consistent with the logic of more agreement with the statement indicating stronger social adaptive capacity.

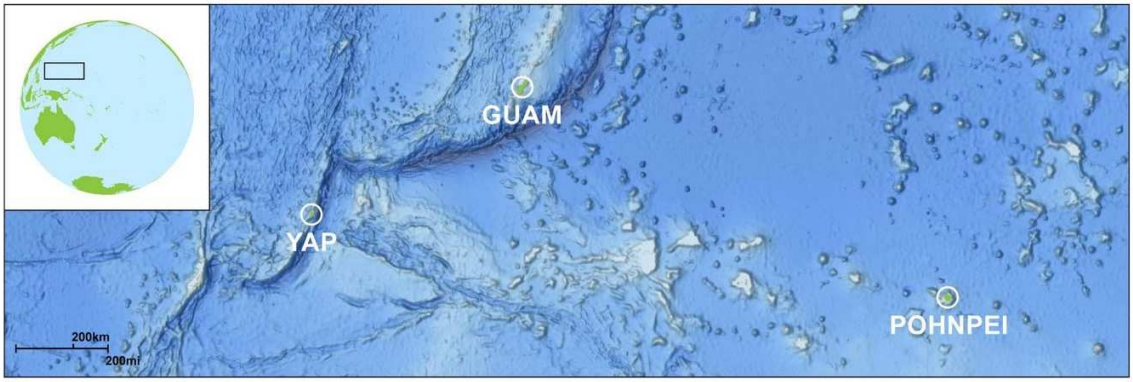
3. Methodology

Local and regional stakeholders related to fisheries, fisheries management, and climate adaptation (community members, leaders, managers, fishers, non-governmental organizations, and scientists) were engaged from the design through the results presentation and discussion of management and adaptation implications. Prior to field data collection, an Institutional Review Board approval for a study with human subjects was acquired through the University

of Hawai‘i and the University of Guam. Informed consent was obtained from all research participants. The study results at each site were presented back to the community members and stakeholders, providing opportunities to validate the results, and further discuss issues and implications together. At the end of the project, a regional workshop was conducted to engage island and regional stakeholders to collaboratively identify actions to support sustainable fisheries management and climate change adaptation plans, and to develop targeted communication, outreach, and policy briefs for fishing communities, conservation organizations, and fisheries management agencies that highlight current climate risks and findings on social adaptive capacity [44] (Micronesia Conservation Trust 2019).

3.1 Site Description

A total of four study sites on three islands are included in this study (Figure 3). All sites were recommended by the local partners as most suitable for this proposed project, based on the following criteria: 1) active fishing communities; 2) fisheries issues and climate impacts are pertinent; 3) good representatives of the islands on which they are located and serve as useful case studies; 4) feasibility of data collection using social science methods; and 5) social-ecological analysis and lessons generated will inform fisheries management and climate adaptation both locally and regionally.



West Fanif, Yap Federated States of Micronesia	Umatac (Humåtak), Guam Insular Territory (USA)	Merizo (Malesso), Guam Insular Territory (USA)	Pehleng (Poahloang), Pohnpei Federated States of Micronesia
Approximately 250 people (2017 project household survey). Subsistence fishing for all and income source for unemployed. The four communities of West Fanif (Yyin, Gilfith, Rang, and Atliw) recently established their own Marine Protected Area. Yap State is the least developed commercial fishery in Micronesia [45] (Johnson et al. 2020). Customary marine tenure practiced village-by-village, and traditional chiefs authorized by Yap Constitution to manage fisheries up to 12-miles from village shoreline, retaining social and cultural fishing responsibilities and working with communities in establishing fishing regulations. (Johnson et al. 2020). *Climate change events and impacts observed and identified as significant by community members: Typhoons, coastal erosion, sea level rise, coral bleaching, high tide/surf, drought, and floods.*	811 people [46] (Guam Bureau of Statistics and Plans 2019). Guam's first community-based fisheries management area in 2018 [47] (Guam Legislative Session Voting Record 2018). *Climate change events and impacts observed and identified as significant by community members: Typhoons, coastal erosion, sea level rise, coral beaching, floods, and ocean acidification.*	1,902 people [46] (Guam Bureau of Statistics and Plans 2019). Community initiated Achang Reef Flat Marine Preserve passed in 1997 and implemented with sporadic enforcement. Manell-Geus watershed designated NOAA Habitat Blueprint Focus Area 2014. Limited fisheries management outside preserve (restrictions on gill net, invertebrate size, commercial harvest). *Climate change events and impacts observed and identified as significant by community members: Typhoons, coastal erosion, sea level rise, coral beaching, floods, and ocean acidification.*	Over 1,000 people. Most heavily fished and fish market center of Pohnpei. Adjacent to largest grouper spawning aggregations [51] (Kitti Municipal Government 2017). Across Pohnpei State: Small-scale commercial fishery approximately 68% of catch. Reef fish annual consumption 93 kg/ person [52] (Rhodes et al. 2015). Open access for subsistence fishing prior to 1960s. Traditional management weakened following state level management and enforcement. Total reef fish harvest exceeded coral reef biocapacity by 360–710% and marketed coral reef fish volumes declined by approximately 20% (2006–2015) [52] (Rhodes et al. 2015). Increases in unsustainable fishing methods (e.g. nighttime spearfishing, small-mesh gillnets, increase in efforts, and shifts from inner to outer reef areas [53] (Rhodes et al. 2018). *Climate change events and impacts observed and identified as significant by community members: Typhoons, coastal erosion, sea level rise, coral bleaching drought, mud and landslides, temperature rise (air and sea), dying seagrass and sea cucumbers, and salt water intrusion.*
	Primarily indigenous Chamorro communities. Certain people fish and share with families. Pre-1990s, fishing access in community waters by permission; currently, subsistence and commercial fishing. Past colonization by Spain, Germany, and Japan, and current affiliation with the U.S. have decreased traditional management of reef systems [48] (Houk et al. 2020). Commercial fishing and technology lead to less regulated and more intensive fishing practices. Vulnerable to rising sea levels. Guam has highest population/reef area in Micronesia (1525/km² of reef up to 20m depth) [49] (Houk et al. 2018), and second lowest fish biomass among 23 island nations [50] (MacNeil et al. 2015).		

Figure 3: Study Sites [45, 46, 47, 46, 48, 49, 50, 51, 52, 52, 53]

3.2 Data collection methods

Data collection instruments include a survey questionnaire with representatives from fishing households, focus groups with fisher or seafood harvester representatives, and interviews

using semi-structured questions with community leaders, resource users, scientists, and other relevant stakeholders. Fishing households are defined as *those who are engaged in fishing for household consumption or for sales on average at least once a month in the last 2 years*. The questionnaires were pre-tested prior to finalizing. English language questionnaires were used in Umatac and Merizo in Guam, and the questionnaire was translated into Yapese for West Fanif and Pohnpeian for Pehleng. The survey was conducted in the language preferred by the respondents. The local site coordinators and village leaders identified and achieved the participation of representatives from all fishing households in the study sites. Although women are important contributors to the fisheries sector, it was difficult to recruit them due to locally perceived gendering of fisheries activities. The households themselves decided on an adult (older than 18 years of age) to represent their household in the survey. Often a male representative was chosen, presumably because fisheries were locally viewed as male-gendered activities. A screening question was asked prior to the survey to ensure that the chosen person was engaged in fishing or harvesting seafoods. To allow for data collection and the interpretation of multi-scalar levels of adaptive capacity, the majority of the questions are household-related with a smaller proportion of individual- and community-scale questions. Surveys were administered from August 2017 to February 2018. See Table A.1 in Appendix A for demographics of respondents.

In order to confront the challenge of accounting for gender-linked differences in perceptions or understandings around fisheries activities, focus group discussions (FGDs) were conducted separately with male and female fishers and harvesters at each site, except in Merizo, where the number of volunteer participants was too small to separate sub-groups. The FGDs were conducted to obtain a greater understanding concerning changes in fisheries, fisheries management, impacts of climate change on fisheries, coping mechanisms of fishers, and their social adaptive capacities. Key informant interviewing was also conducted with community leaders, fisheries management officers, and local scientists who have monitored changes in marine and coastal conditions and resources. The majority of the pool of key informants in all sites were male and this is reflected in the samples. The focus groups and interviews were conducted from September 2017 through October 2018. Sample sizes are listed in Table 2.

Table 2: Sample sizes

<table>
<tr><th></th><th>West Fanif, Yap</th><th>Umatac, Guam</th><th>Merizo, Guam</th><th>Pehleng, Pohnpei</th><th>Total participants</th></tr>
<tr><td>Fishing household survey</td><td>53 (51 men, 2 women)</td><td>23 (20 men, 3 women)</td><td>76 (53 men, 17 women, 6 N/A)</td><td>110 (91 men, 15 women, 4 N/A)</td><td>262</td></tr>
<tr><td>Focus groups</td><td>2 groups (9 men, 4 women)</td><td>2 groups (8 men, 5 women)</td><td>1 group (2 men, 1 woman)</td><td>2 groups (9 men and 7 women)</td><td>45</td></tr>
<tr><td rowspan="2">Key informant interviews</td><td rowspan="2">8 (6 men, 2 women)</td><td colspan="2">6* (4 men, 2 women)</td><td rowspan="2">6 (5 men, 1 woman)</td><td rowspan="2">24</td></tr>
<tr><td>2 (1 man, 1 woman)</td><td>2 men</td></tr>
</table>

*All 6 informants were interviewed for both Umatac and Merizo.

3.3 Data analysis

Both qualitative and quantitative data analyses were used. Before developing quantitative indices of each category of social adaptive capacity, the Cronbach's alpha statistic (Cronbach 1951) was used to test the internal consistency of each of the scales to assess how closely related the grouped statements, using a threshold of 0.7 [54] (Nunnally 1978), and each of the four scales met this threshold of reliability. This suggests that each of the above groupings of statements in Table 1 can be used to create a reliable scale for each category of social adaptive capacity. With the reliability of the scales confirmed, normalized additive indices were calculated for each social adaptive capacity category based on the ordinal responses to the statements. See Appendix A for data manipulation techniques and Table A.3 for Cronbach's alpha results. Each index was transformed to a 0-100 scale, increasing as self-assessed social adaptive capacity increases.

Descriptive statistics for the additive normalized social adaptive capacity indices are provided in Table A.4 in Appendix A. Five Ordinary Least Squares linear regression models (Diversity and Flexibility, Access to Assets, Learning and Knowledge, Governance and Institutions, and Social Adaptive Capacity) are constructed with each of the [28] Whitney et al. (2017) framework social adaptive capacity category indices as dependent variables. Independent variables are chosen to examine what factors (type of livelihood, fishing frequency, frequency of seafood consumption, reasons for fishing, gear used, coral reef dependence, impacts from human driven and climate driven hazards, and demographics) may help explain variance in social adaptive capacity indices. Table 3 details these results. All variance inflation factors for all independent variables in each of the five models are less than 2, indicating that multicollinearity is not an issue in the models. Residuals vs. predicted plots are provided in Figure A.1, and visual plots of statistically significant findings of the regression models are provided in Figures A.2-A.6 in Appendix A. The randomness of the points indicate that heteroscedasticity is not an issue in any of the models either, thus ensuring their validity.

Table 3: OLS Linear Regression Results for each Social Adaptive Capacity Index

	Diversity and Flexibility	Access to Assets	Learning and Knowledge	Governance and Institutions	Social Adaptive Capacity
	adj $R^2 = 0.28$	adj $R^2 = 0.18$	adj $R^2 = 0.26$	adj $R^2 = 0.37$	adj $R^2 = 0.39$
	df = 203	df = 207	df = 209	df = 210	df = 194
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Intercept	65.82	68.09	66.80	62.07	65.94
Fish/harvests almost daily	2.98*	3.25	0.73	-1.22	2.73
Consumes seafood almost daily	-1.03	-2.33	0.85	1.69	0.09
Fishes to sell	-2.56*	-2.54	-3.11*	-3.55*	-3.15**
Relies on tourism for livelihood	6.07***	4.05	4.69	3.16	4.16*
Goes spearfishing	-1.76	-4.12*	-1.73	-3.97*	-2.76*
Has been highly impacted by typhoons	4.18**	4.56**	1.99	6.17***	5.55***
Has been highly impacted by erosion	-0.72	-3.25	-0.13	-5.42**	-4.14**
Has been highly impacted by pollution	-3.57*	-3.48	-6.40**	-8.60***	-5.52***
Depends on coral reefs	4.75***	2.71	8.11***	9.90***	6.39***
Number of household members who cannot read/write	-1.35*	-1.71*	-1.46	-1.20	-1.57**
Number of household members who have completed college	-2.17***	-1.83***	-2.11***	-2.68***	-1.93***
Number of years living in community	0.06	0.08	0.03	0.09	0.07
Household leader over 40 years old	-2.82*	-1.07	-1.99	-1.82	-2.17
Number of females in household who fish/harvest	0.99	0.98	0.76	-0.39	0.04

*=significant with 90% confidence; **=significant with 95% confidence; ***=significant with 99% confidence.

4. Results

Overall, diversity and flexibility are the areas of social adaptive capacity of which households, on average, exhibit the highest levels, followed by learning and knowledge, access to assets, and governance and institutions. Interpretations of the regression models are woven throughout the results and discussion sections, accompanied by relevant context.

4.1 Diversity and flexibility

Almost all representatives from fishing households indicated that they rely on multiple forms of livelihood, with fishing being most important. In terms of reasons for fishing: 100% of respondents do so to feed their family, 99% do so for special occasions/cultural events, 92% do so for fun, 90% do so to give away, and 60% do so to sell. The regression analysis makes clear that reefs are a trusted resource, and that the social adaptive capacity of those who know how to frequently obtain resources from coral reefs is higher than those who do not depend on coral reefs for income and/or livelihood. Dependence on coral reefs contributes positively to four out of five models for social adaptive capacity (diversity and flexibility, learning and

knowledge, governance and institutions, and overall social adaptive capacity). All things held equal, the social adaptive capacity index of an average respondent's household increases by 6.39 if they depend on coral reefs in some form for sustaining their livelihood ($p<0.01$). Nearly all respondents (>99%) indicated that they use multiple gear types and or harvesting methods (Table 4), 84% agreed ("agree" or "strongly agree") that they are able to change fishing methods if necessary, and 85% of respondents would be willing to relocate away from the shoreline in order to be safer from climate impacts. About half of the respondents had fresh and canned fish from store and home-stored seafood (e.g. in freezer, dried or salted) as reserves; however, the average amount of backup seafood was only 6.8 pounds.

Table 4: Percent of Respondents That Use Each Gear Type/Harvesting Method

Gear type	Percent	n
Hand line	78%	257
Atulai (surround net)	67%	148^
Cast net/Talaya	60%	257
Trolling	34%	257
Spearfishing	83%	257
Poison	3%	257
Collecting at low tide	56%	257
Boat	53%	257

^Question not asked in Pehleng

In the Diversity and Flexibility regression model, fishing and harvesting daily has a positive effect on the index. All things held equal, daily fishing/harvesting increases the diversity and flexibility index of an average respondent's household by 2.98 ($p=0.098$). Just over half of respondents reported that their household had developed new ways to use coastal and marine resources in the last five years. From the focus group discussions, it was found that fishers are willing to change fishing efforts and have learned to adapt from their experiences with natural disasters in the past (e.g. typhoons). Their adaptations include increasing time of fishing, harvesting smaller fish, going after pelagic fish, changing fishing methods or locations, and accessing other foods and resources. Men are "*fishing further and deeper"* (Male FGD participant, Pehleng, 2017), and there are "*more women fishing now than in the past"* (Village leader, Pehleng 2017).

While fishers are willing to adapt by supplementing income with alternative livelihoods, they recognized that options to generate cash are few. Salaried jobs on islands are limited [55, 56] (Bureau of Labor Statistics, Department of Labor, Government of Guam 2020; Moody's Analytics 2020). This is reflected among all the surveyed respondents with an average of 36% relying on governmental jobs. In Guam, this figure increases to 45% across the two sites, where 33% of respondents also report relying on public assistance for food. Age may also be a limiting factor in having greater diversity and flexibility, as households with leaders over 40 years old is a variable that contributes negatively to the diversity and flexibility regression model. All things held equal, the diversity and flexibility index of households with leaders over 40 decreases by 2.82 ($p=0.05$). One third of surveyed fishers would be willing to stop fishing for a more secure way of living. However, other fishers showed hesitation to abandon fisheries. A resource manager captured the situation in the following statement: *"even though*

we have seen a drastic decline in fish populations, it's really hard for us to just stop fishing so we have to find a balance somewhere, which is why the word sustainability is very important. We are to use it but use it in a sense that it still sustains itself" (Coastal and marine resource manager, Pohnpei, 2017).

4.2 Access to assets

In all sites, natural and social assets are critically important. Most of the livelihood activities for both income and subsistence are heavily reliant on local natural resources. Of the respondents in all four communities, 83% felt that they have access to the land and sea that they can use for their livelihood. Just under 25% of respondents indicate that their most important livelihood activity has been negatively impacted by external threats in the last five years, with respondents whose households are dependent on coral reefs being more likely to have this sentiment when compared to those who do not depend on coral reefs (X^2=10.00, $p<0.01$). When asked what they would do for food and income if their current job/livelihood were not available, slightly over half of all answers related to natural resource-based livelihoods, such as fishing and farming. However, the degradation of these local resources demonstrates the vulnerability of this adaptation. Perception results based on all methods in this study and biological monitoring (including fish biomass and fish size) firmly concluded that the fish and marine resources are decreasing in size, number, and variety [49, 53, 57] (Houk et al. 2018; Rhodes et al. 2018; Heenan et al. 2017), including indicated household favorites (e.g. parrotfish, rabbitfish, unicornfish).

Strong social networks are evident and another critical asset across Micronesia. Seventy percent of the respondents agreed that community members work well together during natural disasters or difficulties, and 92% of respondents agree that they can rely on friends, relatives, and other community groups during difficult times. For example, 70% of respondents indicate that they can get seafood from friends and relatives if they do not have it. Respondents were also asked what they would need if they were unable to do their current job or livelihood, and 84% said "support from relatives and friends." During disasters, access to social networks plays an important role in recovery. The types of assets with the least access are support from government or leaders (41%) and funding (52%).

4.3 Learning and knowledge

These communities have clearly observed climate change-related threats, including coral bleaching, coastal erosion, and fisheries degradation. Eighty-nine percent of respondents agree that they are willing to learn and do things differently in response to climate impacts and hazards. Focus group participants expressed uncertainty regarding what causes climate change and how to respond. Interviews with community leaders and fisheries resource managers indicate that the levels of understanding of climate change and of its links to changes in fisheries resources are quite limited, and the community leaders emphasize needs for scientific information that will improve climate literacy. "*I would say the number one and most effective ways to regulate fishing is to educate people so they know the adverse effect of climate changes affecting fisheries now" (Village leader, West Fanif, 2017).* However, there seems to be a disconnect between scientific information and its accessibility by communities.

Ninety-one percent of respondents agreed that their household members have knowledge and skills to use local land and sea resources to support their families. Nevertheless, in a scenario where they were unable to do their current job/livelihood, those who fish almost daily indicate higher levels of need for knowledge/skill training (X^2=9.01, p<0.01) and funding (X^2=7.47, p<0.01) when compared to those who do not fish almost daily.

Sharing of information and skills through social networks, including among friends and family and across generations, is prevalent in all sites. Main sources for new skills and knowledge for their livelihoods are "family" (94%), "friends" (77%), and "other community members" (52%). More formal sources of information like government and educational institutions received much fewer responses, at 23% and 25%, respectively (Figure 4).

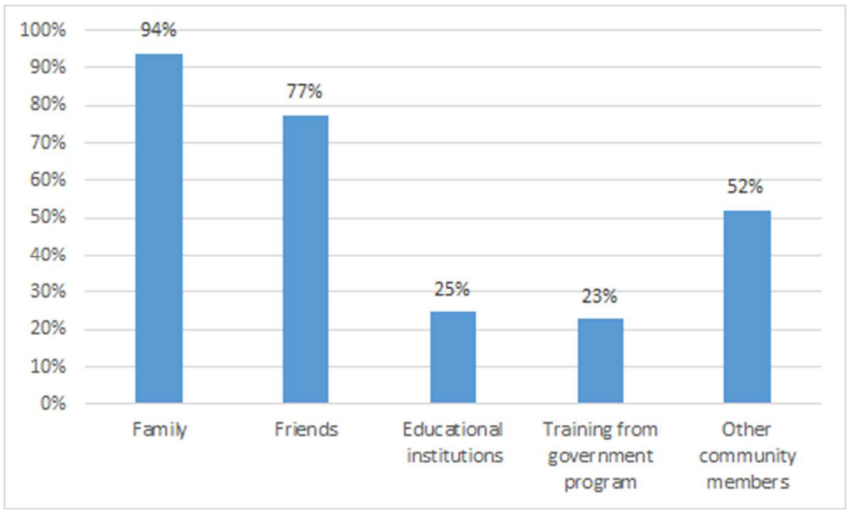


Figure 4: Who or What Respondents Rely on During Difficult Times (n=255)

Regarding traditional knowledge, 86% of respondents agreed that local and traditional knowledge for managing and sustaining fisheries in their families are passed on from elders and parents to young people. While 77% of respondents say that they use traditional practices to help adapt to changing climate, there is also recognition among focus group participants that the magnitude and nature of the changes are unprecedented. Seventy-four percent of respondents agreed that traditional knowledge and practices helped their communities successfully cope with climate events and impacts in the past. When it comes to using traditional practices for the same purpose today, the agreement dropped to 54%, with women (73%) agreeing at higher rates than men (51%).

In terms of formal education, the number of members per household who cannot read or write contributes negatively to social adaptive capacity in three out of the five models (diversity and flexibility, access to assets, and overall social adaptive capacity). All things held equal, an extra household member that cannot read or write decreases the social adaptive capacity index of the average respondent's household by 1.57 (p=0.02). This makes informal approaches to sharing knowledge (e.g. through verbal or visual communications) within social networks even more important. However, the number of college-educated household members also contributes negatively to social adaptive capacity in all five regression models. All things held equal, an extra college-educated household member decreases the social adaptive capacity

index of an average respondent's household by 1.93 ($p<0.01$). To investigate this finding further, Spearman correlation analysis is used to examine relationships between the number of college graduates in a household and their perceptions of traditional knowledge and practices. It is understood using traditional ecological knowledge can increase the resilience of coastal communities [35] (McMillen 2017). The findings from the Spearman correlation analysis show a negative correlation between the number of college graduates in the household and agreement with all the statements related to traditional knowledge and practices, indicating that households with more college-educated members more often lack the knowledge and skills needed to employ traditional local knowledge and practices:

- "In my family, local and traditional knowledge for managing and sustaining fisheries are passed on from elders and parents to young people" (Spearman rho = -0.16, $p<0.01$)
- "In the past, traditional knowledge and practices helped our community to successfully cope with climate events and impacts." (Spearman rho = -0.11, $p=0.09$);
- "Today, traditional knowledge and practices are adequate to help us now successfully cope with climate risks and impacts" (Spearman rho = -0.33, $p<0.01$).

4.4 Governance and institutions

Fisheries governance systems differ across these sites. West Fanif has the strongest traditional fisheries governance with sea tenure still being respected and practiced. In Pohnpei, where open access and Marine Protected Area (MPA) violations are common as there is no effective enforcement outside of a few community-based monitoring programs, fisheries management has been supported by non-governmental conservation organizations. In spite of struggles with fisheries management, there have been several efforts to protect local fisheries resources in the Guam study sites. For example, the community-initiated Achang Reserve in Merizo and Bill 86-34 (Marine conservation Act of 2018) which proposed Umatac as the first community-based fisheries management area in Guam, and was passed by 34th Guam Legislature (Guam Legislative Session Voting Record, Second Regular Session. 2018). While the actual long-term participation of the communities in the fisheries management efforts and their success will need to be examined, at least 62% of all respondents in the study sites, with 96% in West Fanif agree that fisheries management benefits their households. Perceptions concerning fisheries being managed sustainably are mixed with 35% of respondents disagreeing and 48% agreeing. Support and awareness for site-specific management options are moderate to high throughout all sites. These include mangrove preservation and an MPA in West Fanif; fish size regulations, seasonal closures for turtles and for groupers in Pehleng, and the Bill 86-34 for Umatac (Table 5). The need for leadership to address effective fisheries governance and climate adaptation are expressed very clearly in the focus groups and interviews.

Table 5: Support for Management Options in Each Site

Management Option	West Fanif (n=52)		Merizo (n=53)			Umatac (n=16)			Pehleng (n=109)		
	Aware	Support	Level of Support			Level of Support			Level of Support		
			Low	*Med*	*High*	*Low*	*Med*	*High*	*Low*	*Med*	*High*
Rang Mangrove Preserve	62%	100%									
West Fanif MPA	89%	100%									
Micronesia Challenge	25%	100%									
Traditional rules on what and when to catch certain species			11%	74%	15%	19%	31%	50%			
Government Preserve Area			19%	66%	15%	38%	19%	44%			
Proposed Bill to give Umatac Village authority to manage their coastal areas^			24%	29%	47%	7%	14%	79%			
Fish size regulation									22%	17%	61%
Seasonal closure for groupers									30%	14%	56%
Seasonal closure for turtle									33%	8%	59%
Marine Protected Areas									23%	6%	71%

^Only 14 respondents in Umatac, and 16 respondents from Merizo responded to this question

Besides declining fisheries resources and degrading habitats, results further show that communities having been highly impacted by erosion have lower levels of social adaptive capacity in the regression models for governance and institutions and overall social adaptive capacity. The negative coefficient associated with being highly impacted by erosion in the governance and institutions model suggests that respondents impacted by erosion feel that agencies responsible for erosion mitigation efforts have room for improvement. All things held equal, being highly impacted by erosion decreases the governance and institutions index of the average respondent's household by 5.42 ($p=0.03$). Another significant finding, four out of five regression models (diversity and flexibility, learning and knowledge, governance and institutions, and overall social adaptive capacity), indicate that being highly impacted by pollution detracts from social adaptive capacity. The magnitude of pollution's negative contribution is greater than that of erosion (a climate-related impact), indicating that anthropogenic stressors are just as important to mitigate. All things held equal, being highly impacted by pollution decreases the governance and institutions index of the average respondent's household by 8.60 ($p<0.01$).

In a regional meeting at the end of the project, representatives from different countries agreed that while fisheries provide critical livelihood opportunities for communities, it had been difficult to strengthen their management or compete for needed resources due to other administrative priorities such as health care and education. Statements in the interviews and focus group discussions further elaborate the lack of financial and human resources, inefficient legal processes, and political will for fisheries governance, such that *"… residents*

recognize a need to have planned, thoughtful, robust fisheries management, but that it takes political will and resources to accomplish" (Fisheries scientist, Guam, 2017).

Perceived compliance with existing fisheries rules and regulations is low in all sites. When asked about the top three reasons why people do not follow the rules, 57% of surveyed respondents cited that protected areas have more fish to catch, 54% cited that people do not care, and 49% reported the need to earn a living with no other alternatives. The rates of reporting violations to any types of authority are low. Reasons include that reporters themselves could also be violating the rules, or may be related to rule-breakers. In one site, relying on marine resources for income is negatively correlated with MPA support (Spearman's rho = -0.20, p=0.04), indicating that those who rely on marine resource extraction for income may not want the government to encroach upon their income generating activities.

Household participation in management planning and decision making was considered critical, but varied greatly across sites, with respondent agreement levels of 27% in Umatac, 41% in Pehleng, 74% in Merizo, and 77% in West Fanif. While men are primarily associated with fisheries, especially pelagic fisheries, through farming and nearshore gleaning women nevertheless contribute to household nutrition and food security [58, 59] (Anderson 2009; Anderson 2015). Also relevant is that women tend to use traditional practices to cope with climate events and impacts more than men, 73% and 51% respectively. The focus group discussions with female fishers revealed that women are an important part of the fisheries value chain, but among the respondents, fewer than half (less than 30% in some sites) agree that women are included in fisheries-related decisions.

4.5 Agency

Effective adaptation requires those who are being impacted to have freedom, willingness, and ability to decide and respond to the changes [15] (Cinner et al. 2018). Evidently, fisheries are deeply connected to all aspects of life and communities care profoundly about the sustainability of their fisheries and climate impacts. Nearly all respondents agree that the reefs and the ocean are a part of their way of life, and 80% agree that fishing is important for their households, and is a part of their identity. Sixty-two percent of respondents agree that they would like their children to be fishers, and 95% of respondents would like to do more to help sustain their fisheries. Surveys revealed high self-rated agency: 83% reported the ability to rely on one's own household during times of trouble; and, 88% were able to take action to respond to climate change impacts on their current job or livelihood activities.

5. Discussion

This study illustrates the strengths of and opportunities to improve social adaptive capacity among fishing communities in Micronesia. The discussion below addresses the social adaptive capacity categories and related policy implications.

5.1 Building sustainable livelihoods with adaptive flexibility and diversity

For generations, Pacific island peoples, including those in this study, have relied on varied and flexible livelihoods to reduce their vulnerabilities [60, 61, 62, 63] (McMillen et. al 2014; Severence et al. 2013; Pomeroy 2013; Campbell 2009). However, due to the increasing degradation of marine resources, and limited existing salaried employment, alternative and further diversified livelihoods have become critically necessary, both to lessen pressures on coastal resources and to reduce vulnerability of the fishers. The challenges include that primarily nature-based livelihoods which provide substantial support for community wellbeing across Micronesia are dependent on weather and climate. While local resources may have sufficed for subsistence activities, alternative cash income-generating activities will likely require new infrastructure, knowledge, capital, and other assets.

Regression results indicate that engaging in tourism as a form of livelihood increases diversity and flexibility, as well as overall social adaptive capacity. All things held equal, relying on tourism as a form of livelihood increases the social adaptive capacity index of the average respondent's household by 4.16 ($p=0.06$). However, tourism in the region is heavily dependent on climate, knowhow, and infrastructure investments. At the same time, tourism's livelihood potential can be difficult to realize due to uncontrollable external factors as the global economy, international travel, and situations within visitor countries; and may be an uncertain strategy in the age of SARS-COV-2 [64] (Leal Filho et al. 2020). These have been key points of discussion for many resilience and vulnerability assessments for small islands [1] (IPCC 2019). Suggestions from interviews and focus groups also pointed to the challenges for developing aquaculture (e.g. for sponge, rabbitfish, and pearl oyster) and marketing its products [65, 66] (Adams et al. 2001; Ponia 2010), even though it may afford additional income sources and contribute to improved food security.

Policies, institutions, and processes are needed to strengthen sustainable livelihood and reduce vulnerability, including natural, human, social, physical and financial assets [67, 68, 69] (DFID 2000; Neely et al. 2004; and IMM 2008), and should particularly focus on daily fishers who will have the greater need for skill training and financial support for alternative livelihoods if they are unable to fish as their primary livelihood. Value adding in fisheries production [70, 71] (Bush and Minh 2005; Morrisey 2011), along with innovative livelihood diversification into less natural resource dependent or less climate-sensitive options, could reduce vulnerability and increase resilience. This should include programs that can address age and gender-based variation in livelihood and capability, and which also encourage adaptation. These programs need to be supported with place-based and locally relevant education and training for people of all ages and genders. The private sector and public-private partnerships could play a significant role in developing sustainable livelihoods. Given strong gender roles in livelihood activities, fisheries and adaptation programs should consider the importance of women's agency in food security and household nutrition [72, 73, 59] (FAO 2013; Torell and Nyako 2016; Anderson 2015).

5.2 Managing natural resources as economic and sociocultural foundation

The social statuses and valued identities of fishers as contributors to community wellbeing, and thus individual and collective relationships to fishing, have changed significantly over time. As one focus group participant put it, people *"no longer fish for fish as a fisher"*

(Female FGD participant, Pehleng, 2017). Today, fishing is primarily an extractive economic activity and source of cash income. Commercial overfishing is widely perceived as a threat to fisheries resources along with low regulation compliance and weak enforcement. Poorly enforced commercial fisheries rules allows increased use of highly productive but destructive methods that further degrade resources. Weak governance is one of the main causes of the overfishing that exists. Lack of political will is one of the primary factors characterizing weak governance in fisheries [74] (Carbonetti et al. 2014). Lack of political will manifests itself in a number of ways in fisheries governance. The most visible of these is the inaction of political and judicial leaders in enforcing laws and regulations. Lack of political will may also exhibit itself as a lack of commitment of adequate resources (funds, staff, equipment) necessary to undertake fisheries management and as a lack of interest in or priority for fisheries management or the fisheries sector in general (political and economic marginalization). Several pathways exist to address lack of political will including local leaders with adequate interest to make an effort to coordinate local resources, educating the public by tapping into the local knowledge-base, and cooperation between local and state institutions to ensure workable policies and enforcement.

Regression results indicate that fishing for sale is recognized to contribute negatively to social adaptive capacity in four out of the five models (diversity and flexibility, learning and knowledge, governance and institutions, and overall social adaptive capacity). All things held equal, fishing to sell decreases the social adaptive capacity index of the average respondent's household by 3.15 ($p=0.02$). The study shows that fishers themselves understand well the value of measures to restore resources, but there is a temptation to fish where there are more fish, even in an MPA, when other alternatives are scarce and income is needed to feed their families. Using spearfishing contributes negatively to social adaptive capacity in three of the models (access to assets, governance and institutions, and overall social adaptive capacity). This could suggest that those who spearfish may be well aware of these impacts and perceive this as an unsustainable fishing practice.[1] Spearfishers commonly harvest herbivorous fish that regulate algal growth [75,76] (Bejarano et al. 2013; Lindfield et al. 2014), which further stresses coral reef habitats. All things held equal, using spearfishing as a method decreases the social adaptive capacity index of the average respondent's household by 2.76 ($p=0.095$).

In all the study sites, except those where traditional sea tenure [77, 78, 79] (Johannes 1978; Friedlander 2018; Mulalap et al. 2020) is still relatively intact, fisheries management was perceived as ineffective, and the enforcement of illegal fisheries deemed problematic. Community-based approaches and traditional practices, such as seasonal closures for important species and size limits, have proven to help sustain the resources, and reviving these practices has been identified as a goal by the communities. Given how important fisheries and their associated habitats are for ecosystem service production in Micronesia, governments need to prioritize fishery management and policies that strengthen ecosystem approaches to fisheries management [80] (Secretariat of the Pacific Community, 2010), both to address anthropogenic issues, and to better prepare for climate change impacts on fisheries,

[1] In March 2020, a law was passed to prohibit fishing with the use of a self-contained underwater breathing apparatus (scuba) and similar devices in the waters of Guam or in any vessel in the waters of Guam.

ecosystems, and livelihoods. Government also needs to provide adequate resources (funds, staff, equipment) necessary to undertake fisheries management.

The adaptation of fishing households towards increasing fishing effort is a negative one and highlights the need for community-based fisheries co-management as locally managed marine area (LMMA) based on a plan developed through a participatory process to address the unsustainable fisheries practices. Collaborative management has been shown to be a desirable tool for fisheries management in the region where communities and non-governmental organizations serve as critical partners, and have shared roles and responsibilities for protecting local resources. As a key informant has stated: *"They [communities] need to be part of a solution that involves resource agencies and policy makers to really address the fisheries issues" (Reef scientist, Guam, 2017).* Co-management must go further to recognize the specific roles that women and men have in managing various aspects of the fisheries and marine resources, and to foster increased participation by women in decision-making and fisheries management.

5.3 Maintain social networks, social learning, and collective action

Strong social networks are valuable assets for mobilizing and supporting communities in dealing more effectively with climate change challenges [81] (Dacks et al. 2020). In the study communities, the strength of existing social networks are highly important for all aspects of social adaptive capacity. Families and friends are fundamental sources of support for food, knowledge and learning, assistance during disasters and difficulties, and agency empowerment at all levels. Willingness to learn from their social networks can result in shared understandings that provide a basis for collective actions and decision making to increase adaptive capacity [82, 83] (Keys et al. 2014; Eakin et al. 2011). The current networks, which primarily include family, friends, and other community members, could expand to cover other actors such as scientists and resource managers. A diversity of actors can increase the quality of social networks and can trigger social learning, both within the community and between the community and partners or groups peripheral to the community [82] (e.g. Keys et al. 2014). Taking into account gender roles and social inclusion will enhance the impacts of collective social action [84] (Anderson et al. 2009). Maintaining social networks is thus a means to strengthening adaptive capacity, reducing vulnerability to climate change, and implementing fisheries management.

Other critical needs identified by focus group participants are those for a champion to link communities, government and other stakeholders, and a community disaster team/committee that is supported by science and those with resources. Government and community leaders themselves need to take active and proactive roles supporting efforts to incorporate climate change impacts into fisheries management planning, providing relevant information and other resources to the communities, and becoming reliable nodes, especially during difficult times.

5.4 Learning, traditional knowledge, and formal education

Eighty-nine percent of respondents agree that they are willing to learn and do things differently in response to climate hazards. Those who report experiencing typhoons

documented having to learn how to successfully cope with the disaster, support one another and persist in living their lives. Overcoming prior disaster-related challenges has contributed positively to social adaptive capacity in four of the five models (diversity and flexibility, access to assets, governance and institutions, and overall social adaptive capacity). All things held equal, having been highly impacted by a typhoon increases the social adaptive capacity index of the average respondent's household by 5.55 ($p<0.01$). Focus group discussions of typhoons support this finding as well: *"can adapt because they know what needs to be done"* (Village leader, Umatac, 2017). In short, the capacity to learn is highly important and positively affects community adaptive capacity [83] (Eakin et al. 2011), especially when this is coupled with strong social networks. In a similar manner, knowledge about fisheries (e.g. seasonality, species presence) passes through generations, and there are many examples in the literature of fishing knowledge increasing community resilience [60, 63] (McMillen et al. 2014; Campbell 2009).

Local and traditional knowledge for managing and sustaining fisheries, along with traditional practices useful in adapting to changing climate are prevalent in Micronesia [85, 86] (Nunn et al. 2017; Perkins et al. 2018), and are still being passed on from the elders to the younger generation, often along gendered divisions of labor and roles in fisheries, and are employed by the majority of respondents' households [85, 87, 84] (Nunn et al. 2017; Kronen and Vunisea 2009; Anderson et al. 2009). However, the use of traditional knowledge and practices to help communities successfully cope with climate impacts are much lower today than in the past. This indicates that other types of knowledge and actions may be needed. Combining local traditional knowledge and scientific information is seen by focus group participants as an effective strategy for addressing climate change impacts: *"We cannot use traditional solutions for modern problems. That's where the two knowledge(s) needs to come together in addressing some of these management practices"* (Coastal and marine resource manager, Yap, 2017). Policies should strengthen the knowledge and awareness of climate change impacts through education and outreach, with the aim of increasing preparedness and the adaptive capacity of individuals and households in relation to their impacts on fisheries and coastal resources. To be effective, adaptation education programs must actively consider locally gendered divisions of labor and roles in fisheries value chains and natural hazards, while being mindful of benefits and consequences to communities [87, 58, 84, 88] (Kronen and Vunisea 2009; Anderson 2009; Anderson et al. 2009; Lau et al. 2021).

The findings discussed in Section 4.3 indicate that the number of college-educated household members contributes negatively to social adaptive capacity in all five regression models, and that having more college-educated household members is negatively correlated with the use of traditional knowledge and practices. These findings suggest that the lack of understanding and using traditional ecological knowledge may outweigh the benefits of formal educational attainment in contributing to social adaptive capacity among these particular households with higher levels of college-educated household members. This result was further examined in consultation with community experts who explained that formal higher education does not necessarily equip people with the diverse range of place-based knowledge and skills that would prepare them to make use of local resources if they had to handle a difficult situation on their own, or address daily needs without a store or other supports. Those who completed a college degree most likely have spent a lot more time in urban areas (or even off island)

and away from immediate elders and other more knowledgeable local practitioners. They may have not gained, or have lost, traditional knowledge assets and local social systems that are useful for dealing with natural hazards and climate adaptation. The notion of traditional ecological knowledge and practices being effective for enhancing social adaptive capacity to climate change is supported in the literature: Lauer (2017) [34] notes that conservation practitioners have increasingly turned more of their attention to "local islander knowledge and practices" to effectively manage marine environments; and Lauer and Aswani (2009) [89] discusses the merits of "rethinking knowledge" so that indigenous knowledge is on par with Western science as it relates to marine resource management. A significant policy implication of this is that it is important to maintain local knowledge among younger generations and to advance both informal and formal education to ensure useful place-based knowledge is accessible when needed.

The magnitude of pollution's negative contribution to social adaptive capacity in the regression models is greater than that of climate-related impacts (erosion). This suggests that learning and knowledge to find solutions to existing anthropogenic problems are equally important if social adaptive capacity is to be strengthened. In addition to climate literacy, future efforts to understand and address the feedback loops between pollution and social adaptive capacity should be targeted.

6. Conclusions

Understanding the complex dynamics required to sustain or advance social adaptive capacity is both difficult and necessary. This study developed an quantitative and qualitative approach to assess it in four fishing communities in Micronesia. The results help to better understand the different characteristics of social adaptive capacity of the fishing households in relation to climate change and other environmental threats, and afford important insights for managers and policymakers committed to increasing the resilience of these communities and ecosystems in the face of climate change. Key findings regarding the ability of people to adapt in the face of challenges and their levels of agency in addressing risks include: the importance of alternative and diversified livelihoods to fisheries, the power of social networks, the value of traditional knowledge combined with scientific information, and the need to develop effective sustainable fisheries management that engages multiple stakeholders. Social adaptive capacity will directly affect the success of fisheries management actions and policies, and understanding it is essential for identifying strategies to address climate change impacts, and for effectively prioritizing conservation investments to maximize social and ecological benefits.

Acknowledgement
The authors acknowledge the project funding from the Saltonstall-Kennedy grant program of the U.S. National Oceanic and Atmospheric Administration (NOAA) Fisheries. We are grateful for the information provided by the fishers and other participants in the survey, interviews, focus groups, result presentations, and communications workshop. We thank especially the project site coordinators and Amanda Dillon for her assistance with the graphic design of the map.

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