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Climate Change Awareness and Risk Perceptions in the Coastal Marine Ecosystem of Palawan, Philippines

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ABSTRACT

Understanding the coastal communities' awareness and risk perceptions of climate change impact is essential in developing effective risk communication tools and in developing mitigation strategies to reduce the vulnerability of coastal communities. In this study, we examined the coastal community's climate change awareness and risk perceptions of climate change impact on the coastal marine ecosystem, sea level rise impact on the mangrove ecosystem, and as a factor affecting coral reefs and seagrass beds. The data were gathered by conducting face-to-face surveys with 291 respondents from the coastal areas of Taytay, Aborlan, and Puerto Princesa in Palawan, Philippines. Results showed that most participants (82%) perceived that climate change is happening and a great majority (75%) perceived it as a risk to the coastal marine ecosystem. Sea level rise was perceived by most participants (60%) to cause coastal erosion and affect the mangrove ecosystem, but they also perceived that coastal erosion can be prevented by mangroves. On coral reefs and seagrass ecosystems, anthropogenic pressures and climate change were perceived to have a high impact, while marine livelihoods had a low impact. In addition, we found that climate change risk perceptions were influenced by direct experiences of extreme weather events (i.e., temperature rise and excessive rainfall), and climate-related livelihood damages (i.e., declining income). Climate change risk perceptions were also found to vary with household income, education, age group, and geographical location. The results suggest that addressing poverty, and effectively

communicating climate change risks can improve climate change awareness and risk perceptions.

Keywords: climate change awareness, risk perception, exposure, experience, impact, policy

1. INTRODUCTION

Climate change is the challenge of our generation. Its impacts can already be seen on human health [1], agriculture, water resources [2], food safety [3], food security [4], and coastal and marine ecosystems [5]. In coastal and marine ecosystems, climate change is causing two important impacts: sea level rise [6] and changing ocean chemistry [7]. Sea level rise is caused primarily by thermal expansion due to the warming of the oceans and melting of land-based ice, such as glaciers and ice sheets. Meanwhile, changes in ocean chemistry are caused by anthropogenic climate drivers including increasing amounts of greenhouse gases and aerosols [8]. The ocean has absorbed over 93% of the excess heat from greenhouse gas emissions [9]. The absorption of greenhouse gases makes the oceans more acidic, making it more difficult for corals to build their skeletons [9]. Aside from acidification, higher sea surface temperatures also increase the risks of coral bleaching, which can lead to coral death and the loss of critical habitats for other species [10]. Understanding the public's perception of these climate change impacts is key to getting public support and fostering collective action for effective climate change adaptation, mitigation, and sustainable resource management [11–13].

In the Philippines, the serious impacts of climate change are becoming more apparent, thus the need for mitigation and adaptation to climate change has become an urgent public concern. The Philippines is one of the most vulnerable countries to sea-level rise and its impacts due to its numerous low-lying coastal areas. Seven out of 25 cities most vulnerable to a 1-m sea level rise are in the Philippines [14]. Based on the Marine Geological Survey Division report, from 1992 to 2011, the rate of sea level rise in the Philippines was 5.8 (± 0.6) mm per year [15]. This is faster compared to the global rate of sea level rise averages of 3.3 (± 0.4) mm per year [16]. At the current rate of sea level rise, it would lead to the inundation of more than 167,000 ha of coastal land (about 0.6% of the country's total area) and 171 towns, as well as the displacement of 13.6 million Filipinos [17]. In Palawan particularly, which ranks second among the provinces in the Philippines as most vulnerable to sea level rise [18], the declaration of the province as a UNESCO Biosphere Reserve (BR) is one way of mitigating the impact of climate change [19]. The province's 1-m rise in sea level is projected to inundate 6,428.16 ha of land [15]. The results of the Marine Geological Survey Division survey suggest that the island municipalities of Palawan are moderate to highly susceptible to coastal erosion [15].

Previous research in Palawan has explored adaptation strategies for enhancing climate resilience at the local level [20], assessed long-term climate variability's effects on coral reefs' biophysical conditions [21], and studied fishers' perceptions and adaptation capacities [22]. To better mitigate and adapt to climate change impacts in the province, further understanding of the community's awareness and risk perceptions can provide a complete picture on which we can base conservation decisions and environmental management [23]. Moreover, this could lead to greater participation, more suitable management measures that fit the capacities of the involved stakeholders, and ultimately, faster restoration of marine resources [24]. In Asia, the most important indicator of risk perception of climate change impacts is local temperature change [25,26], whereas globally, climate change awareness is determined by educational attainment [25]. Furthermore, personal experiences of other extreme weather events and impacts of climate change also influence climate change risk perceptions [27–29], as well as socio-demographic characteristics which include gender, income [25,26], age [30], and geographical location [31,32]; and occupation [26]. However, studies on climate change awareness and risk perceptions of climate change impacts on the coastal marine ecosystem, particularly in Palawan, are less explored.

The present study focuses on climate change awareness and risk perceptions of the impacts on coastal communities. Public opinion research finds that climate change awareness varies greatly [25]. The study on risk perceptions will focus on the climate change and sea-level rise impacts in the coastal marine ecosystem which includes the mangrove areas, as well as the climate change and anthropogenic pressures' impact on the coral reefs and seagrass beds [25,33]. This is a part of a larger survey of the GCRF Blue Communities project that aims to investigate the complex impacts of changes in the regulatory backdrop of marine spatial planning for coastal communities located in and around UNESCO Biosphere Reserves and Marine Protected Areas (MPAs) across Southeast Asia. It was formed as part of Project 6 of the program, which assessed the well-being benefits and risks of coastal living. The study approach was patterned with the ecosystems-enriched Drivers, Pressures, State, Exposure, Effects, Actions or 'eDPSEEA' model, which recognizes convergence between the concept of ecosystems services that provides a human health and well-being slant to the value of ecosystems while equally emphasizing the health of the environment and the growing calls for 'ecological public health as a response to global environmental concerns [34]. Specifically, the four research objectives we aimed to address were as follows: (i) whether the participants are aware that climate is changing or not; (ii) whether they have observed or experience climate change impacts or not; (iii) whether climate change and sea level rise affect the coastal ecosystem; (iv) whether climate change, anthropogenic pressures and marine livelihood affect the state of coral reefs and seagrass beds. Answers to these questions will contribute to the knowledge gap in understanding the climate change awareness and risk perceptions of the coastal communities to design more effective mitigation measures to address climate change impacts at the local level and for policies, programs, and activities aimed at building resilience to climate change and managing marine resources.

2. MATERIALS AND METHODS

2.1. Study Area and Sample

The Palawan province, known as the "last ecological frontier" of the Philippines, is an archipelago composed of the main island and more than 1,700 islands [19]. Its coastal marine ecosystems include coral reefs, seagrass meadows, mangroves, and several marine mammals [19]. The province was declared as Mangrove Reserve Swamp in 1981 by virtue of Presidential Proclamation No. 2152 for having the largest remaining mangrove forest in the country which was estimated at 63,532 hectares in 2010 [35]. In 1991, it was also declared by UNESCO as a Biosphere Reserve to serve as a learning area to promote sustainable development and conservation of biodiversity [19]. The projected population of Palawan in 2022 is 1,254,111 [36]. The major economic activities are agriculture, fisheries, tourism, on-shore, and off-shore mining, gathering of minor forest products, and pearl farming [19].

The three study areas are Aborlan, Puerto Princesa City, and Taytay (Fig. 1). Aborlan is a coastal municipality located in the southern part of the province; Puerto Princesa City is a highly urbanized coastal city located in the central part; while Taytay is a coastal municipality located in the northern part. Ten (10) coastal villages from these areas were chosen as study sites. In the simulation conducted by Lapidez et al. (2015), it was shown that Palawan, due to its low coastal elevation zones is one of the most vulnerable provinces in the Philippines to coastal flooding [37]. In the climate change exposure map from the Department of Environment and Natural Resources (DENR), it was shown that Aborlan, Puerto Princesa City, and the rest of southern Palawan are vulnerable to sea level rise; while Taytay and the rest of Northern Palawan are vulnerable to extreme heating events, unstable water supply, and sea-level rise [38]. Additionally, Taytay and the rest of northern Palawan is a "hotspot areas of exposure to climate hazards", with extreme human sensitivity to climate change [35]. Puerto Princesa City and Aborlan were also identified as highly vulnerable to landslides. Furthermore, Puerto Princesa City has the highest population vulnerable to storm surges [39]. In addition, both areas have mainstream economic activities including airports, seaports, malls, schools, and populated urban areas on the east coast where storms land first, making them more vulnerable. The province is the largest producer of seaweed in the country, and Taytay is one of the main producers of the province [40]. The most recent onslaught of Typhoon Odette caused unprecedented losses to seaweed farmers, which environmentalists identified as an escalating issue fueled by climate change [40].

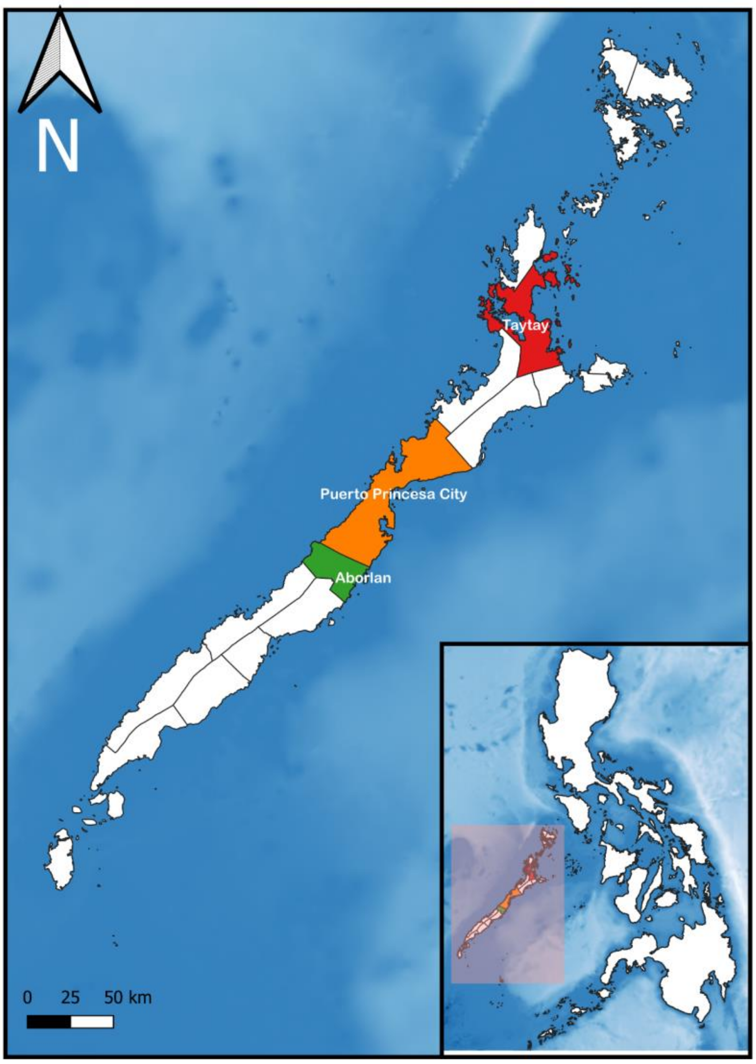

Figure 1. Map of Palawan showing an inset of the Philippines, with Palawan highlighted with a light red shade. Aborlan, Puerto Princesa City and Taytay are highlighted in green, orange, and red colors, respectively.

Thus, due to the vulnerability of the chosen study areas, they are ideally suited to explore how coastal communities perceive climate change and anthropogenic pressures that impact the coastal marine ecosystem.

The target populations were households within coastal marine areas in our three selected study areas, and the respondents were restricted to 18 years old and above. Literacy rates among the target populations were variable which is why we decided to use a face-to-face survey, rather than self-completion. However, it was evident during the stakeholder workshops and discussions that they have good knowledge of the local environmental conditions and causes, so the topics of the survey were more familiar to them.

2.2. Survey procedure

The survey was divided into 4 questions (See supplementary material 1). The first question aimed to understand if the participants believe that the climate in the locality was changing, using a semantic differential (bipolar) response rating scale with anchor points (1) “fully disagree” to (7) “fully agree”. The second question sought to understand the participants' observations and experiences of the various climate change impacts, using a semantic differential (bipolar) rating scale with anchor points (1) “very low” to (7) “very high”. The third focused on perceived risks of climate change impacts on the coastal areas using a semantic differential (bipolar) rating scale with anchor points (1) “fully disagree” to (7) “fully agree” while the fourth question explored participants' perceived risks of climate change impacts and anthropogenic pressures on coral reef and seagrass ecosystems, using a semantic differential (bipolar) rating scale with anchor points (1) “very low” to (7) “very high”.

A two-stage pilot testing was conducted to ensure that participants would understand the questions. An in-home face-to-face survey was conducted using a Computer Assisted Personal Interviewing (CAPI) method, employing a tablet computer (Samsung Galaxy Tab A) with a pre-loaded questionnaire available in Filipino and English languages. The questionnaire was formatted using free data collection software (KoBo Toolbox v.2).

The development of the survey was through a co-creation approach, with most of the content emerging from discussions and workshops with local stakeholders. The survey was drafted in line with the eDPSEEA model which integrates human health and environmental impact on the ecosystem [34]. The finalized survey was quite complex as it contained all aspects of the eDPSEEA model. In this study, the focus was only on climate change awareness and the perceived climate change risks in the coastal areas of Palawan.

2.3. Data Analysis

SPSS version 26.0 for Windows was used for all data analyses. The relationships analyzed were the influence of the "Exposure" and "Effect" (as per the "eDPSEEA" model) on the perception of climate change impacts on the coastal communities (Fig. 2). Descriptive statistics (mean, standard deviation, and standard error) were used to analyze and organize the characteristics of the data.

An Exploratory Factor Analysis (EFA) using Principal Component Analysis (PCA) was used to reduce data on risk perceptions of climate change impact in the coastal areas (6 variables) and on the risk perceptions of factors affecting coral reefs and seagrass beds (17 variables), to a smaller set of summary variables (factors) and to explore the underlying theoretical structure relating to these perceptions (Supplementary Table 1 & 2) [41]. To confirm if PCA was suitable, the Kaiser-Meyer-Olkin (KMO) value was set at ≥ 0.70 to indicate good sampling adequacy, and Bartlett's Test of Sphericity was set at $p < 0.001$ to confirm highly significant correlations among the variables [42,43]. The number of the retained factors was based on the criterion of the eigenvalue (> 1.0) and examination of the scree plots. The retained factors underwent reliability analysis with Cronbach value set at $\alpha \geq 0.70$ to indicate good internal consistency [44]. Finally, we used linear regression to analyze the relationships between the risk perceptions of climate change impacts and the predictors [45]. The risk perceptions of climate change impacts based on PCA factoring will be the outcome variables, while the personal experiences of climate-related events and socio-demographic variables will be used as predictor variables (see Supplementary Tables 1 & 2 for groupings).

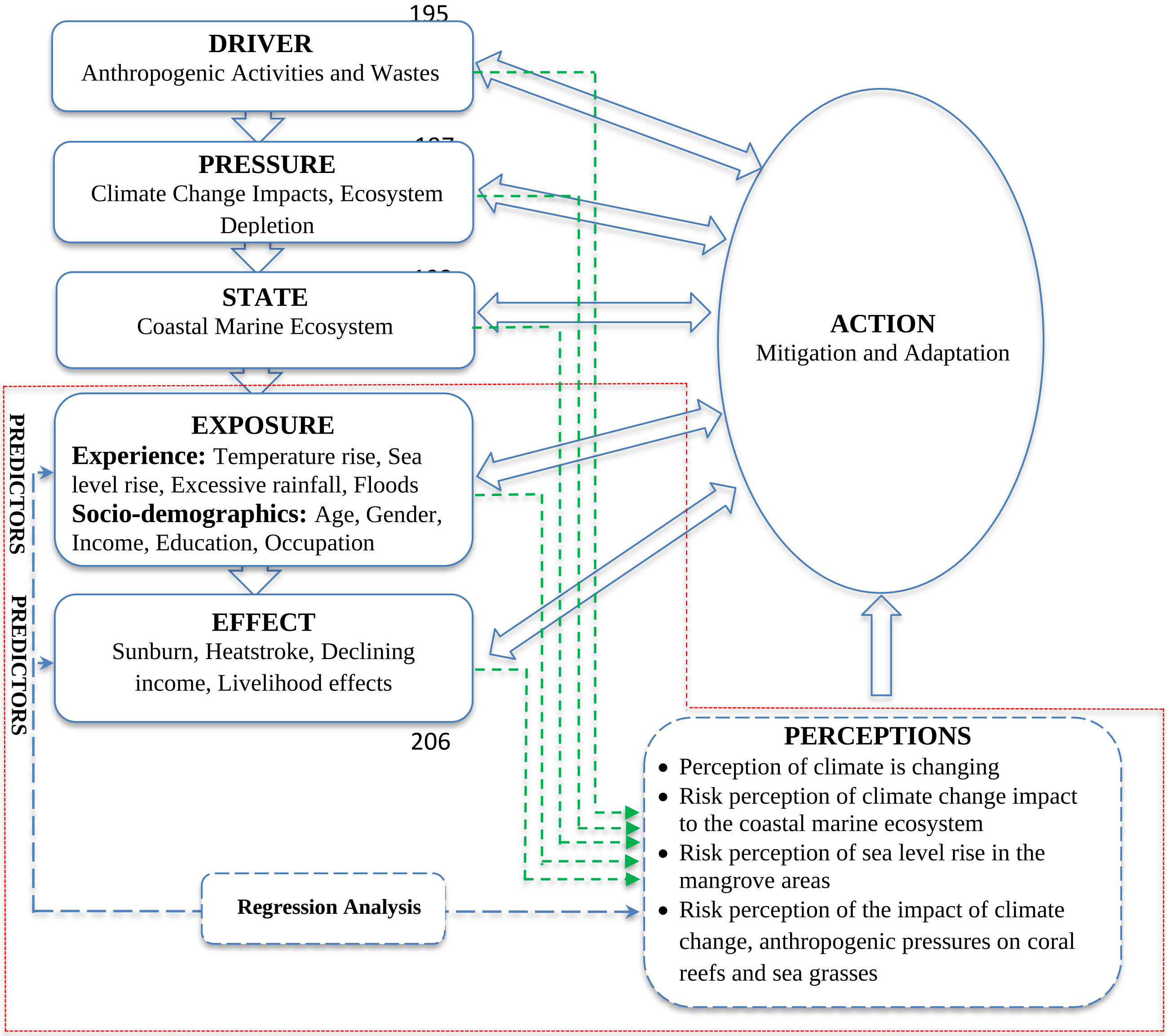

Figure 2. Conceptual framework used in data analysis of the relationship between Predictors and Risk Perceptions of Climate Change Impacts based on eDPSEEA model. (Analysis is focused only on the highlighted, red-dotted line.)

On the risk perception of sea level rise impact on the mangrove areas, we used an additional test (paired samples t-test) to determine if the presence of mangroves compared to the absence of mangroves had a significant effect on risk perception of sea level rise impact. This was followed by calculating the effect size using Cohen's D.

3. RESULTS

3.1. Socio-Demographics

A total of 291 respondents participated (Table 1) across 10 barangays: two barangays in Aborlan, four in Taytay, and four in Puerto Princesa City, with a higher number of females (59.1%) than males (39.5%). The higher percentage of female participants was in part due to

Table 1. Socio-demographic characteristics of the respondents (n = 291)

Category	Aborlan (n = 61)		Puerto Princesa (n = 68)		Taytay (n = 162)		Total Sample (n = 291)	
	N	%	n	%	n	%	n	%
Gender								
Female	33	54.1	44	64.7	95	58.6	172	59.1
Male	27	44.3	23	33.8	65	40.1	115	39.5
Missing Data	1	1.5	1	1.5	2	1.2	4	1.4
Income								
Poor (< $ 196.70 / mo.)	47	77.0	47	69.1	121	74.7	215	73.9
Not Poor (≥ $ 196.70 / mo.)	9	14.8	18	26.5	30	18.5	57	19.6
Missing Data	5	8.2	3	4.4	11	6.8	19	6.5
Age								
19 – 29	12	19.7	10	14.7	21	13.0	43	14.8
30 – 39	15	24.6	15	22.1	33	20.4	63	21.6
40 – 49	16	26.2	21	30.9	45	27.8	82	28.2
50 – 59	10	16.4	12	17.6	31	19.13	53	18.2
60 – 99	7	11.5	9	13.2	29	17.9	45	15.5
Missing Data	1	1.6	1	1.5	3	1.9	5	1.7
Education								
Elementary	32	54.2	32	47.8	55	35.3	119	42.2
High School	23	39.0	27	40.3	75	48.1	125	44.3
College	4	6.8	8	11.9	26	16.7	38	13.5
Missing Data	2	3.3	1	1.5	6	3.7	9	3.1
Occupation								
Fisherfolk	53	86.9	57	83.8	142	87.7	252	86.6
Non-Fisherfolk	5	8.2	10	14.7	15	9.3	30	10.3
Missing Data	3	4.9	1	1.5	5	3.1	9	3.1

the time of day the interviews were conducted (morning and afternoon), as many male household members would have left home for work at sea as elaborated in another paper from the same survey [46].

3.2. Climate Change Awareness

Most of the respondents (82%) agreed that the climate in the locality is changing, a small portion disagreed (8%) while the rest had a neutral stance (10%) (Fig. 3). Their socio-demographic characteristics and their personal experiences of climate-related events which may have influenced their awareness that the "climate is changing" were used as predictors. The participants' personal experiences of local temperature rise ($B = 0.17$, $p < 0.05$) and excessive rainfall ($B = 0.17$, $p < 0.05$) were significant risk predictors of climate change awareness showing positive relationship (Table 2). This implies that higher climate change awareness is associated with the experience of local temperature rise and excessive rainfall. In terms of socio-demographic variables, the 40-49 years old ($B = -0.69$, $p < 0.05$) has significantly different climate change awareness compared with the 19-29 years old.

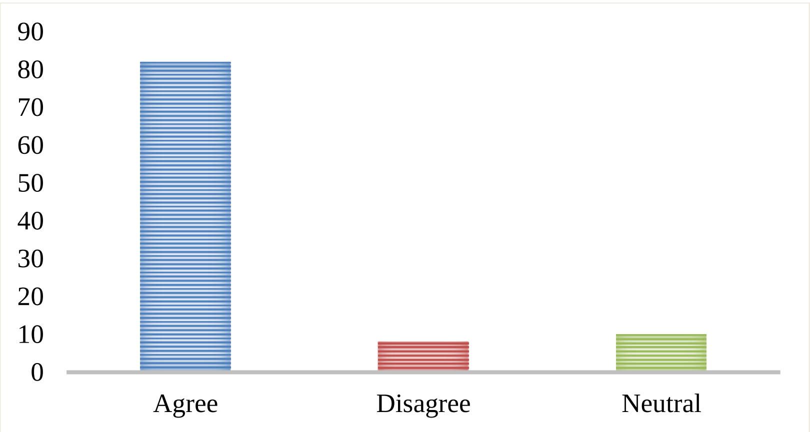

Figure 3. Proportion of participants who perceived that the climate in their locality is changing. (n = 291). (Percentage was based on valid responses).

Table 2. Results of linear regression model exploring the association between participants' personal experience and climate change awareness; personal experience and risk perception of climate change impacts in the coastal marine ecosystem in Palawan, Philippines (standard errors in parenthesis).

Predictors (Experiences)	**Outcome Variables (Awareness and Risk Perceptions)**		
	Climate Change Awareness	**Risk Perception of Climate Change Impact on Coastal Marine Ecosystem [1]**	**Risk Perception of Sea Level Rise Impact on Mangroves Ecosystem [1]**
Constant (B)	4.497 (0.40) ***	4.733 (0.49) ***	3.650 (0.43) ***
Local temperature rise	**0.17* (0.08)**	0.01 (0.09)	-0.03 (0.08)
Sea level rise	0.09 (0.07)	**0.19* (0.09)**	0.36*** (0.08)
Excessive rainfall	**0.17* (0.08)**	0.01 (0.10)	0.07 (0.09)
Floods	-0.06 (0.07)	-0.16 (0.08)	-0.03 (0.08)
Heatstroke	-0.01 (0.07)	-	-
Sunburn	0.06 (0.06)	-	-
Declining income	0.16 (.09)	0.11 (0.10)	-0.14 (0.09)
Livelihood effect	-0.17 (0.09)	-0.13 (0.11)	0.03 (0.10)

****** p < 0.001; * p < 0.05***

[1] Variable obtained from the data reduction method (PCA) see Supplementary Table 1

Note: Heat stroke and sunburn were used as predictors only in climate change awareness.

Table 3. Results of linear regression model exploring the association between participants' socio-demographic characteristics and their awareness; socio-demographic characteristics and risk perceptions of climate change impacts in the coastal marine ecosystem in Palawan, Philippines (standard errors in parenthesis).

Predictors (Experiences)	**Outcome Variables (Awareness and Risk Perceptions)**		
	Climate Change Awareness	**Risk Perception of Climate Change Impact on Coastal Marine Ecosystem [1]**	**Risk Perception of Sea Level Rise Impact on Mangroves Ecosystem [1]**
Constant (B)	6.429 (0.51) ***	4.296 (0.57) ***	4.467 (0.54) ***
Gender (ref = male)	-	-	-
Female	-0.18 (0.22)	**0.69 (0.25) ****	0.25 (0.23)
Education Level (ref = Elementary)	-	-	-
High School	0.27 (0.24)	0.33 (0.26)	0.29 (0.25)
College	0.58 (0.33)	0.64 (0.37)	0.28 (0.34)
Income (ref = poor)	-	-	-
Not Poor	0.28 (0.27)	**0.59 (0.29) ***	-0.24 (0.27)
Occupation (ref = non-fisherfolks)	-	-	-
Fisherfolks	-0.17 (0.36)	0.16 (0.41)	-0.42 (0.38)

Age Group (ref = 19 – 29 years old)	-	-	-
30 – 39 years old	-0.36 (0.35)	-0.12 (0.39)	0.60 (0.36)
40 – 49 years old	**-0.69 (0.33)** *	-0.05 (0.37)	**0.78 (0.34)** *
50 – 59 years old	-0.16 (0.36)	0.57 (0.41)	**1.40 (0.37)** ***
60 – 99 years old	-0.07 (0.38)	0.84 (0.43)	**1.35 (0.41)** ***
Study Sites (ref = Puerto Princesa)	-	-	-
Aborlan	-0.50 (0.32)	-0.15 (0.36)	**-0.76 (0.33)** *
Taytay	-0.27 (0.26)	0.01 (0.28)	**-0.59 (0.27)** *

****** $p < 0.001$; * $p < 0.05$.***

[1] Variable obtained from the data reduction method (PCA) see Supplementary Table 1

3.3. Perceived personal experiences of climate change impacts

Study participants perceived that the most common climate change impact they experienced was local temperature rise, followed by excessive rainfall, declining income, sea-level rise, and livelihood effect. The occurrence of flood, heatstroke, and sunburn was relatively low (Fig. 4).

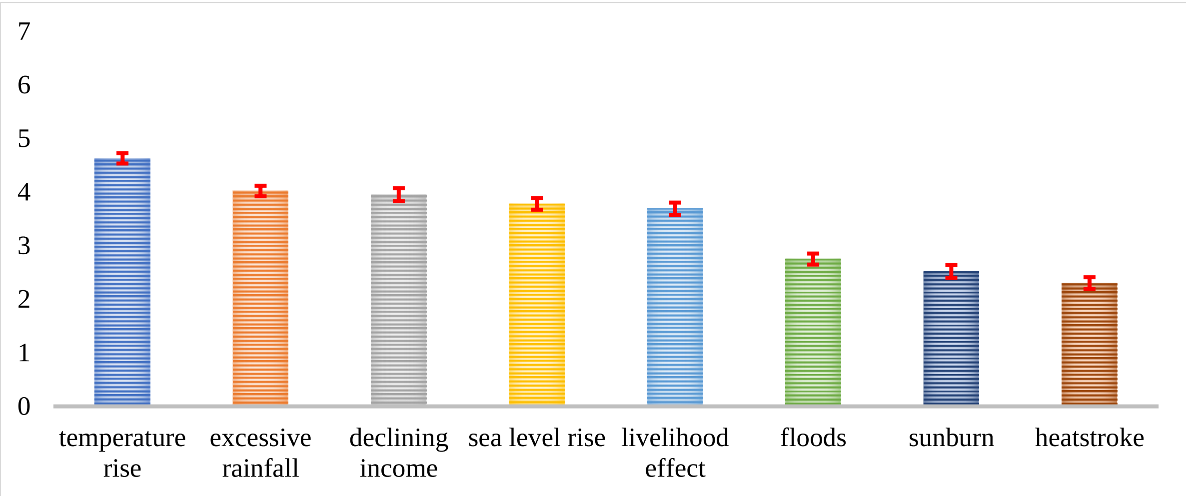

Figure 4. Mean score with standard deviation of the responses to the question "have you observed/experienced the following phenomenon in your area?". The response options provided to the respondents was a bipolar rating scale: 1 = very low to 7 = very high. n = 291 (graph whiskers are standard error of the mean).

3.4. Risk perception of climate change impact on the coastal marine ecosystem

The "climate change impact on the coastal marine ecosystem" factor was a result of the PCA of two variables (Supplementary Table 1). Most of the participants (75%) perceived that "climate change impact" is a risk to the mangrove ecosystem as well as to the function and structure of the whole coastal marine ecosystem (Fig. 5). The personal experience of sea level rise (B = 0.19, $p < 0.05$) was the only significant risk perception predictor of the impact of climate change on the coastal marine ecosystem. Females were also found to have a higher risk perception (B = 0.69, $p < 0.05$) than males. Further, the not-poor group (B = 0.59, $p < 0.05$) had a significantly higher risk perception than the poor group. Other socio-demographic predictors did not show significant differences (Table 3).

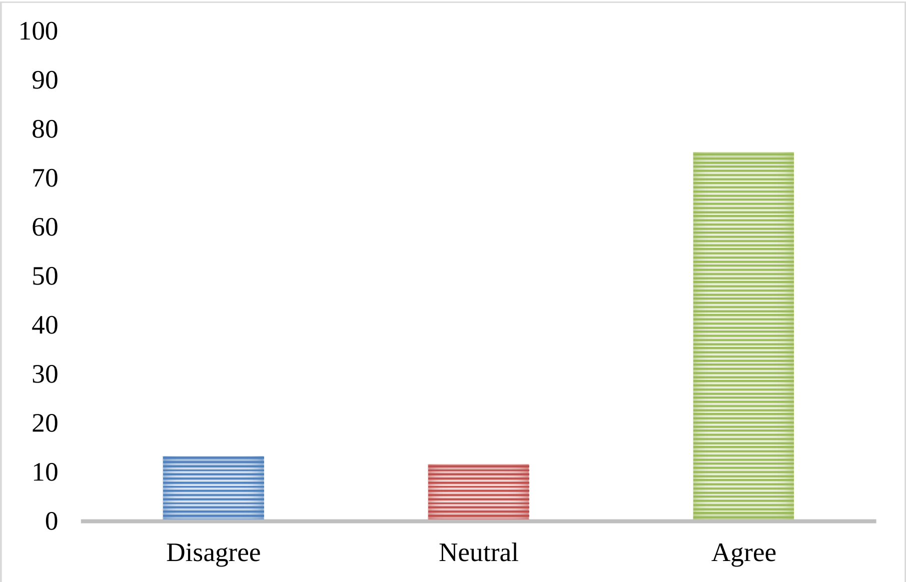

Figure 5. Proportion of participants who perceived that climate change is a risk in the coastal marine ecosystem (n = 291). (Percentage was based on valid responses).

3.5. Risk perception of sea level rise impacts on the mangrove ecosystem

The "sea level rise impact" factor was a result of the PCA of four variables (Supplementary Table 1). In general, the "sea level rise impact" was perceived by many (59.5%) of the participants to cause coastal erosion to areas without mangroves and will affect the mangrove ecosystem, and the sea level is rising regardless of when there is a typhoon (Fig. 6). Analysis of the individual variables in the sea level rise impact showed that 60% agreed that the sea level was rising regardless of typhoon occurrence. Most participants also perceived that the sea level rise had eroded areas without mangroves (61.7%) and that it will affect the coastal ecosystem (64.6%). A considerable portion of the participants (44.5%) also perceived that sea level rise had eroded areas with mangroves (Fig. 7). The impact of sea level rise on coastal erosion based on the participants' perception in areas with mangroves and without mangroves displayed a significant difference; t = -6.65, $p < 0.001$ (Supplementary Table 3). Further, Cohen's d value (d = 0.42) suggested a moderate effect size.

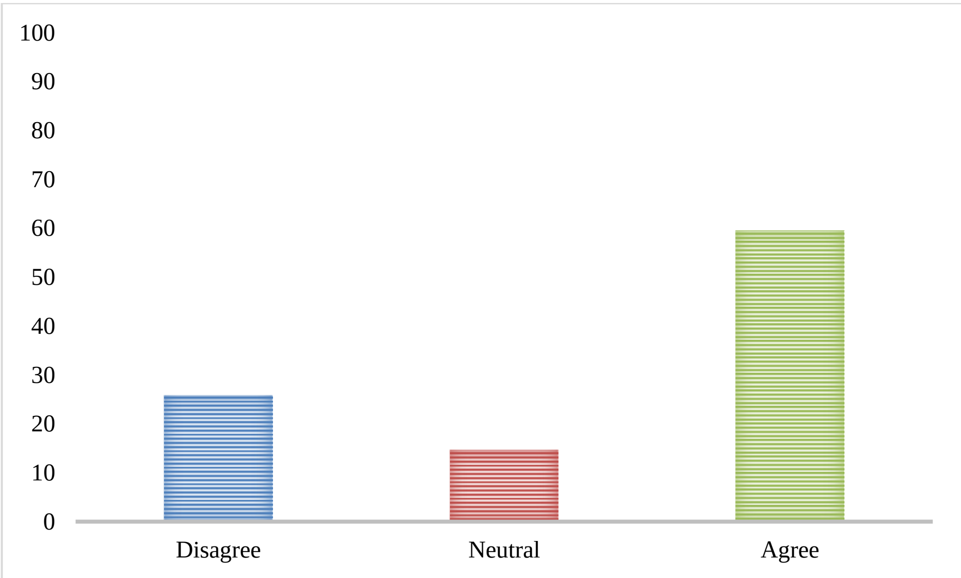

Figure 6. Proportion of participants who perceived "sea-level rise impact" will affect the mangrove ecosystem. n = 291.

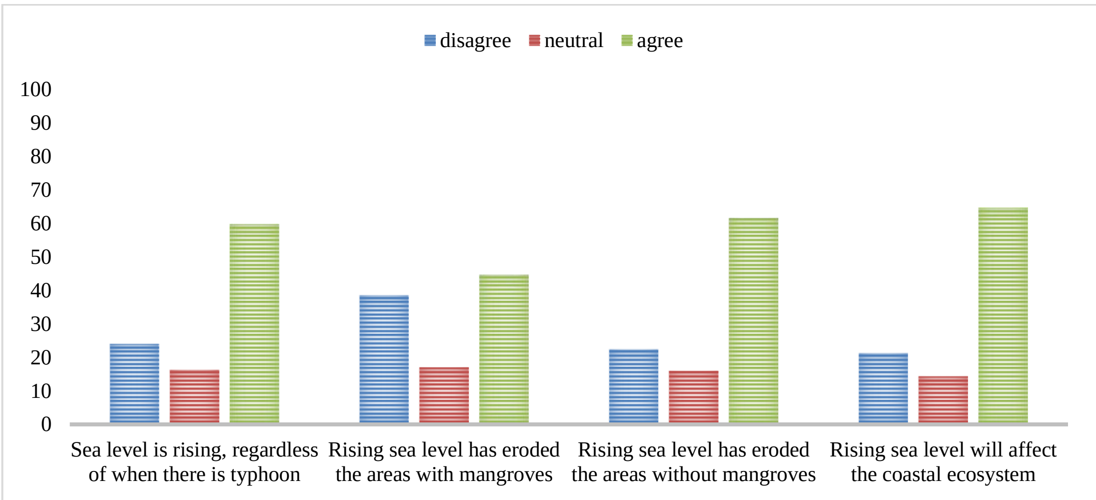

Figure 7. Proportion of participants' risk perceptions on the individual variables regarding "sea-level rise impacts". n = 291

In our analysis, the personal experiences or observations of rising sea level was the strongest predictor of the risk perception of sea level rise impact (B = 0.36, $p < 0.001$). Furthermore, the 60-99 years old (B = 1.35, $p < 0.05$), the 50-59 years old (B = 1.41, $p < 0.05$) and the 40 – 49 years old group (B = 0.78, $p < 0.05$) have a significantly higher risk perception than the 19-29 years old group (Table 3). The study site was also found to influence the risk perception of sea level rise impact as the Aborlan (B = -0.76, $p < 0.05$) and Taytay (B = -0.59, $p < 0.05$) participants have significantly lower risk perception as compared with Puerto Princesa City participants.

3.6. Risk perceptions of the factors affecting the coral reefs and seagrass beds

Three factors affecting the coral reefs and seagrass beds were derived from PCA, namely: climate change impacts, anthropogenic pressures, and marine livelihood (Supplementary Table 2). Results showed that most of the participants perceived the anthropogenic pressures (57.6%) and climate change (50.3%) to have a high impact on the coral reefs and seagrass beds, while marine livelihood was perceived to have a low impact (51.8%) (Fig. 8).

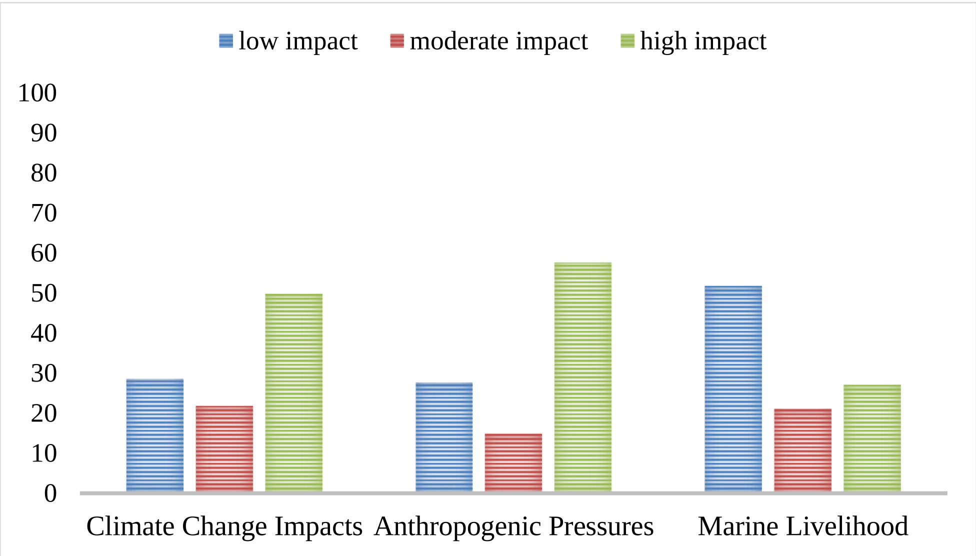

Figure 8. Proportion of respondents who perceive high, moderate, or low impacts to coral reefs and sea grass beds from different drivers. The response options provided to the respondents is a bipolar rating scale: 1 = very low to 7 = very high. Low category included scores 1-3, Moderate category score 4, and High category scores 5-7 n = 291.

The local temperature rise is a significant predictor of the perceived climate change impact (B = 0.16, p < 0.05), anthropogenic pressures (B = 0.25, p < 0.01) and marine livelihood impact (B = 0.21, p < 0.01 (Table 4). Additionally, excessive rainfall and declining income are perceived as significant risk predictors of climate change impact and anthropogenic pressures (Table 4).

On socio-demographic variables, the group categorized as not poor have significantly higher risk perception of climate change impact (B = 0.94, p < 0.001), anthropogenic pressures (B = 1.19, p < 0.001), and marine livelihood (B = 1.07, p < 0.001) compared to poor participants. The high school group (B = 0.51, p < 0.05) has shown a significantly higher risk perception of climate change impact compared with the elementary group. On the other hand, the 40-49 years old group (B = -0.73, p < 0.05) has shown also significantly lower risk perception compared with 19-29 years old.

Table 4. Results of linear regression predicting the participants' risk perception of climate change impact, anthropogenic pressures, and marine livelihood from their personal experiences of climate-related events in the coastal marine environment of Palawan, Philippines (standard error in parenthesis).

Predictor variables	Perceptions of Factors Affecting the Corals reefs and Seagrasses (Outcome Variables)		
	Climate Change Impact [1]	**Anthropogenic Pressures** [1]	**Marine Livelihood Impact** [1]
Constant (B)	2.19*** (0.36)	2.21*** (0.39)	1.41** (0.46)
Local temperature rise	**0.16 (0.07) ***	0.25*** (0.08)	0.21** (0.09)
Sea level rise	0.08 (0.07)	-0.03 (0.07)	0.03 (0.09)
Excessive rainfall	**0.19 (0.08) ***	**0.17* (0.08)**	0.09 (0.10)
Floods	-0.10 (0.06)	-0.08 (0.07)	-0.07 (0.08)
Declining income	**0.30 (0.07) *****	**0.23* (0.08)**	0.09 (0.08)
Livelihood effect	-0.05 (0.08)	-0.01 (0.09)	0.08 (0.11)

* *p < 0.05;* ***p < 0.01; p< 0.001*

[1] Variable obtained from the data reduction method (PCA) see Supplementary Table 2

Table 5. Results of linear regression analysis predicting the participants' risk perceptions of climate change impact, anthropogenic pressures, and marine livelihood from key socio-demographic characteristics in the coastal marine environment of Palawan, Philippines (standard error in parenthesis).

Predictor variables	**Risk Perceptions of Factors Affecting the Corals reefs and Seagrasses (Outcome Variables)**		
	Climate Change Impact [1]	**Anthropogenic Pressures [1]**	**Marine Livelihood Impact [1]**
Constant (B)	3.658 (0.48) ***	4.182 (0.52) ***	3.862 (0.56) ***
Gender (ref = male)	-	-	-
Female	0.27 (0.21)	0.20 (0.22)	0.10 (0.25)
Education Level (ref = Elementary)	-	-	-
High School	**0.51 (0.22)** *	0.11 (0.24)	-0.14 (0.27)
College	0.30 (0.33)	0.21 (0.35)	0.18 (0.39)
Income (ref = poor)	-	-	-
Not Poor	**0.94 (0.24)** ***	**1.19 (0.26)** ***	**1.073 (0.30)** ***
Occupation (ref = non-fisher folks)	-	-	-
Fisher folks	0.20 (0.35)	0.03 (0.37)	-0.28 (0.42)
Age Group (ref = 19 – 29 years old)	-	-	-
30 – 39 years old	-0.40 (0.33)	-0.40 (0.35)	-0.62 (0.39)
40 – 49 years old	-0.40 (0.31)	-0.57 (0.33)	**-0.73 (0.36)** *
50 – 59 years old	-0.41 (0.34)	-0.51 (0.37)	-0.38 (0.41)
60 – 99 years old	-0.19 (0.37)	-0.40 (0.40)	0.04 (0.44)
Study Sites (ref = Puerto Princesa)	-	-	-
Aborlan	0.14 (0.30)	0.46 (0.32)	0.55 (0.37)
Taytay	0.29 (0.24)	0.38 (0.26)	0.52 (0.29)

* *p < 0.05;* ***p < 0.01; p< 0.001*

[1] Variable obtained from the data reduction method (PCA) see Supplementary Table 2

4. DISCUSSION

The results from this study contribute to a greater understanding of the relationship between coastal community perceptions and climate change impacts which, in turn, adds knowledge to the gaps about how to involve the public in building climate change resilient efforts.

4.1. Role of Personal Experiences in Climate Change Awareness and Shaping Risk Perceptions

Climate change awareness and risk perceptions can be shaped by direct experiences of extreme weather events, local weather anomalies (i.e., temperature rises) [47,48], and climate-related livelihood damages [49,50]. In our results, most study participants (82%) perceived that climate change was happening and this is consistent with the results from a nationwide survey conducted in the Philippines in February 2021, which found that 83% of Filipinos believe the climate was changing [11]. Of the various extreme weather events and weather anomalies, the personal experience of temperature rise is the strongest predictor of climate change in Asian and African countries [25–27]. In our study, it was found that temperature rise significantly predicted the response variable “climate is changing” ($B = 0.17$, $p < 0.03$). The findings are in line with more evidence suggesting that personal experiences of local weather anomalies (i.e., local temperature rises) and extreme weather events could influence perceptions and attitudes toward climate change [27,51–54]. Personal experience of excessive rainfall ($B = 0.17$, $p < 0.05$) is another significant predictor of the response variable “climate is changing” (Table 2). It is uncommon in Palawan to have extreme weather events like excessive rainfall, thus deviations from normal occurrences like this may serve as an indicator of what climate change will mean for the province [55]. The relationship of other climate-related experiences compared with the “climate is changing” variable is not significant in this study may be because they are not: (1) relatively recent [56]; (2) linked with significant personal and/or financial damages [49,50]; and (3) experienced as abnormalities in temperature [49]. The occurrence of extreme weather events is rare in Palawan and thus may not have a significant impact on climate change perception, because they cannot be easily recalled [47,57]. The recentness effect can be amplified if the event was linked with personal and financial damage [49,50].

Climate change is a disaster risk driver and is perceived by the coastal residents (75%) in this study to impact the mangroves and the coastal marine ecosystem. This is higher public concern about the risk brought about by climate change compared to the 67% in a nationwide survey in 2018 (Philippines) [58]. The higher climate change concern among the coastal community compared to the public can be attributed to the higher vulnerability of coastal areas to adverse impacts caused by climate stressors on their surroundings and livelihoods which shape people's climate risk perception [59,60]. However, there is still a substantial percentage of skeptics who do not consider climate change as a coastal risk driver. This could be attributed to the perception of some coastal communities that the land along the coastal margin will persist permanently, and that those living there will be safe from natural coastal hazards (apart from rare storm surge events) [61].

Personal observation of sea-level rise was also a significant predictor of climate change risk perception to the mangrove ecosystem and the marine coastal ecosystem which is consistent with many studies that sea-level rise is the main threat to the coastal ecosystem. [6,14]. Additionally, other studies stated that experience is one of the drivers of perception of sea level rise and how they respond to the impact [47]. However, only a slight majority of coastal residents agree that sea-level rise will cause coastal erosion and affect the coastal ecosystem (Fig. 7). The skepticism expressed by some coastal residents that sea-level rise will cause major damage to coastal areas could be attributable to various factors, like the perception that mangroves can prevent coastal erosion (Fig. 7). The skeptical perception of sea level rise as a coastal risk is in line with findings that public perceptions of sea level rise in the US Gulf Region remain to be a temporally distant issue among coastal residents [62]. In contrast, the research in New Zealand found that adults were overestimating the amount of sea-level rise expected by 2100 which can result in feeling anxious rather than being motivated to mitigate and adapt [61]. Overestimation of sea-level rise impact in New Zealand results from indiscriminate media reporting of the sea level rise warning that it could reach 5 meters by 2100 [61]. While, in contrast, we could attribute the skeptical risk perceptions of sea level rise impact in the Philippines to a lack of prominence given by the media outlets [63]. Additionally, coastal residents in the Philippines tend to disregard the risk of sea level rise possibly because of their fisheries' livelihood causing them to generally prefer in situ adaptation strategies rather than relocation to the mainland [64].

Our study also examines how coastal communities perceive the effects of climate change, anthropogenic pressures, and marine livelihoods on coral reefs and sea grasses. We found that coastal communities perceived anthropogenic pressures to be the major driver affecting coral reefs and sea grasses, and climate change impact was also perceived to have similar effects. On the other hand, marine livelihood is perceived to have a low impact. The results of this study are consistent with the report of the UNEP-IOC-ASPEI-IUCN Global Task Team, which states that human anthropogenic pressures pose a far greater immediate threat to coral reefs than climate change [65]. However, on the contrary, another research study found that climate change is the main driver affecting coral dynamics and can exacerbate the impact of anthropogenic drivers [66]. The perception of the respondents that marine livelihood, especially illegal fisheries can also impact the coral reefs and seagrasses is in line with the findings of previous research. This unsustainable fishing practice has been identified as the primary threat to coral reefs and the quality of the coastal marine environment [46,67]. On the other hand, long-term fish cage operations, if poorly located and managed, will result in the reduction of the abundance and diversity of local benthic species and degrade the habitats surrounding the cages [68]. A study found that the impact of long-term fish farming resulted in seagrass decline in the areas surrounding the fish farm site even though at the time of sampling the fish farm operation had already ceased [69]. This could be due to the excess organic matter remaining in the sediments, resulting in the organic pollution of seagrass meadows [69].

In our analysis, personal experience of local temperature rise is a significant predictor of the perceptions of the effect of anthropogenic pressures and marine livelihood impact on the sea grasses and coral reefs (Table 4). There is empirical evidence about the anthropogenic influence on the observed temperature rise trend in different regions of the world [70]. The warmer temperatures can cause coral reefs to bleach and seagrasses to alter growth rates, resulting in reef fish deaths [71,72]. Anthropogenic pressures result in contamination of aquatic environments which is one of the leading types of pollution that has significant negative impacts on coral reefs and seagrasses [73]. Because of these negative impacts, coral reefs and seagrass farming can suffer, thus reducing the income of seaweed farmers. These negative anthropogenic pressure impacts may have significantly affected their perceptions and behavioral responses to climate change [74,75].

Personal experience of excessive rainfall is also a significant predictor of the climate change impact on the seagrasses and coral reefs (Table 4). Excessive rainfall results in increased runoff of freshwater, sediment, and land-based pollutants that contribute to algal blooms and cause murky water conditions that reduce light – which is a key factor to coral reef survival and physiology and can contribute to the decline in seagrass growth and distribution [76–78].

Coastal and low-income communities are most vulnerable to climate change impacts [71,79]. Our results showed that participants perceive that declining income is the strongest predictor of climate change and anthropogenic pressures impact seagrasses and coral reefs. The impact is already felt by fishers by getting lower revenue which creates a domino effect of several other socio-economic consequences including low economic standing, non-existent social welfare or pension systems for fishers, and poor health and living standards for their families [71,80]. Fisher folks perceived that loss of income was a result of climate change impacts such as rising sea levels, excessive rainfall, temperature rise, the decline in fish catch, and loss of coral reefs, and seagrass cover [71]. Anthropogenic pressures result in contamination of aquatic environments which is one of the leading types of pollution that has significant negative impacts on coral reefs and sea grasses [73]. Because of these negative impacts, coral reefs, seagrass meadows, and seaweed farming can suffer, thus reducing the income of seaweed farmers. These negative anthropogenic pressure impacts may have significantly affected their perceptions and behavioral responses to climate change [74,75]. These vulnerable fishers in the coastal areas need to acquire different adaptation and coping strategies to mitigate these impacts [81,82]. To enhance their resilience to the impacts, fishers need development assistance that protects their well-being, prioritizes alternative livelihoods, and provides technical skills training [71,83,84]. Additionally, the coastal community must support the conservation of mangroves, seagrass, and coral reefs, which provide a habitat for important commercial and recreational species and stabilize the seafloor [71,85,86].

In this study, our findings suggest that the perceptions of the coastal residents are consistent with the established scientific information that anthropogenic pressures, climate change consequences, and marine livelihoods have a significant impact on corals and seagrasses. This high level of climate-relevant knowledge on the impact of climate change and anthropogenic pressures on corals and seagrasses is vital for preserving reef systems and accepting climate change policies [87].

Our results open an exciting new avenue of study focused on what and how the coastal communities are doing to preserve reef ecosystems. Specifically, on how they adapt and mitigate the impact of climate change and reduce anthropogenic pressures on the corals and sea grasses. Moreover, we also suggest explanatory research or applied scientific research to determine the actual impact of climatic pressures and anthropogenic pressures on corals and seagrasses.

4.2. Role of Socio-Demographic Factors in Climate Change Awareness and Shaping Risk Perceptions

Understanding population dynamics and heterogeneity is essential for improving our understanding of climate change and risk perceptions of the impacts. Our results showed that age, educational attainment, household income, and study sites influence the climate change awareness and risk perceptions of the participants.

In terms of gender, we found that women have a higher risk perception of climate change's impact on the coastal marine ecosystem. This is consistent with findings that women consistently have a higher risk perception and concern about climate change compared to men [88]. In a similar finding, it was reported that women express slightly greater concern about climate change than men [89]. Since 2010, the gender gap in this form of knowledge has remained relatively stable, even though men's understanding of the consensus has improved over time [90].

Climate change's impact on coral reefs and seagrasses is perceived differently depending on educational attainment, in line with previous studies which showed that those with higher education tend to have more concern for the environment [91,92]. Surprisingly the high school category has a slightly higher risk perception than the college category, although they are not significantly different at $p < 0.05$. The slight difference could be attributed to the fact that there is a higher ratio of women to men among the college group (65%) compared to the high school group (51%) (See Supplementary Fig. 1). A previous study showed that women's self-perceived knowledge is higher than men's among people with low levels of education but higher for men among people with high levels of education [93]. It should be noted, however, that our study had some gender imbalances, so we should be cautious when interpreting the interaction between gender and education results.

Poor households have a significantly lower risk perception of climate change's impact on the coastal marine ecosystem, which is in line with another study conducted in Singapore which found that low-income households reported a lower level of knowledge compared with higher-income households [94]. Poor households also have significantly lower risk perceptions of the impact of climate change, anthropogenic pressures, and marine livelihood on sea grasses and coral reefs compared with not-poor households (Table 5). Lower climate change risk perception for poor households compared to not-poor households could be explained by the fact that low-income households and communities develop academic skills at a slower rate than those from higher-income groups [94]. Poverty levels are strongly linked to educational attainment. In the Philippines, the heads of two of three poor households have only reached elementary education and below [95]. Further, the lack of economic resources was a major barrier to paying attention to climate change, as they had more pressing priorities, such as the financial pressure of daily living [96]. For poor households who face more financial pressure than high-income households, climate change is less likely to be a concern.

The 19-29 years old have higher climate change awareness and risk perception of marine livelihood impact on coral reefs and seagrasses compared with other age groups (see Table 3 &5), in line with other studies that report the younger generation in the USA worries more about the effects of global warming than the older generation [30]. In contrast, for the risk perception of sea-level rise impact on the mangrove ecosystem, the older generations group was found to have the higher risk perception compared with 19-29 years old. (Table 3). Scientific knowledge about the causes, impacts, and solutions to climate change generally increased with age, as would be expected with increased scientific education and exposure to information [97]. Having lived many years and experienced the various changes that have taken place in coastal areas, the older generation may have acquired enough wisdom or experienced enough changes in their youth to know about the threat climate change poses [97]. This could be because younger generations have less experience and exposure to the impact of rising sea levels and since older generations have more experience, they perceive greater damage caused by sea-level rise compared with younger generations.

Puerto Princesa City participants have higher climate change awareness compared with Aborlan and Taytay participants (Table 3). These results suggest that climate change awareness might be influenced by geographical context [31,98]. The differences in climate change awareness could be attributed to the more publicized people's participation in the reforestation of mangroves in Puerto Princesa which has been going on for more than two decades and resulted in the planting of millions of mangrove trees, thereby increasing beach coverage. [98–100]. In Aborlan and Taytay, which are more rural than Puerto Princesa, there are fewer environmental conservation activities publicized and participants have limited media coverage of those activities, which may explain the lower climate change awareness [100,101]. Similarly, Puerto Princesa participants have significantly lower risk perception ($p < 0.05$) of the impact of marine livelihood on the sea grasses and coral reefs as compared with Aborlan participants (Table 5). Further studies are necessary to conclude a causal association between the differences in perceptions.

The positive finding of this research is that the coastal residents understand that mangroves are beneficial to them in preventing coastal erosion. Thus, conserving mangroves for their protection becomes a concern. Our findings also suggest the importance of training and communication tools to effectively relay information about coastal risks brought by climate change and sea level rise impacts to help motivate coastal residents to act. By increasing their knowledge about climate change causes and impacts, they will be more concerned about climate change and more likely to support climate-friendly policies [65]. Although there is no significant difference among different education levels in this study, other studies suggest that participants with higher education tend to have a higher risk perception of climate change impacts compared with lower education [26].

4.3. Limitations

The findings of this study must be seen considering some limitations. The first is that we did not include in this study questions about how they perceived the impact of climate change on their livelihood and food security. This could be significant in predicting their overall perception of climate change as a coastal hazard. However, we intend to address these limitations in future studies.

The second limitation concerns the actual status of climate change impact on the coastal areas. Directly cross-verifying the actual status of climate change impact in the coastal areas compared to their perceptions would give a good measurement of their current level of climate-relevant knowledge. Nevertheless, their perceptions are useful in understanding their mental model. Furthermore, this limitation is another avenue for potential future research.

5. CONCLUSIONS

As the impacts of climate change are likely to worsen the problems in vulnerable coastal areas, it is important to understand how experiences of climate-related events and various socio-demographic characteristics of the coastal community shape their awareness and risk perceptions. This study suggests that the coastal communities in our study sites have high climate change awareness, but a number remain unaware of the damaging effects of climate change. The most common climate change impacts observed or experienced by the participants are temperature rise and excessive rainfall. In descending order, other impacts of climate change experienced or observed by the participants in low frequency include declining income, sea-level rise, flood, sunburn, and heat stroke. Among these climate change experiences, temperature rise, and excessive rainfall are significant predictors of climate change awareness.

Experience or observation of sea-level rise is a significant predictor of risk perception of climate change impacts on the mangroves and coastal marine ecosystem. This study also established that "women" and "not poor" participants perceived the risk of climate change to the coastal marine ecosystem as higher compared to the reference groups. Furthermore, the 19-19-29 years old have higher climate change awareness and more concern about marine livelihood impact on coral reefs and seagrasses compared with other age groups. In contrast, the 19-29 years old have lower risk perception compared with older age groups in the risk perception of sea-level rise impact on the mangrove ecosystem. Moreover, the risk perception of sea level rise impact is influenced by geographical context.

Most participants consider perceived anthropogenic pressures and climate change impacts have a high impact, while marine livelihood is perceived as having a low impact on the coral reefs and seagrasses. Local temperature rise, excessive rainfall, and declining income are significant predictors of these risk perceptions. Education has a significant influence on the risk perception of the impact of climate change on coral reefs and seagrasses. While the "not poor" participants have significantly higher risk perception compared to the poor group in perceiving the impact of the various factors affecting coral reefs and seagrasses.

Future research on climate change mitigation should focus on how to improve the coastal community's awareness and increase their willingness to support climate-friendly policies. There is a need for a bespoke climate change "knowledge management system" and risk communication tools for different demographics to further increase awareness and concern for a healthy and sustainable coastal community. By addressing these issues from an interdisciplinary perspective, we can build adaptive capacity and reduce the vulnerability of coastal communities.

6. DATA AVAILABILITY STATEMENT

The datasets presented in this article and from the entire survey will be made open access after an embargo period currently under discussion with the international consortium. Requests to access the datasets should be directed to the last author.

7. ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University of Exeter Medical School Research Ethics Committee (May19/B/185) and Philippines National Ethics Committee (2019-002-Creencia-Blue). The patients/participants provided their written informed consent to participate in this study.

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10. AUTHOR CONTRIBUTIONS

LA: conceived and design the analysis, development, and design of methodology, performed analysis, wrote the original draft, revised, and edited the paper. JRV: collected data, contributed to methodology and analysis, performed analysis, reviewed, and edited the paper. KM: collected data, reviewed, and edited the paper. JBJ: contributed data, reviewed, and edited the paper. LC: collected data, supervised, reviewed, and edited the paper. FC: contributed to methodology, reviewed, and edited the paper. All authors contributed to the article and approved the submitted version.

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Questionnaire

Climate Change Awareness and Risk Perceptions in the Coastal Marine Ecosystem of Palawan, Philippines

Climate Change Awareness	Fully disagree						Fully agree	No Answer
1. Do you think the climate on your locality is changing	1	2	3	4	5	6	7	99
Experiences of Climate Change Impacts								
2. Have you observed/experienced the following phenomenon in your area?	Very low						Very high	No Answer
• Floods	1	2	3	4	5	6	7	99
• Local Temperature Rise	1	2	3	4	5	6	7	99
• Sea level rise	1	2	3	4	5	6	7	99
• Excessive rainfall	1	2	3	4	5	6	7	99
• Heatstroke	1	2	3	4	5	6	7	99
• Sunburn	1	2	3	4	5	6	7	99
• Income	1	2	3	4	5	6	7	99
• Affecting livelihood activities	1	2	3	4	5	6	7	99
Perceptions of Climate Change Impacts								
3. Climate Change Impacts on the Coastal Marine Ecosystem:	Fully disagree						Fully Agree	No Answer
• Risk to mangroves ecosystem	1	2	3	4	5	6	7	99
• Risk to the marine coastal ecosystem as a whole	1	2	3	4	5	6	7	99
• Sea level is rising rapidly, regardless of when there is a typhoon	1	2	3	4	5	6	7	99
• The rising sea level has eroded the areas with mangrove trees	1	2	3	4	5	6	7	99
• The rising sea level has eroded the areas without mangrove trees	1	2	3	4	5	6	7	99
• The rising sea will affect the mangroves ecosystem	1	2	3	4	5	6	7	99
Climate Change Impacts on Coral Reefs and Seagrass Beds								
4. At what level does the following affect the state of your corals, reefs, and sea grass beds?	Very low						Very high	No Answer
• Changes in environmental temperature	1	2	3	4	5	6	7	99
• Excessive rainfall	1	2	3	4	5	6	7	99
• El Nino (droughts)	1	2	3	4	5	6	7	99
• Frequent typhoons and floods	1	2	3	4	5	6	7	99
• Runoffs	1	2	3	4	5	6	7	99
• Sewerage	1	2	3	4	5	6	7	99
• Domestic wastes	1	2	3	4	5	6	7	99
• Pollution	1	2	3	4	5	6	7	99
• Red tide (HABs)	1	2	3	4	5	6	7	99
• Land use change	1	2	3	4	5	6	7	99
• Urbanization	1	2	3	4	5	6	7	99
• Natural Calamities	1	2	3	4	5	6	7	99
• Illegal Fisheries	1	2	3	4	5	6	7	99

• Tourism-related development	1	2	3	4	5	6	7	99
• Pearl farms	1	2	3	4	5	6	7	99
• Fish cages	1	2	3	4	5	6	7	99
• Shellfish (mussel) farms	1	2	3	4	5	6	7	99

This final section will ask you various background questions to help us understand what different sections of the local population think about marine issues. Please remember that all the information you provide is **confidential.**

Interviewer, please note: Gender (Male/Female)

Interviewer please note: Name of village/barangay ____

Q1) Can I ask how old you are please ________yrs.

Q2) Do you or any member of your household do any of the following types of work (Please select all that apply)

□ Fishing for the market (wild fish/shellfish)
□ Fishing/gleaning for family food
□ Aquaculture (farmed fish/shellfish/seaweeds)
□ Shipping (including freight, passenger, etc.)
□ Coastal tourism/recreation (e.g., tourist boats, seaside walking guides, swimming/snorkeling guides)
□ Coastal management (e.g., coastline protection, wastewater treatment)
□ Marine environment protection (e.g., environmental group or government agency, mangrove protection)
□ Marine policy/research
□ Others (Specify__________)
□ None of the above (No one in my household works in the marine sector)
□ Don't know/ Prefer not to answer

Q3) Do you get income from any of the following activities?

□ Fishing
□ Crabbing/shrimping
□ Aquaculture (caged fish/fin-fish)
□ Seaweed farming
□ Post-harvest activities
□ Taking tourists on boats etc.

Q4) And approximately how much money do you make from all these activities together per month?

□ ……….. (Pesos)

And finally, a few questions about your background and affiliations:

Q5) What is your highest education level?

□ Elementary level
□ Elementary graduate
□ High School level
□ High School Graduate
□ College Level
□ College Graduate

Supplementary Table 1. Perceptions of climate change impact in the coastal areas. The response options provided to the respondents was a bipolar rating scale: 1 = fully disagree to 7 = fully agree. n = 291

Perceptions	Responses (%)							Missing (%)	Mean	SD	Loadings
	1	2	3	4	5	6	7				
Climate Change Impact on coastal marine ecosystem[1]	9.5	0.8	2.9	11.6	14.9	21.1	39.3	16.8	**5.41** [a]	1.87	
Climate Change is a threat to the mangroves	12.8	1.7	2.1	16.7	15.8	16.2	34.6	19.6	5.08	2.00	0.94
Climate Change is a threat to the coastal ecosystem	10.5	1.3	0.4	12.2	11.8	18.1	45.8	18.2	5.51	1.92	0.94
Sea level rise impact on mangroves ecosystem[1]	11.2	5.2	9.4	14.6	14.2	22.8	22.5	8.2	**4.74** [a]	1.97	
Sea level is rising, regardless of when there is typhoon	18.0	1.5	4.5	16.2	9.8	12.0	38.0	8.6	4.86	2.24	0.79
Rising sea level has eroded the areas with mangroves	30.4	1.6	6.5	17.0	9.7	13.0	21.9	15.1	4.0	2.34	0.72
Rising sea level has eroded the areas without mangroves	15.6	2.0	4.8	16.0	11.2	13.2	37.2	14.1	4.94	2.16	0.86
Rising sea level will affect the coastal ecosystem	15.1	1.6	4.5	14.3	13.9	17.6	33.1	15.8	4.95	2.10	0.79

[a] Factor means

[1] Factor obtained from data reduction thru Principal Component Analysis of perceived climate change impact in the coastal areas

Supplementary Table 2. Perceptions of factors affecting the coral reefs and seagrass beds. The response options provided to the respondents was a bipolar rating scale: 1 = fully disagree to 7 = fully agree. n = 291

Factors	Responses (%)							Missing (%)	Mean	SD	Loadings
	1	2	3	4	5	6	7				
Climate Change Impacts [1]	9.2	5.9	13.4	21.8	24.7	14.2	10.9	17.9	**4.28** [a]	1.53	
Temperature rise	13.0	3.5	11.3	18.6	26.8	12.1	14.7	20.6	4.38	1.84	0.73
Excessive rainfall	16.6	4.7	9.4	26.0	21.3	12.8	9.4	19.2	4.06	1.83	0.76
El niño (drought)	13.4	3.9	7.8	22.1	22.1	15.6	15.2	20.6	4.43	1.87	0.79
Frequent typhoons	11.6	4.7	12.5	19.4	21.1	17.7	12.9	20.3	4.38	1.82	0.72
Runoffs	12.9	4.4	12.4	22.7	21.8	12.4	13.3	22.7	4.27	1.82	0.63
Natural calamities	15.3	4.8	10.5	16.7	18.7	21.1	12.9	28.2	4.33	1.94	0.42
Anthropogenic Pressures [1]	9.5	7.1	11.0	14.8	18.6	23.3	15.7	27.8	**4.52** [a]	1.60	
Sewerage	12.3	4.8	8.3	14.0	23.7	18.0	18.9	21.6	4.61	1.92	0.72
Pollution	9.9	4.5	4.9	13.9	22.0	20.6	24.2	23.4	4.92	1.87	0.79
Domestic wastes	8.3	3.0	7.8	13.5	25.7	21.3	20.4	21.0	4.91	1.76	0.67
Land use change	25.9	6.5	6.5	20.4	17.9	10.0	12.9	30.9	3.80	2.09	0.64
Urbanization	20.7	6.1	8.9	15.0	23.0	14.1	12.2	26.8	4.05	2.02	0.66
Red tide	35.4	3.9	1.1	20.8	11.2	12.9	14.6	38.8	3.66	2.28	0.72
Illegal fisheries	8.6	3.6	5.0	5.4	15.3	25.7	36.5	23.7	5.38	1.88	0.71
Marine Livelihood [1]	31.2	11.9	8.7	21.1	13.8	9.6	3.7	25.1	**3.22** [a]	1.74	
Pearl farms	41.9	5.8	6.8	22.0	6.3	6.8	10.5	34.4	3.07	2.12	0.82
Fish cages	31.5	8.0	9.0	31.0	9.0	5.5	6.0	31.3	3.19	1.86	0.83
Shellfish farms	44.8	4.4	4.4	26.5	4.4	6.1	9.4	37.8	2.97	2.09	0.90
Tourism related development	28.2	4.8	8.6	28.7	12.9	10.0	6.7	28.2	3.50	1.93	0.47

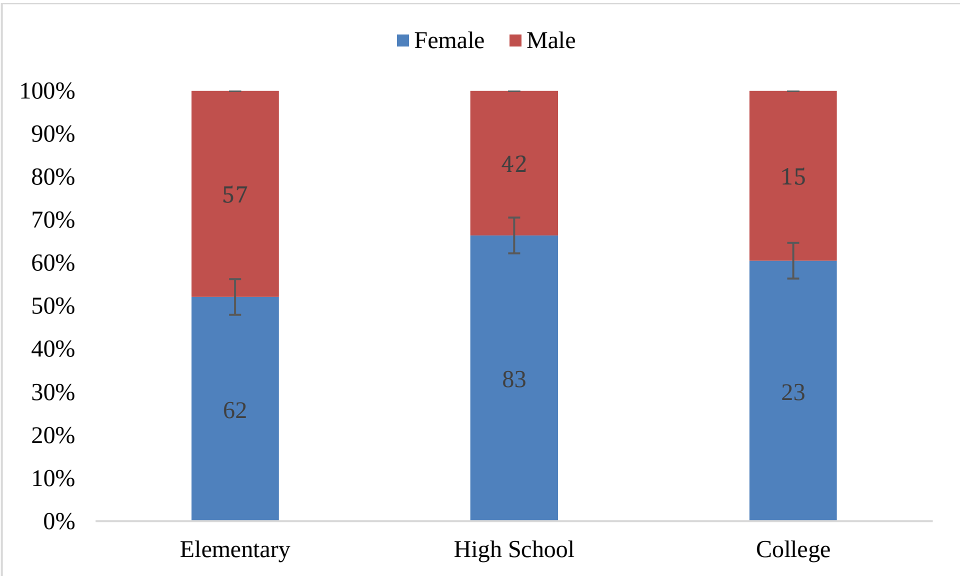
[a] Factor means

[1] Factor obtained from data reduction thru Principal Component Analysis of perceived impact of factors affecting the coral reefs and seagrass beds

Supplementary Table 3. Paired samples t-test comparing sea level rise impact on coastal erosion when there are mangroves compared to when there are no mangroves in the coastal areas of Palawan, Philippines.

Pair variable	Mean	SD	SE	95% Confidence Interval of the Difference		t	DF	p
				Lower	Upper			
Rising sea level has eroded the areas with mangroves	3.99	2.34	0.15					
Rising sea level has eroded the areas without mangroves	4.94	2.16	0.14					
Pair: w/ mangroves – w/o mangroves	-0.95	2.24	0.14	-1.23	-0.67	**-6.65*** **	244	0.000

Note: Cohens D = 0.42; *** p < 0.001



Supplementary Figure 1. Cross-tabulation count of participants' gender and educational attainment who perceived the climate change impact on coral reefs and seagrasses. (n = 291). (The count was based on listwise deletion).