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Stressors Influencing Availability of Shellfish in Zanzibar Island, Tanzania

Hassan Rashid Ali[1, 2, *], Khadija Mustafa Zuberi[1]

[1]School of Natural and Social Sciences, The State University of Zanzibar (SUZA), Zanzibar, Tanzania

[2]Tropical Research Centre for Oceanography, Environment and Natural Resources, The State University of Zanzibar, Zanzibar, Tanzania

Email address:

hassan.ali@suza.ac.tz (H. R. Ali)

[*]Corresponding author

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Abstract: Shellfish play crucial roles in the ecosystem as well as for human. In recent decades, there is an increased concern to constant extraction of these shellfish and climatic events disrupt their production. Previous studies showed increasing of deterioration of shellfish in the coast. This study assessed the current stressors affecting shellfish availability from three study sites, which are Nyamanzi, Pongwe and Unguja Ukuu of Zanzibar Island, Tanzania. A cross-sectional design was used to gather information from the gleaners. Data were collected from each study site through interview-administered questionnaire. Data were analyzed using descriptive and inferential statistics, in which bar-chart; pi-chart and percentage distribution were specifically employed for descriptive part, whereas Chi-squired test and Fisher exact test were used to test statistical significance of the relationship between dependent variables and each of independent variables. The results of this study show that, there is a relationship between climatic and non-climatic variables (p-value < 0.05) resulting to the decrease in the number of shellfish. The climatic factors considered in this study are increase in sea surface temperature (SST), strong winds, ocean acidification, sea level rise (SLR) and sand accumulation while the non-climatic human factors are tourism activities, husk burying, seaweed farming, boat anchorage and poor fishing methods; causing adverse affect in shellfish production. Therefore, in order to obtain shellfish sustainability; authority must emphasize on strong policies regulation, implementation and enforcement on shellfish conservation and management in the future.

Keywords: Shellfish, Gleaners, Climate Extremes, Coastal Resources, Human Activities

1. Introduction

Coastal areas produce a huge number of services that benefits the ecosystem. Coastal ecosystems yield 90% of global fisheries and almost 171 million tons (80%) of known marine fish species (about 13,200 species) worldwide in which it produces 20% of the protein of the food in which human consume in our daily basis [8]. This consumption has led to the over usage of coastal resources which is more likely to harm the coastal and marine resources [27]. The aim of this study is to determine the status of calcified species on the impact of climate change on the availability of shellfish in Zanzibar Island, Tanzania.

The major trending components from aquatic environment are calcified fish especially in the Islands. Shellfish are basically of two types, which are *crustaceans* and *molluscs* originating from animal Kingdom. Calcified fish are also known as shellfish which are the major trending component of aquatic food supply from the global context to the local level especially in the Islands [36].

There is cyclical relationship between carbon dioxide, shell formation and the increase in temperature where by, a constant increasing of carbon dioxide to the atmosphere leads to a more rapid warming as well larger absorption of carbon to the ocean react with hydrogen ions and make the water to be more acidic which in turn lead to decrease in calcified organisms such as clams, oysters and others. Seashells are self-repairing (high ability of shellfish to recover when they

get damage); they use the calcium carbonate secretions from their mantle tissue to fix any damage [11, 23]. These shellfish are basically interrupted by both climatic and non-climatic factors. The climatic factors considered in this study are rainfall, sun's intensity and wind speed and the non- climatic human factors are tourism activities, husk burying, seaweed farming, boat anchorage and poor fishing methods.

In Tanzania especially in Islands, fisheries play a crucial role in the economy as they provide a source of income about 20% of the population [10]. Both men and women who are living in the coastal communities usually engage themselves in harvesting marine resources [29]. However, most women collect bivalves and gastropods during low spring tides in the intertidal areas while men fish and dive for octopus and snorkel for other types of marine species, such as sea cucumber [37]. One among the major income generating activities of the coastal communities is collecting and selling calcified fish. A study that conducted by [37] from the Institute of Marine Science (IMS) which was done at Fumba and Unguja Ukuu, claim that shellfish collectors (gleaners) obtain about 25,000/= to 30,000/= Tsh per person per day during a low spring tide season, where it accounts for their house hold income. Beside this income-generating tool, currently the availability of calcified fish was reported to decrease compared to the past 30 years where gleaners used to harvest minimum 3 to 4 buckets (10 litters) of shells fish per person a day, while now it is very hard to collect a bucket per day [37].

Despite the fact that, there is regular decrease of the availability of calcified fish and the efforts to maximize the availability shellfish, this study conducted to assess the stressors affecting calcified species in coastal communities basing on perceptions of gleaners on the impact of climate variability with other factors on the availability of calcified fish. The results of this study will create awareness and technical knowhow on the conservation the calcified fish so as to improve productivity, which in turn increase the living standards of coastal communities as well as ecosystem services.

2. Materials and Methods

2.1. Study Sites

This study was conducted in three areas of Zanzibar Island, which are Unguja Ukuu, Pongwe and Nyamanzi between August to October 2019 (Figure 1). Unguja Ukuu is a village found at the South of Unguja Island, Tanzania about 250 miles (403 km) east of Dodoma, the country's capital city. Unguja Ukuu has a population of 4737 with total houses of 1048. The population of Unguja Ukuu is a combination of two areas, which are Tindini and Kaepwani. Nyamanzi is located at West of Zanzibar with a total population of approximately 736. The houses in Nyamanzi are 436, covering an area of about 2.26 km^2. Pongwe is found in Central of Zanzibar and has a population of 1200 and having 538 houses. Usually, coastal communities share the same activities as a source of income. Apart from gleaning activities, others depend on agriculture and marine activities, such as fishing, seaweed farming, husk burying and tourism.

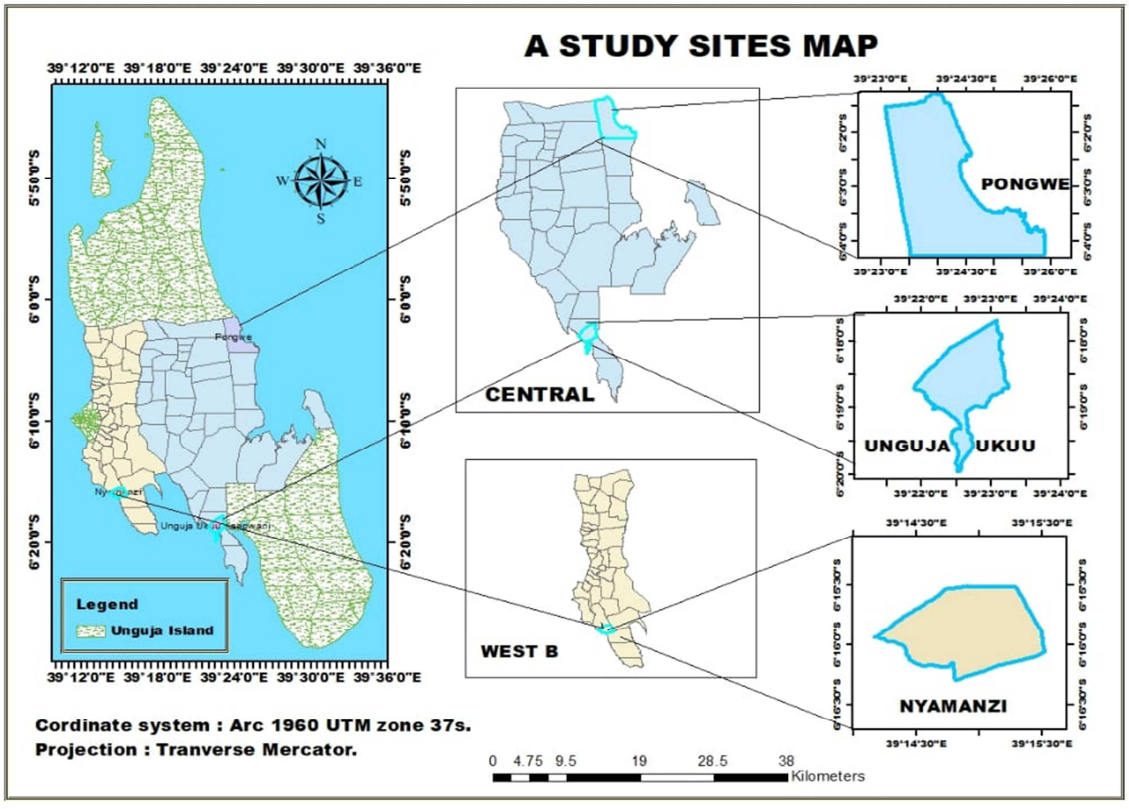

Figure 1. *A map represents the location of the study sites.*

2.2. Selection of Respondents

Respondents selected by the help of village leaders purposefully. The assistant helped in selecting those respondents who are dealing with collecting shellfish corresponding to each site. This method was chosen due to the nature of the gleaners at each study site. The nature of the shell collectors is non-randomly available hence purposeful method was applied. For the purpose of assessment, information of the gleaners as well as climatic and non-climatic stressors influencing shellfish availability basing on gleaners' perception was purposefully collected from these study sites. There was special intervention project about the management of no-take zones in order to allow maximum production of shellfish in Unguja Ukuu, Kikungwi, Fumba, Bweleo and Nyamanzi. Thus, Unguja Ukuu is the new site that practiced the no-take zone project. Nyamanzi was an open area that allowed people to glean without any restriction during the study phase and Pongwe is an area that is not under the project and the data represent the whole population.

2.3. Data Collection Method

The field survey and observation method were used to collect information on the availability of calcified species, the most season that these species are available more than the other, stressors affecting calcified species availability. The sample data collected in three villages were 161 (114 women and 47 men) in which the shell collectors reported reasons behind the shellfish availability.

2.4. Data Analysis

Tables and charts and statistical tests based on climatic and non-climatic stressors affecting calcified fish availability are represented. The descriptive analysis method has been used to explore the variables. The categorical variables were represented as percentages. Fisher's Exact test and Pearson's Chi-squared test was used to test the relationship between climatic and non-climatic variable. The general information for the gleaners represented as frequency and percentages. These tests were reasonable since nature of our data were mainly categorical qualitative [30].

3. Results

3.1. Information of the Gleaners

A total of 161 gleaners were interviewed where 114 (71%) were female and 47 (29%) were male from three coastal sites. These sites were Nyamanzi, with 54 respondents while Unguja Ukuu and Pongwe had 53 and 54 respondents respectively (Table 1). The other variables were age of the gleaners, their experience and gleaning seasons. The frequencies and percentages are summarised in Table 1.

Several studies including this one have shown that women are commonly engaged in gleaning activities as their main source of income. However, men are also emerging in collecting shellfish since they were found to have higher risk perceptions of climate change and the decrease in availability of marine resources and increase in demand and value of the shellfish [5, 24, 28, 31, 34, 38]. The results of this study showed that, about 70% of women are participating in gleaning activities (n=161) similar to the study of [2, 9, 34, 38]. In addition to that, [16, 21] reported men are also emerging rapidly in gleaning activities due to decrease in availability of marine resources and increase in demand and value of the shellfish. The same has been found in this study where about 29% reported to participate in gleaning activities in Zanzibar. Report of [29] in Zanzibar also found similar trend. Although most gleaners were of age between thirty-four and above they had gleaning experience of more than nine years (Table 1). Other studies [7, 24] reported the similar findings.

This study revealed that, more shellfish are collected during the inter-monsoon periods where about 78% were collected (Table 1). During the harsh conditions such as windy and higher temperature conditions is the worst collection period. For instance, during the Southeast (SE) and Northeast (NE) monsoon the collection was about 20% only (Table 1). The same scenarios of worst collection of shellfish during windy and higher temperature conditions were also observed in other studies [4, 18, 22, 37]. Thus, the shellfish are available throughout the year and their distribution is relatively imaginable [33].

Table 1. *General information of the gleaners (n=161).*

Variable	Category	Frequency	Percentage (%)
Field sites	Nyamanzi	54	33.5
	Pongwe	54	33.5
	Unguja Ukuu	53	33.0
Gender	Female	114	70.8
	Male	47	29.2
Gleaners' Age (years)	34 to 49	94	58.4
	18 to 33	42	26.1
	50 and above	25	15.5
Gleaners' Experience (years)	9 to 17	69	42.9
	18 and above	60	37.3
	0 to 8	32	19.8
Gleaning Season in which maximum shellfish are obtained	Inter-monsoon	127	78.9
	South-east	18	11.2
	North-east	16	9.9

3.2. Information on the Availability of Shellfish

The most common species collected among the gleaners were *Anadara sp*. about 48 (29.8%) times (Figure 2). The jugged shell or branched murex and horse conch shell both *Chicoreus ramosus* and *Pleuroploca trapezium* (Figure 3) were collected 28 (17.4%) times where 24 (14.9%) responded to collect *Strombus gibberulus*, which is commonly known as humpbacked conch (Figure 4). The gleaners responded to collect *ostreidae (the true oysters)* were 12 (7.5%) (Figure 5), while 5 (3.1%) collected *Acanthopleura gemmata* (*Chiton)* (Figure 6) and 44 (27.3%) were collecting mixed shells. The amount collected per season, cash earned (in Tsh) and experiences in availability are reported in Table 2.

Figure 2. *Anadara antiquate (Kombe/Makorobwe).*

Figure 3. *Chicoreus remosus (left) and Pleuroploca trapezium (right) (Kome).*

Figure 4. *Strombus gibberulus (Chuwale).*

Figure 5. *Acanthopleura gemmata (Nyamata).*

Figure 6. *Oyster (Pinctada sp.).*

Table 2. *Information on the availability of shellfish (n=161).*

Variable	Category	Frequency	Percentage (%)
Amount collected per season in kg	Five to nine	103	64.0
	Less than five	37	23.0
	Ten and above	21	13.0
Cash earned per season in Tshs.	46000 to 72000	89	55.3
	More than 72,000	52	32.3
	45,000 or less	20	12.4
Experience in availability	Decreased	132	82.0
	Increased	16	09.9
	Do not know	13	08.1

It is known that in each catch there is a common type of fish species collected than other species. For example in lake Wamala of Uganda the African catfish was mostly collected by the year 2013 which contributed about 73.4% than Nile tilapia [17]. In this study the most common type of shellfish collected from all study areas is Anadara sp. (29.8%; Figure 2) originating from bivalves, followed by mixed collectors (27.3%). *Pwani* Project reported similar findings, based mainly on production of *Anadara* and cockles [29].

The average collected amount of shellfish by majority was five to nine kilogram in each month while earning per person was about forty-six thousand to seventy-two thousand Tanzanian shillings while previously they were earning less than fort- five thousand for less than ten kilograms and thus it leads to increase in income though the availability has become very difficult [14].

3.3. Climatic and Non-climatic Stressors Affecting Shellfish Availability

Among the gleaners, 98 (60.9%) perceived increase shell harvesters, 18 (11.2%) poor fishing methods, 16 (9.9%) has decrease their production, 10 (6.2%) seaweed farming, and 19 (11.8%) other reasons such as they do not know the answer, no specific reason for shellfish to change or they just change because of God's will (Figure 7). It was explained that, daily human activities such as seaweed farming, boat anchorage, poor fishing methods and increase in shellfish harvesters are contributing to the decrease in shellfish availability where by over fishing alone is not a reason for the decline [13, 20]. Hence, as the previous studies a constant decrease in shellfish led to increase in price of the shellfish species especially in the Indian ocean [12, 14, 32]. The impacts of gleaning on reef systems can result a substantial and directly contribute to habitat degradation and overfishing [1, 21]. The amount of shellfish has been constantly declined (over 85%) of shellfish ecosystem compared to five years back through combinations of actions including overfishing, destructive fishing practices whereby the main reason for decreasing is increasing number of shell harvesters and hence it led to increase in price of the calcified fish species especially in the Indian ocean [12, 13, 14, 32]. The impacts of gleaning on reef systems can result a substantial and directly contribute to habitat degradation and overfishing [1, 21].

In addition to that an observation on other activities that are performed at the shellfish collection sites are similar in all

coastal areas except for tourism activities in Nyamanzi, while poor fishing methods such as illegal fishing is not practiced at Nyamanzi and Pongwe but is very common practice in Unguja Ukuu (Table 3). There are other activities in which people practice that contribute to destruction of shellfish breeding areas example of these activities are boat anchorage, poor fishing methods commonly known as *"Gole"* which is an illegal method of fishing which is commonly practiced in Unguja Ukuu as reported by [15]. Most gleaners commented that husk burying help shellfish to attach themselves at the stones although fishermen who anchor their boats causing destruction of shellfish as well as the husk shells soaking activity affect them. Also, in Pongwe they are not practicing sea cucumber farming yet (Table 3).

Table 3. *Observation on other human activities in the study sites.*

Kind of activity	Study sites		
	Nyamanzi	Pongwe	Unguja Ukuu
Seaweed farming	✓	✓	✓
Boat anchorage at shellfish collection sites	✓	✓	✓
Tourism activities	×	✓	✓
Poor fishing methods	×	×	✓
Husk burying	✓	✓	✓
Sea cucumber farming	✓	×	✓

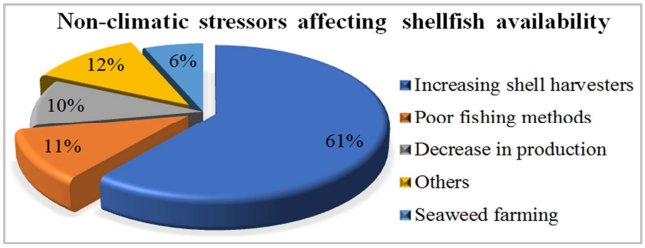

Figure 7. *Percentage responses of the non-climatic stressors affecting shellfish availability.*

In the case of climatic reasons, 57 (35.4%) claimed on mixed climatic impacts, while 42 (26.1%) claimed increase in sea surface temperature (SST). However, 30 (18.6%) they claimed the climatic reason was due to strong winds, 23 (14.6%) were claiming on sea level rise (SLR) and sand accumulation while 9 (5.6%) perceived ocean acidification (Figure 8). Apart from non-climatic impacts, the results of these climate extremes are that, the shellfish are highly affected and the effects are mainly cumulative where calm conditions favor their growth and harsh conditions of higher temperatures and strong winds causes shellfish to burrow deeper the soil hence their availability decreases [19, 20, 35]. Shell-collectors reported that shells are now more precious than previously, which compromises product quality, and line-fishers reported changing weather patterns and changing seasonal distributions of some fish species. Operations of fishing and farming activities are also expected to be affected, whether by short-term events such as extreme weather events or medium to long-term changes such as lake levels or river flow that could affect the safety and working conditions of fishers and fish farmers in the coastal areas that affect daily life activities [3]. This information can be supported by [25], that shelled species especially *C. gasar* when raised in its natural environment, presents a better growth performance during the rainy-dry transition period and the dry season, especially on farms located close to the coast, favors the development of the oysters, and optimizes their growth performance.

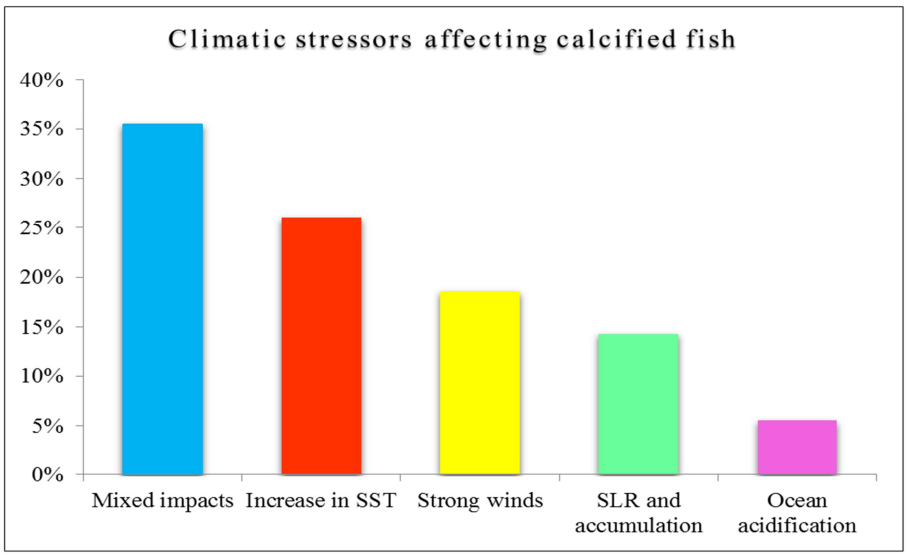

Figure 8. *Percentage responses of climatic stressors affecting shellfish availability.*

In addition to that, the relationship between climatic and non-climatic stressors affecting shellfish availability, two variables were tested with changes in weather pattern; experience in availability versus results of weather changes as well as reasons for shellfish availability against weather changes. The variables were first tested by Pearson's chi-squared and if the test failed to meet the assumption it warns and then fisher's exact tests was used test the relationship for their association on the climatic and non-climatic impact of climate change with the availability of shellfish (Table 4). Pearson's chi squared test was used to test the relationship between the reasons in shellfish availability versus changes in weather patterns and the results showed that p-value is 2.182×10^{-2}. Similarly, the relationship between experiences in shellfish availability versus the results of weather changes were tested using fisher's exact test revealing the results of p-value is 1.449×10^{-3} (Table 4). These values are highly significant ($p<0.05$) indicating that there is relationship between climatic and non-climatic variables. The decreases in calcified species occur through combinations of both human actions and changes in climatic conditions [24].

Table 4. *Relationship/association between variables.*

Variable tested	Test used	p-value	Decision	Conclusion
Experience in availability versus results of weather changes	Fisher's exact test	1.449×10^{-3}	Reject (H_0)	Highly significant
Availability reasons versus results of weather changes	Chi-squared test	2.182×10^{-2}	Reject (H_0)	Highly significant

Note: Null hypothesis (H_0): There is no significant association between variables

Table 5. *Common practices that are locally practiced in the study areas (n=161).*

Variable	Category	Frequency	Percentage (%)
	Harvesting shellfish by shifting at nearby areas	106	65.8
Management action	Harvesting large shells only	32	19.9
	Harvesting shellfish by shifting at the Islands	23	14.3
	Closure of shellfish harvesting	112	69.6
Preferred practice	Diversification of income	45	28.0
	No response	04	2.4

3.4. Local Measures Taken by the Community to Overcome the Stressors

The management action such as harvesting shellfish by shifting at nearby areas, harvesting large fish only and harvesting shellfish by shifting at the nearby Islands were considered (Table 5). The most preferred practices as local measures the gleaners preferred closure of shellfish harvesting to ensure availability, practicing diversification of income and others do not practice any method (Table 5).

Most gleaners especially women collect shellfish by shifting at the nearby places, some of them shift at the nearby Islands and others collect large shellfish only [6, 7, 16]. Studies have reported several conservation methods that gleaners and researchers are preferring are closure harvesting shellfish for a certain time, diversification of income so as to have several ways to earn income which can be achieved through interventions [7, 29] as reported in this study. Coastal areas close to community sites are often selected for fisheries closures due to smoothness of implementation, but interventions rarely assess local legitimacy and transparency with all user groups, such as women fishers [26].

4. Conclusions

The results revealed association between the variables in which the collection of shellfish is affected by weather changes, gleaning practices, nature of the area which determines the amount of shellfish collected per season in Zanzibar where some shellfish for example *Anadara sp.* are obtained throughout the season. Marine environment offers abundant and diverse resources and environmental functions and services for human productivity as well as life processes. Most countries worldwide have cheaply exploited and used sea and ocean to develop marine economy for some repetitive years. Because of this action, the coastal areas have become the most concentrated area developed by human. This has been outlined in the results from this study that most gleaners knew that there is decrease in availability of shellfish as one among the marine resources depletion. Both human and natural processes have caused this loss of marine resources in Zanzibar. The most common activity causing marine resources to deplete is the increase in calcified fish harvesters. Despite the increasing number of shell harvesters and increasing number of human activities in Zanzibar, climate extremes are also affecting shellfish availability to some extent. The major reasons for decrease in availability is the increase in demands of food consumption as well as a source of income to most families hence very valuable. Therefore, the fisheries sector in Zanzibar should take special effort to improve the shellfish breeding areas and create awareness to the gleaners on improving shellfish availability.

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