Vulnerability of Fishing and Fisheries Sector to Climate Change and Non-climate Risks as Perceived by Fishermen in Zanzibar Coastal Villages

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Vulnerability of Fishing and Fisheries Sector to Climate Change and Non-climate Risks as Perceived by Fishermen in Zanzibar Coastal Villages*

Vulnérabilité de la pêche et du secteur de la pêche aux changements climatiques et aux risques non climatiques. Perceptions des pêcheurs des villages côtiers de Zanzibar

Summary

Climate variability and change as well as sea level rise pose significant challenges to fisheries, other livelihood activities, water and food security in Small Island States including the Zanzibar Islands. Without planned strategic adaptation, the future projected changes in climate and sea level will intensify the vulnerability of these sensitive areas. In fact, climate and sea levels in East Africa respond from both regional and global events such as El Niño and La Niña, so that variability in these is likely to increase in the future. This requires adaptation at both local and national levels. This article is based on research conducted in two sites located in the north-eastern parts of each island: the main island of Zanzibar, namely Kiuyu Mbuyuni, Pemba Island and Matemwe, Unguja Island. The research focuses on existing conditions of the fisheries sector that create vulnerability, and secondly examines the perceived risk of climate change and non-climate risk on fisheries. Using mainly survey data, the study found that current scale and technologies involved in fisheries create their own set of vulnerability and that climate change risks add more pressure on the fisheries sector. The study finally suggests ways that could be used to build a resilient coastal fisheries activity among coastal communities in both of Zanzibar main islands.

Keywords

Vulnerability, fishers, perception, risk, climate variability, climate change, Zanzibar.

Résumés

La variabilité et le changement climatiques ainsi que l'élévation du niveau de la mer posent des défis importants pour la pêche, les autres activités de subsistance, l'eau et la sécurité alimentaire dans les petits États insulaires, y compris les îles Zanzibar. En l'absence d'une adaptation stratégique planifiée, les changements futurs prévus en termes de climat et de niveau de la mer intensifieront la vulnérabilité de ces zones sensibles. En fait, le climat et le niveau de la mer en Afrique de l'Est réagissent à des événements régionaux et mondiaux tels que El Niño et La Niña, de sorte que leur variabilité est susceptible d'augmenter à l'avenir. Cela nécessite une adaptation aux niveaux local et national. Cet article est basé sur des recherches menées dans deux sites situés dans les parties nord-est de chaque île : l'île principale de Zanzibar, à savoir Kiuyu Mbuyuni, l'île de Pemba et Matemwe, l'île d'Unguja. La recherche se concentre sur les conditions existantes du secteur de la pêche qui créent la vulnérabilité, et examine ensuite le risque perçu du changement climatique et du risque non climatique sur la pêche. En utilisant principalement des données d'enquête, l'étude a révélé que les technologies impliquées dans la pêche créent leur propre ensemble de vulnérabilité et que les risques de changement climatique ajoutent plus de pression sur le secteur de la pêche. L'étude suggère enfin des moyens qui pourraient être utilisés pour construire une activité de pêche côtière résiliente parmi les communautés côtières des deux îles principales de Zanzibar.

Mots-clés

Vulnérabilité, pêcheurs, perception, risque, variabilité climatique, changement climatique, Zanzibar.

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Introduction

According to FAO (2018), fisheries and aquaculture substantially contribute to the food security and livelihoods of millions of people all over the world. According to FAO (2014), fisheries and aquaculture directly contribute $24 billion to the African economy, representing 1.3% of the total African GDP in 2011. The sector (both fishing and processing) provides employment to over 12 million people. It also plays an important role in food security and employment in Zanzibar. It is dominated by artisanal fisheries, mostly fishing for local markets (FAO, 2004). However, the Government of Zanzibar has recently revived its Fisheries Company to invest in large-scale commercial fishing with a view to increasing state revenue and employment. This shows that fisheries are essential for local livelihood and state economy. The observed overdependence of fishing in many Zanzibar fishing villages (Makame, 2013), increases their vulnerability as the sector is highly sensitive to global and regional changes in climate (FAO, 2018; Barange et *al.,* 2014). In its Fifth Assessment Report (AR5), the Intergovernmental Panel on Climate Change (IPCC) argued that climate change and ocean acidification are altering the global ocean and its resources at an unprecedented rate compared with the recent past (IPCC, 2014; Cisneros-Mata et *al.,* 2019; Barange et *al.,* 2018; also see Table 1). According to Lam et *al.,* (2020), under the RCP8.5 emissions scenario the maximum catch potential of tropical fish stocks including western Indian Ocean is projected to decline by up to 40% by the 2050s. Studies show that climate change risks such as increasing warming conditions, sea surface temperature changes, extreme regional events such as ENSO, floods, drought and sea level rise are already affecting, or likely to affect, the productivity and distribution of fishery resources in both marine and inland waters as well as fishery infrastructure (Stenevik and Sundby, 2007; Sundby and Nakken, 2008; Miller, 2007; Badjeck et *al.,* 2010; Allison et *al.,* 2009; Table 1). Coastal communities that are largely dependent on fishery resources linked to coral reefs and mangrove ecosystems, such as in Zanzibar, are particularly vulnerable as these ecosystems are highly sensitive to both climate change and sea level rise (Cinner et *al.,* 2012; Boko et *al.,* 2007).

Table 1: Climate change impact on fisheries

Type of change	Climate risks	Impacts	Potential outcome for fishers and fishery resources
Physical environment	**Ocean upper layer warming**	Warm water species replace cold-water species.	Shifts in distribution of plankton, invertebrates, fish, and birds towards the North or South Poles; reduced species diversity in tropical water.
		Plankton species move to higher latitudes.	
		Timing of phytoplankton bloom changes. Zooplankton composition changes.	Potential mismatch between prey (plankton) and predator (fish population) and decline production and biodiversity.
	Sea level	Coastal fish breeding and nursery habitats (e.g. mangrove and coral reefs) lost.	Reduced production of coastal and related fisheries.
Fish stocks	**High water temperature**	Sex ratio changes. Spawning time alters. Migration time alters. Peak abundance time alters.	Possible impacts on timing and levels of productivity across marine and fresh water.
	Change in ocean currents	Invasive species, disease and algal blooms increase.	Reduced productivity of target species.
		Fish recruitment success affected.	Abundance of juvenile fish, and therefore production, affected.
Ecosystems	**Increased frequency of ENSO events**	Timing and latitude of upwelling change. Coral bleaches and dies off.	Changes in pelagic fish distribution.
			Reduced fishery productivity.
Coastal infrastructure and fishing operations	**Sea level rise**	Coastal profile change, loss of harbours and homes. Increased exposure of coastal areas to storm damage.	Costs of adaptation make fishing less profitable; risk of damage increases costs of insurance and/or rebuilding; coastal household vulnera-bility increases.
	Increased frequency of storms	More days at sea lost to bad weather, risks of accident increase.	Risks of both fishing and coastal fish-farming increase, making this a less viable livelihood option for the poor.
		Aquaculture installations (coastal ponds, sea cages) more likely to be damaged or destroyed.	Reduced profitability of large-scale enterprises; insu-rance premiums rise.

Adapted from FAO (2007) and Allison et *al.,* (2005).

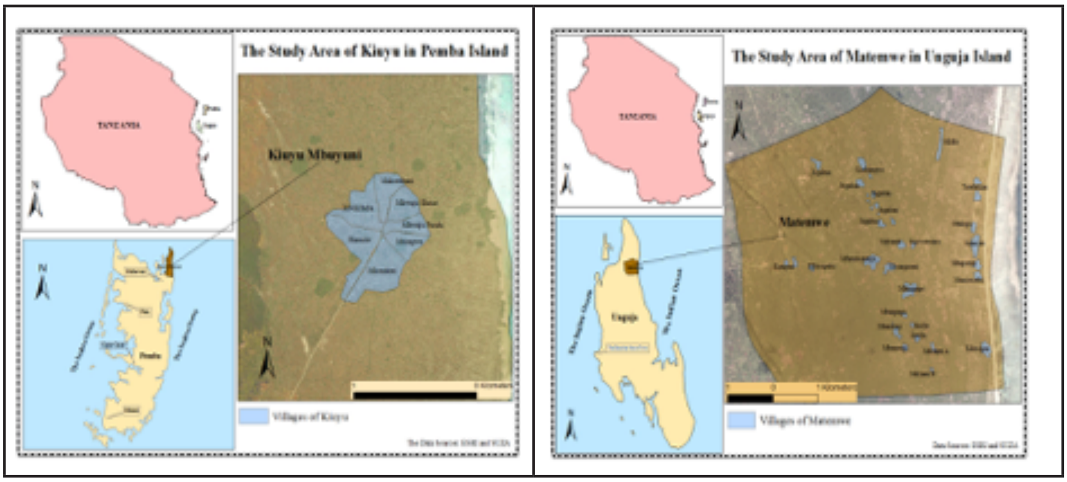
O'Connor et *al.,* (1999:462) defined risk perception as "perceived likelihood of negative consequences to oneself and society from one specific environmental phenomenon." Over the years, various environmental studies have studied human behavioural change in relation to environmental changes and have come up with different conclusions. According to cultural theory, risk perception is constructed within social and cultural realms (Rippl, 2002; Steg and Sievers, 2000). In this view Kahan et *al.,* (2007) argued that a combination of social culture, value and identity influence risk perception. A study by Kahan et *al.,* (2007:498) found that "men and women, whites and minorities, form distinct attitudes toward risk in a manner that protects from interference the activities on which their identities depend." This means that variations in risk perception between people within social systems are not only influenced by the culture that defines people, but also by the extent to which individuals protect their identity. People may choose to underestimate the risks related to climate variability in order protect their identity. For example, apart from ambiguity in the likelihood of risks related to climate change, the resistance of a flood-prone community in Mozambique to resettlement was also influenced by the value of the local place and associated identity as defined by residents (see Patt and Schroter, 2008). A study by Nursey-Bray et *al.,* (2012:754) shows that risk perception is determined by "(1) the level of knowledge, (2) the probability of harm, (3) the ability to cope with or mitigate the risk and (4) the value of the resources at risk." With regard to the value of the resources at risk, risk perception may also vary between individuals who have different connections to the resources at risk. A fisherman who solely depends on fishing to make a living may have a different opinion about an increase in temperature, or storms that affects fish stock distribution, compared with a fisher with a diversified livelihood portfolio. People's perceptions are also informed by direct experience, knowledge of the environment and extreme events such as floods, drought and stronger north- or south-easterly winds that operate beyond normal. This study examines the vulnerability of fishing and fisheries to climate change and other linked risks as perceived by fishermen. Specifically, the study seeks to examine the existing conditions of fishing to understand its vulnerability and to examine the perceived risk of climate change and other linked stressors on fisheries.

Methods

Study areas

This study was carried out in two areas (*shehia*): Kiuyu Mbuyuni in Pemba Island and Matemwe in Unguja Island, located in the northeast corner of each of the two major islands of Zanzibar (Fig. 1). Fishing is the main livelihood activity in both areas. Recent studies show that climate in Zanzibar has already experienced variability over the last decades (Makame, 2013). For example, the 1997/1998 El Niño event had a tremendous impact on coral reef in Zanzibar and the Indian Ocean (Payet and Obura, 2004) while storms over the Indian Ocean–also increased over time. Temperature (both minimum and maximum) and rainfall has been reported to experience variability over time. For example, in 2019, both minimum and maximum temperatures in Tanzania were high compared with annual average. Average annual total rainfall for 2019 was 1,283.5 mm, which is higher than the long-term average in the period 1981-2010. This makes 2019 the fourth wettest year on record since 1970 (TMA, 2019).

Figure 1: Location of the study areas. Left is Pemba and right is Unguja Island.



Data collection

98 fishermen were interviewed for the study on both sites, of whom 50 from Kiuyu Mbuyuni, Pemba, and 48 from Matemwe, Unguja. These individuals were randomly selected from the sampling frame. The paper combines data from several complementary sources; most of the data were obtained through surveys administered to fishermen. Additionally, we interviewed key informants at district level. Interviews were also conducted with two key informants from the Department of Fisheries and Marine Resources to establish the validity of the data obtained from the field, based on their experience of fishing and fisheries. Extra comments made by respondents during the survey were recorded and used to back up the quantitative data. Additionally, related literature was used extensively to explain the existing context of each sector. The main areas covered in the perception survey are outlined below.

Part 1: Existing context of the sectors

To understand the existing context of fishing across the sites, fishermen were asked to: (1) identify the type of vessels they used for fishing trips; (2) identify physical fishing assets they owned; (3) identify the position they held on the fishing vessels (e.g. crew member, gear owner, captain), and (4) estimate their monthly income. The percentage of responses to all four questions was then determined. Additionally, a cross tabulation and bivariate correlation test was performed to determine the relationship between the income of fishermen and ownership of physical fishing assets.

Part 2: Risks related to climate variability and change and other linked stressors affecting fishing and fisheries

Respondents were asked to what extent variability in climate was affecting fishing and fisheries (e.g. quantity of fish caught, stock distribution, variability in species caught). Respondents were asked to give one of the following responses: 1 = high impact; 2 = moderate impact; 3 = low impact; and 4 = no impact. Additional questions were asked to identify fish species that have declined or disappeared over time. Then the percentage of responses for each question was determined. With regard to other linked stressors and drivers of change, respondents were asked to identify those stressors that they thought were affecting the sector. The question was open and respondents were free to identify as many stressors as they wanted.

Results and Discussion

Existing context that creates vulnerability to climate change and other linked stressors

Fishing and Fisheries: Scale, technology, physical assets and income

The findings show that the majority of interviewed fishermen across the sites go out fishing in small vessels such as outrigger and dugout canoes (see Table 2 for the description of various vessel types). As expected, because of the lack of financial services and assistance, very few motorised boats are found across the sites. The findings also show that there are fishermen in both sites who do not use vessels but fish by wading into the water and walking to the reef (foot fishing/seaweed farming). This is due to low access to financial assets and services such as loans. The findings match the district data obtained from the Department of Fisheries and Marine Resources (DFMR, 2012) based on the summary of a fisheries survey (2010). The report shows that Micheweni, Pemba, where Kiuyu Mbuyuni is located, had 4,825 fishermen and 1,017 foot fishermen, whereas North 'A', Unguja, where Matemwe is located, had 5,370 fishermen and 1,164 foot fishermen. Across the sites there are few motorised boats. Fishing in the areas is also characterised by unsophisticated gear. This includes various types of nets (dominated by gill nets), lines, spears (mainly targeting octopus and big fish) and traps (large and small traps, fishing weir fence). The sophisticated fishing nets, locally known as *jarife,* which target certain species, are mostly found in Government-funded boats.

Table 2: Description of usual vessels available in the areas

Types of vessels	Description
Outrigger canoes (*Ngalawa*)	Length up to 6 m; draft to 0.5 m. The hull is basically a dugout canoe, often with an upwardly-curved and fanned bow and a pointed stern where the rudder is fixed. Two stabilising outriggers are attached to poles fixed inside the hull. The short mast, supported by movable stays, carries a spar (often bamboo) and a lateen sail.

Dug-out canoes (*Mtumbwi*)	Length up to 3 m, rarely more; draft to 0.5 m. The most basic and probably the oldest water craft in the western Indian Ocean region. The hull is carved out of a single tree trunk (mango trees being popular in some areas).
Sailing boats (*Mashua*)	Length up to 10 m; draft to 0.6 m. A smaller version of the dhow *(Jahazi*). Many carry outboard petrol engines in addition to or instead of sails.
Motorised boats (*Boti*)	Look like sailing boats but always carry an outboard petrol engine.

Description of outrigger, dug-out canoes and sailing boats adapted from Richmond (2010). Description of motorised boat is our own.

The study also found that the majority of vessels used for fishing across the sites were not owned by the fishermen themselves but rather by middlemen and wealthy persons in the villages or towns. The findings suggest that fishermen are characterised by low physical capital. This is probably attributable to poor saving of the income obtained from fishing caused by the increasing frequency of fishing failure across the sites as commented on by one fisher from Kiuyu: *"We earn very little from fishing and almost all of our earnings is used for buying food (rice)."* Low physical capital may reduce fishers' resilience to climate change risks. For instance, fishermen may sometimes land large amounts of fish that exceed market demand, but most of them are forced to sell their catch at cheaper prices as they do not have electricity, let alone refrigerators, to keep them until the next day. This makes them vulnerable to climate change.

Furthermore, the study found that the income of fishermen was highly dependent on their position on a vessel and ownership of physical capital including vessels. The cross tabulation result in Table 3 shows that a large proportion of the respondents who own the vessels, and at the same time are the captain, earned higher incomes (USD 70-90 and above 100) than just crew members without assets. A Pearson correlation test also revealed a significant correlation between income and position held in the fishing vessels. The result demonstrates that the majority of fishermen are relatively vulnerable, as many of them do not own physical assets such as vessels and fishing gear. Furthermore, fishermen's income is also sensitive to wind patterns. Because of their small size, the vessels used cannot withstand strong winds especially during the south-easterly wind season: during this time of the year, fishermen normally using these vessels remain at home. *"During north-easterly wind (*kaskazi*) I may earn more than USD 100 per season, while during south-easterly wind (*kusi*) I earn as little as USD 20 as outrigger canoes limit us from fishing far from the shore where the fish stock is very high."* North-easterly winds, apart from helping small vessels sail back from a fishing trip, are also perceived to drive fish stocks close to the shore as they blow in that direction, whereas south-easterly winds are considered risky for fishermen's safety as it pushes vessels away from the coast and are perceived as chasing fish stocks away (Feidi, 2005).

Table 3: Income and position in the fishing boat.

Positions in fishing boat	Income per month (%) in USD				
	10-30	30-50	50-70	70-90	100 and above
Gear owner/big traps	20	7	7	4	-
Crew member	60	57	52	33	20
Captain	20	-	15	-	8
Vessel owner and captain	-	14	22	54	68
Vessel owner and assistant captain	-	7	-	-	-
Both gear owner and captain	-	-	4	-	7
Both crew and vessel owner	-	14	-	8	-
Pearson correlation	**P=.01***				

*Significant correlation between income and position of a fisher in fishing boat (Exchange rate in 2011 was 1 USD = Tsh.1,600).

Almost all fish caught across the sites are sold locally at the landing sites within the village or neighbouring villages and mostly through auctions. Some fishermen sell their catch at the village market in retail fashion; most of those falling in this category were foot fishermen. On the other hand, octopus, squid and lobster are often sold outside auctions using weights measured on a scale (Crona et *al.,* 2010). Although most fishermen do not have complaints about the auctions, they do not trust the process entirely, as fishermen from Kiuyu Mbuyuni and Matemwe respectively commented:

> *"Auctions have many tricks, sometimes the auctioneer may influence price to favour a buyer he knows, but sometimes we take back our fish if we are not satisfied with the price."*
>
> "*We are not always happy with the price at the auction, but we have to accept it because we have no freezers for storing fish to sell them the next day*."

Middlemen also play a major role in fishery businesses all over Zanzibar, coastal Tanzania and Kenya (Crona, et *al*., 2010). Due to the limited availability of micro-credit, both from banks and government institutions that could help poor fishermen acquire assets such as vessels and fishing gear (Mohamed 2003), fishermen in most cases acquire this from middlemen, who in return secure priority access to the fish catch. This reciprocal agreement between fishermen and middlemen is likely to influence the price and fishermen's income in the long run (Crona et *al.*, 2010). In Pato Lagoon, Brazil, middlemen were also found to control the price of the catch in return for their assistance to fishermen, including lending money (Kalikoski et *al.*, 2010). Although the nature of artisanal fisheries may vary from country to country, they are mostly considered as having poor resilience. Because it is characterised by the small size of vessels, poor technology, low physical capital, poor market systems, over-dependency on fishery resources for income and food, the sector is very sensitive to climate change and other interacting stressors such as over-fishing, conflicts and socially-constructed stressors (DuBois and Zagrafos, 2012; Kalikoski et *al.*, 2010; Allison and Ellis, 2001; Badjeck et *al.*, 2010).

Fishermen's perceptions of risks and impacts related to climate variability and change

Although over-fishing and illegal fishing may have the upper hand in the vulnerability of marine ecological niches (Boko et *al.,* 2007), climate change has also significantly influenced the sensitivity of physical and biological processes at various scales (Allison et *al.,* 2009; Boko et *al.,* 2007; Barros et *al.,* 2009; Nagy et *al.,* 2009). A large proportion of respondents across the sites believed that the perceived variability in climate had an impact on the quantity of fish landing, quality and size of fish, stock distribution, species and breeding grounds (Table 4).

Table 4: Perceived risks and impacts of climate variability and change on fishing.

Responses	Quantity (%)		Stock distribution (%)	
	K	M	K	M
1	64	68	41	64
2	11	15	30	14
3	23	17	30	22
4	2	-	-	-
Impact score Mean±SE	1.64±0.138	1.49±0.122	1.89±0.127	1.53±0.140

Responses	Species caught (%)		Breeding ground (%)	
	K	M	K	M
1	9	46	29	63
2	12	12	19	8
3	76	42	52	29
4	3	-	-	-
Impact score Mean±SE	2.73±0.117	1.96±0.188	2.23±0.159	1.67±0.187

K = Kiuyu Mbuyuni, Pemba, M = Matemwe, Unguja.
1 = high impact, 2 = moderate impact, 3 = low impact, 4 = no impact.

Perceived risks and impacts of climate variability and change on the quantity of fish landed

About 64% of interviewed fishermen in Kiuyu Mbuyuni and 68% in Matemwe perceived the impact of climate change on the quantity of fish caught per fish trip to be high (Table 4). About 23% of fishermen in Kiuyu Mbuyuni and 17% in Matemwe believed that the impact is very low. Moreover, 2% of Kiuyu Mbuyuni fishermen perceived no impact of climate variability and change on the quantity of fish caught. Despite the fact that fishing is controlled by seasonality, most fishermen believed that even during a good fishing season the amount of fish caught had declined over time. Quotes in Box 1 also support the perception of fishermen regarding the decline in fish catch. However, the decreasing fish catch may also be attributed to depleted fishery resources close to the shore. A large number of foot fishers and a dominance of small vessels in the fishing system results in fishers having concentrated very close to the shore for decades. Although fishery resources are dynamic, such concentration may have depleted the resources and thus affected fish catch per fisher.

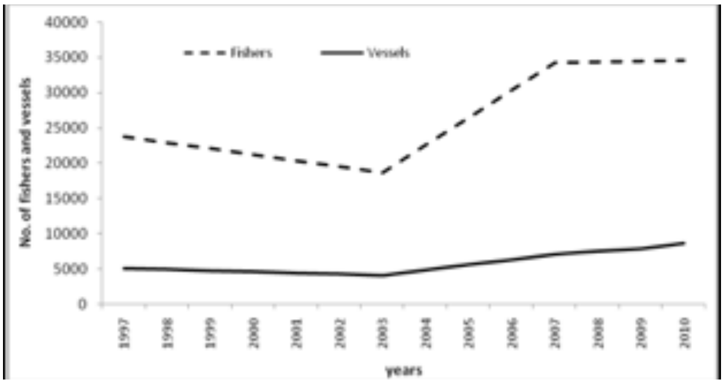
Box 1: Fishermen's comments on variations in fish quantity in the areas.

"Our parents used to fish along the ridge very close to the shore (within a kilometre in both sites) and they used to land large catches of fish of varying species, but now we reach as far as close to Mombasa, Kenya, looking for fish."
"You can't compare north-easterly season (locally known as kaskazi*, a good season for fishing) nowadays and* kaskazi *in those years. In those previous years we used to land a large amount of fish during* kaskazi*."*
"Although generally the fish catch declined over time, I remember that during the 1997-1998 El Niño year we used to land large amounts of fish."
"Impacts only affect shallow water areas close to the shore. If we had big fishing vessels with modern gear, we would fish a lot out there."

The fishermen's comment on increased fish catches during the 1997-1998 El Niño year, which was characterised by heavy rainfall and warm temperature, is supported by a study by Feidi (2005) who noted that fish catches in Zanzibar increase with increasing rainfall, because high run-off brings nutrients from the land, which attracts fish close to the shore. Elsewhere in the world, warmer conditions caused by ENSO events produced mixed results (Allison et *al.,* 2009; Badjeck et *al.,* 2010). Although local fishermen perceived a decline of fish in their territorial water, which affected their catch over time, the analysis of data obtained from the Department of Fisheries shows a significant increase in artisanal fish landing in Zanzibar from just 8,851 tons in 1990 to 28,759 tons in 2011. In-depth interview with key informants revealed that the low fish catch landed in the 1990s could be attributed to poor data collection at landing sites, while the significant rise in the 2000s can be attributed to the improvement of data collection methods, increased number of motorised boats that can fish off-shore, the use of gear that targets certain species, and the introduction of a protected marine area. Whatever the case, it seems that the amount of fish landed through artisanal fishing is increasing towards what the FAO calls a "sustainable potential yield limit" (Mkenda and Folmer, 2001).

Based on the potential yield for various fishing grounds available in Zanzibar (reefs, coral reefs, mangrove ecosystems, continental shelves and continental slopes) including pelagic fish, the potential yield was estimated at 25,000 to 30,000 metric tons per year (FAO, 1991, cited in Mkenda and Folmer, 2001). Given the constant increase in the tons of fish landed recently, the 30,000-ton limit as suggested by the FAO will be exceeded within the next two or three years. The constant increase is probably caused by the influx of more fishermen, attributed to increasing population, agriculture failure, lack of alternative sources of income in coastal villages, and an increasing demand for fishery products in the urban and tourism sectors. For instance, the number of fishermen increased from 2,373 in 1997 to 34,571 in 2010, whilst the number of vessels jumped from 5,149 to 8,639 in the same period (Figure 2).

Figure 2: Number of fishermen and vessels (source of data: DFMR 2012)



Perceived risks and impacts of climate variability and change on species caught

With regard to the species caught, the results in Table 4 again show some variation in the perceptions of fishermen on this. About 76% of interviewed fishermen in Kiuyu Mbuyuni believed that the impact on the types of species caught was low, while 46% of Matemwe fishermen perceived the impacts to be high. This means there are some species that are no longer caught or have declined over time. Three percent of interviewed fishermen in Kiuyu Mbuyuni perceived no impact on the type of species landed. Mean results show that the perception of Kiuyu Mbuyuni fishermen (2.73±0.117) falls at 3 (low impact) whereas, in Matemwe (1.96±0.188) this falls at 2 (moderate impact). Although the results revealed a difference in perception across the sites, fishermen in both sites identified various species which had either declined or disappeared over time. This decline, however, may not necessarily be caused by climate change. A wide array of species that had declined was mentioned, but the study selected only those species which scored a high frequency. These are *Chanos chanos* (milkfish), bluefin trevally, Indian mackerels, anchovies, spangled emperors, sharks and rays, spinefoot and goatfish. Some of the species identified by fishermen were also identified as threatened both in Zanzibar and at global level. A study by Crona et *al.,* (2010) categorised spangled emperors (*changu*), that were cited as declining in Matemwe, Unguja, and as having medium and high vulnerability in Kenya and Zanzibar. Emperors are in high demand in both local and tourism markets. The decline of sharks may be partly linked to the increasing popularity of shark fin soup in South-East Asia (also see Richmond, 2010). Other species cited in Matemwe, Unguja, such as blue rays and goatfish, were also perceived to have disappeared in Chwaka Bay, Unguja (Muhando, 1995). However, Muhando (1995) attributes the disappearance of these species to overfishing.

The perceived decline of Indian mackerel and anchovies in Kiuyu Mbuyuni, Pemba, may be partly associated with the observed variability of rainfall which reduced run-off to the ocean mainly because plankton, the main food of Indian mackerel (see Richmond, 2010), feeds off nutrients which are largely brought to the sea by rainwater run-off. It has been argued by Feidi (2005) that the abundance of fish in Zanzibar is partly influenced by rainfall which brings nutrients crucial for fish feeding down to the sea. In an interview with a key informant it was noted that these two species are seasonal, small pelagic species, so it is possible that they were out of season during the field survey. However, it is also possible that the changing characteristics of the seasons caused by climate variability and other climate-related factors may have influenced the abundance of these species (see Allison et *al.,* 2009). For example, studies by Sun et *al.,* (2006) and Avaria et *al.,* (2000) cited in Badjeck et *al.,* (2010) show that the landing of mackerels fell nearly 50% in Taiwan and 70% in Chile in the aftermath of the 1997-1998 El Niño events.

Mangrove ecosystems are among the most common habitats for both *Chanos chanos (mwatiko)* and bluefin trevally *(kole kole)* (Richmond 2010). Their disappearance or decline as perceived by fishermen in Kiuyu Mbuyuni may be linked to habitat degradation through human-induced activities. Climate variability may have a stake too as mangroves are considered an ecosystem vulnerable to climate change and sea level rise (see Nicholls et *al.,* 2007). During a group discussion at the Pemba site, one participant also commented that the decrease in the number of people using the mangrove forest as a toilet may also be reducing the number of fish in their territorial waters because the supply of nutrients has decreased. A study by Muhando (1995) cited in Mkenda and Folmer (2011), also recorded that fishermen observed that *Chanos chanos* had disappeared in Chwaka Bay, Unguja, which had experienced massive mangrove deforestation through the urban demand for firewood and poles. A study by Bagarinao (1991) of the life of *Chanos chanos* shows that, despite variability and regional extreme events such as ENSO, the climate of the sea water in Zanzibar still offers favourable conditions for the survival of *Chanos chanos,* based on their temperature and salinity tolerance levels. Their decline may therefore be caused by either over-fishing or habitat loss attributable to both human-induced actions and climate change (Mkenda and Folmer, 2001).

Perceived risks and impacts of climate variability and change on fish stock distribution and breeding grounds

About 41% of interviewed fishermen in Kiuyu Mbuyuni and 64% in Matemwe perceived high levels of change in the distribution of fishery resources, while about 20% in Kiuyu Mbuyuni and 22% in Matemwe perceived the impact of climate change on the distribution of the fishery resources in territorial water as low (Table 4). On the other hand, the results also show that the majority of interviewed fishermen in Kiuyu Mbuyuni (52%) perceived the impact of climate variability and change on breeding grounds such as coral and mangrove ecosystems as low. By contrast, 63% of interviewed fishermen in Matemwe perceived the impact as high, while only 29% of interviewed fishermen in Kiuyu Mbuyuni shared this perception. The mean results of fishermen's perceptions regarding the impact on breeding grounds were 2.23±0.159 (moderate impact) in Kiuyu Mbuyuni and 1.67±0.187 (high impact) in Matemwe (Table 4).

With regard to fish stock distribution, most fishermen believed that wind direction influences the movement of fishery resources. As discussed earlier, north-easterly winds (*kaskazi*) indicate a good fishing season since they bring more fish into the near-shore water, while south-easterly winds (*kusi*) chase fish into deeper water. In examining the potential for new investment for Zanzibar fisheries, Feidi (2005) commented that north-easterly winds with short spells of rain attract more pelagic migratory fish species into territorial water. This means that the variability of wind as perceived by foot fishers and fishermen may have some implications for the distribution of fish resources in the areas. Apart from seasonal distribution resulting from seasonal variation in winds, disturbance of fish resources distribution may also be the result of the destruction of breeding grounds and habitat. The use of GPS by fishermen, especially in the Unguja site, to locate the position of fish (Makame, 2013) may reflect the changing patterns of fish resource distribution. This is highlighted by the following comment made by a fisher in Matemwe:

> "*In those early years, we used to know which type of fish species we could trap in this place and which type of species in that place. But now things have changed*."

As discussed earlier, mangrove and coral reefs are among the crucial breeding grounds for fishery resources in Zanzibar (Mkenda and Folmer, 2001). However, these ecosystems are under pressure, not only from climate change and sea level rise but also from human-induced activities. In Kiuyu Mbuyuni, mangrove forests are an important source of fuel wood and live wood pegs for foot fishers. Similarly, respondents indicated that, apart from variability in winds and storms, human activities significantly affect the forests. It is worth noting that in Matemwe there are no stands of mangrove forests. Similarly, a large number of in-shore pools which act as breeding and habitat grounds for fish species have been buried by massive sand deposits attributed to variability in winds, thus reducing the quantity and distribution of fishery resources close to the shore. Some fishermen in Matemwe, Unguja, however, associate deterioration of in-shore breeding and habitat grounds with foot fishing (also see Richmond, 2010).

In terms of coral reefs, respondents perceived no impact of temperature on coral reef ecosystems. However, they believed that human activities such as the use of illegal fishing methods like spear guns, are moderately affecting the reefs. In a similar manner, respondents in Matemwe perceived the impact of human activities on coral reefs as moderate. Despite the variations in the perceptions between sites, it is widely understood that coral reef ecosystems, which act as a safe haven for the majority of fish species, are sensitive to global warming (Obura, 2005; Boko et *al.,* 2007; Nicholls et *al.,* 2007). Coral reefs have become one of the Earths' first ecosystems to directly suffer large-scale mortality from climate change (Ateweberhan and McClanahan, 2010). In Zanzibar, coral ecosystems are highly vulnerable to extreme regional events such as ENSO. For example, during the 1997-1998 El Niño, coral ecosystems in Zanzibar experienced massive bleaching which extensively affected the tourism industry and fishery resources as well (see Boko et *al.,* 2007). The findings therefore tally with Table 1, which indicates that the variability of sea surface temperature, storms, sea level rise and ENSO events have a large impact on species distribution, abundance of juvenile fish and off-shore fishing grounds (also see Cinner et *al.,* 2012; Allison et *al.,* 2009; Miller, 2007; Boko et *al.,* 2007).

Fishers' perceptions of risks and impacts related to other linked stressors and drivers of change on fishing and fisheries

Fishermen across the sites were asked to identify non-climate drivers or stressors that they thought affected fisheries and fishery resources. The four most cited stressors across the study sites were: increased numbers of fishermen, use of illegal fishing methods, increased demand for fishery products, and Allah's will (Table 5). Other stressors that emerged are deterioration of coral reefs, changes in the ocean and the increased duration of south-easterly winds (Table 5), In addition, a small number of fishermen across the sites identified the Indian Ocean tsunamis of 2004, the use of nets and foreign fishing fleets as stressors for fisheries and fishery resources. Stressors that were identified only in Matemwe, Unguja by a few fishermen include pollution, and conservation practices such as the Marine Protected Areas, which was seen to limit fishers' access to fishery resources.

With regard to the increasing number of fishermen, about 22% of interviewed fishermen in Kiuyu Mbuyuni and 18% in Matemwe believed that increasing numbers of fishermen as a result of population increase had caused the decline in catch per fisher over time (Table 5). Decreasing fish catch means reduced access to food as well as reduced saving capacity at both individual and household levels. Their perceptions tally with the results in Figure 2, which show that, even at national level, the number of fishermen and vessels has increased tremendously. The increased number of fishermen is attributed to the lack of alternative sources of income among youth who either completed or dropped out from school. Illiteracy, low skills related to tourism and hotel owners' perceptions of the incapacity of local people to take part in tourism-related work exclude most of the youth from the tourism sector. Similarly, most young males regard foot fishing as a job for females. In other words, fishing is the only available option for the majority of people and this puts more pressure on fishery resources. In other parts of the world, the problem of increasing pressure on fishery resources has also been observed. For example, Kronen et *al.,* (2010) found that the lack of income diversification in increasing populations of the Pacific fishing community has resulted in high pressure on fishery resources.

In terms of illegal methods of fishing and the increasing demand for fish products, Table 5 results show that about 10% of fishermen interviewed in Kiuyu Mbuyuni and 22% in Matemwe believed that illegal fishing methods affected fishery resources. On the other hand, 13% of fishermen interviewed in Kiuyu Mbuyuni and 17% in Matemwe believed that the increasing demand for fishery products also increased pressure on fishery resources. The increased demand for fisheries products caused by expanding tourism and the increase of an affluent population in urban areas threatens the resilience of the fishery resources and may cause extinction of the desired species (see Crona et *al.,* 2010). Given the low technology involved in fishing, coupled with low access to modern equipment, increasing demand is likely to encourage the use of illegal techniques of fishing such as spear guns, beach seining nets, small-eye nets and dynamite.

Table 5: Other perceived linked stressors and drivers of change on fishing and fishery resources

Stressors on fishing and fishery resources	Kiuyu (%)	Matemwe (%)
Illegal methods	10	22
Change in the sea	17	7
Increased number of fishermen	22	18
Increasing demand for fishery products	13	7
Long duration of south-easterly wind (*kusi*)	8	11
Conservation practices	-	7
Deterioration of coral reef	7	10
Last Indian Ocean tsunamis	3	6
God's will	15	3
Foreign fishing fleets	4	6
Low temporal migration system (*dago*)	1	1
Pollution produced by vessels	-	2
Total	**100**	**100**

With regard to God's will, about 15% of interviewed fishermen in Kiuyu Mbuyuni, Pemba and 3% in Matemwe, Pemba, believed that declining fish stocks and fish species was a result of God's will (Table 5). It was very difficult to establish the exact reasons why more people in Kiuyu Mbuyuni ascribed fishing problems to God compared with Matemwe, Unguja. Attributing declining fish catch to God's will is highlighted by the comment made by a fisher in Matemwe during the survey: *"God used to bring to the ocean one basket of fish in a day of rainfall, that could be used for 15 years for the whole world, so we had nothing to worry about."* This perception may affect both fishery resources and coping strategies as fishermen believe that all problems are solved naturally, so that they are reluctant to address or respond to perceived and observed risks related to climate change. This perception may also influence the use of illegal methods that could further affect ecological resilience.

Furthermore only 7% of interviewed fishermen in Matemwe believed that conservation practices through marine protected areas (MPAs) affect their fish catch and livelihoods as it reduces access to key fishing grounds. This claim came up more strongly in the discussions during PLA workshops in Matemwe. Their perceptions, however, differ from the general understanding that MPAs help to revive the health of coastal and marine ecosystems and improve local livelihoods (see Warner and Pomeroy, 2012). Local people believe that the introduction of protected coral reef patches off Mnemba islet limits local fishermen's fishing activities in the area and ultimately impacts on their income. Respondents claimed that they had not benefited from the money paid by tourists who dive and snorkel on the coral reef inside the MPAs. For instance, they claimed that they received only USD 500 ten years ago, which was used to build toilets in their schools. Restricted access to fishing grounds associated with MPAs as stressor was only depicted in Matemwe, Unguja because there is no nearby MPA in Kiuyu Mbuyuni, Pemba.

Other identified drivers of change in the fisheries systems were the last Indian Ocean tsunamis (3% in Kiuyu Mbuyuni and 6% in Matemwe) and a decrease in temporal migration amongst fishermen (*dago*) (1% in both Kiuyu Mbuyuni and Matemwe). Results show that more people cited tsunamis in Matemwe compared with Kiuyu Mbuyuni, probably because the aftermath temporary effects of tsunamis such as waves were stronger in Matemwe, Unguja than in Kiuyu Mbuyuni, Pemba. Fishermen believed that the Boxing Day tsunami, which occurred on Sunday 26 December 2004, triggered by the Sumatra-Andaman earthquake, also contributed to the decline of fish across the sites. Local fishermen believed that the tsunami had disturbed fish breeding grounds and habitats and therefore fish migrated to the other areas; as a fisher from Kiuyu Mbuyuni, Pemba, explained: *“We know the local habitat of certain species in the ocean, but since the 2004 tsunami some of the species have migrated from one place to the other; probably their habitat was affected by the tsunami.”* The decrease in temporal migration of fishermen was also mentioned as a stressor on fishery resources. This decrease may be influenced by the expansion of the tourism industry and conservation practices through MPAs on the tiny islets off major islands (Unguja and Pemba). Most of these islets were previously used as fishing camps when fishermen engaged in short-term migration within the islands. The migration of fishermen between islands or to the coast of mainland Tanzania has also declined over time as commented by a fisher: *“Myself I think the disuse of the seasonal fishing camp outside Matemwe has contributed to the decline of fish resources in our area. I remember we used to migrate to Pemba, south of Unguja, and sometimes within North of Unguja, but now we have concentrated in our area throughout the year.”* Temporal migration of fishermen may initially improve the health of an ecosystem, but is likely to finally increase pressure and conflicts. In West and Central Africa both spatial and temporal migration of various kinds was employed by fishermen to cope with and adapt to declining fish stocks and climate change (Njock and Westlund, 2010).

Conclusion

The findings show that the existing context of these activities makes them sensitive to their own set of characteristics. For example, low ownership of important assets such as vessels and gear was found to be one of the major sources of vulnerability among fishermen. The study found that income increased with increased ownerships of assets. Additionally, the size of vessels used is also a source of vulnerability. Because of the small size of vessels, fishing activities are controlled by wind pattern seasonality (north- and south-easterly winds) and fishing activities are limited to short distances. This adds more pressure to in-shore fishery resources and causes overfishing. In other words, even without climate variability, the fishing sector’s existing conditions create its own vulnerability condition. Increasing warming conditions, coupled with human activities that threaten fishery habitats and breeding grounds, are perceived to have a high impact on the quantity of fish, fish stock distribution, and the types of fish caught. Species such *Chanos chanos* (milkfish), bluefin trevally, Indian mackerel, anchovies in Kiuyu Mbuyuni, and spangled emperors, sharks and rays, spinefoot and goatfish in Matemwe, were perceived to have declined over time due to changes in the ocean attributed to both climate variability and human actions. Furthermore, as in other studies, the findings show that impacts from climate variability interact negatively with non-climate stressors, many of which operate beyond the control of the coastal communities and thus intensify their sensitivity to changes in climate. The findings substantiate the fact that these three sectors are already vulnerable to a wide range of stressors, and that, without adaptation, future climate change will intensify the situation and affect peoples' efforts to overcome poverty.

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