Ocean and Coastal Management 163 (2018) 437–444

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Assessment of ecological vulnerability to climate variability on coastal fishing communities: A study of Ungwana Bay and Lower Tana Estuary, Kenya

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ARTICLE INFO

Keywords:
Small scale fisheries
Climate change
Susceptibility
Ungwana bay
Lower Tana Estuary
Kenya

ABSTRACT

Fisheries resources are important in supporting the livelihood of many coastal communities especially in the developing tropical countries. Fisheries resources however, continue to face unprecedented pressure from the impacts of climate change, and this presents both ecological and socio-economic challenges to the dependent communities. This paper assessed the ecological vulnerability to climate variability of artisanal fishing communities in Ungwana Bay and the Lower Tana Delta in Kenya, using selected fin fish species. A combination of approaches were adopted and used to identify and determine exposure, sensitivity, and adaptation indicators. These included a critical review of existing literature, socio-economic survey, and computation of temperature and rainfall variation using long term data from 1983 to 2015. The method of Equal Weights (EW) was applied to all indicators after normalization. The data was normalized in a scale of 0–1, where 0 indicated low vulnerability level and 1 high vulnerability. By using composite index, the selected Ngomeni and Ozi fishing communities within the larger Ungwana Bay and Lower Tana Delta indicated high levels of vulnerability of 0.9 and 0.8 respectively. Due to high vulnerability level and poor adaptation capacity by the local fishing communities in the selected study sites, we recommend government and non-governmental agencies to reinforce community based organizations (CBOs) activities on ecological conservation and social network creation to promote short and long term adaptation measures.

1. Introduction

Coastal and marine ecosystems are sensitive to climate variability even with minimal degree of fluctuation (Pallewatta, 2010). In addition to climate variability, these ecosystems experience over-exploitation as a result of increasing human population demands (Palmer et al., 2011). Therefore, climate variability as well as human pressure threaten the sustainability of fisheries resources (Brander, 2010). Globally, temperature has significantly changed and has increased[1] for the last three decades (IPCC, 2014; Rahmstorf et al., 2017). Climate variability has been described as unequivocal thus, causing implication on the long term condition of fisheries resources (IPCC, 2007; Caputi et al., 2015). Severe variations of climatic elements may result to reduced abundance as a result of death and migration of some fish species (Welch et al., 2014). The compounding effects of climate variability and anthropogenic pressure may cause high rate of degradation of coastal and marine ecosystems and result in reduced or lost ecosystem services (Palmer et al., 2011).

Degraded ecosystems such as those of coastal and marine have high potential to affect the social and economic wellbeing of the dependent fishing communities (Pallewatta, 2010). These effects are associated with reduced fish catches which then affect the social and political life of the communities (Nayak et al., 2014; Bhatta et al., 2016). For example, Bhatta et al. (2016) observed that changes in wetland ecosystem in Maguri-Motapung, India resulted to essential reduction of fish stocks. Likewise, the source of poverty among small scale fisheries in Brazil and

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[1] The average global temperature on Earth has increased by about 0.8° Celsius (1.4° Fahrenheit) since 1880. It is argued that two-thirds of the warming has occurred since 1975, at a rate of roughly 0.15–0.20 °C per decade (IPCC, 2014).

https://doi.org/10.1016/j.ocecoaman.2018.07.015
Received 23 October 2017; Received in revised form 27 June 2018; Accepted 18 July 2018
0964-5691/

India has been linked to ecological changes (Nayak et al., 2014).

Studies have made significant effort in addressing the socio-economic wellbeing of fishing communities in terms of their vulnerability to climate variability (Cinner et al., 2011; Islam et al., 2014; Metcalf et al., 2015). Cinner et al. (2011) conducted a regional study which examined vulnerability of coastal communities to the impacts of climate change on coral reef fisheries. Existence of different levels of vulnerability to coral reef fisheries was observed in different countries studied where Kenya showed the highest level of vulnerability compared to Tanzania, Seychelles, Mauritius and Madagascar (Cinner et al., 2011). Metcalf et al. (2015) also examined the vulnerability of marine socio-ecological systems as a precursor for adaptation strategies. It was noted that vulnerability assessment assist communities to realise their strengths and weaknesses thus ensuring appropriate assimilation of adaptation measures. Understanding the level of vulnerability in a community is necessary to identify and develop appropriate interventions and acceptable coping measures that would contribute to sustainable use of fisheries resources (Laukkonen et al., 2009).

The Ungwana Bay and Lower Tana Delta in north coast Kenya are important fishing areas sustaining the artisanal (small scale as well as traditional fisheries) fishing communities (Munga et al., 2014a). The bay is considered as one of the richest in fisheries resources along the Kenyan coast (Government of Kenya, 2015). However, pressure on the fisheries resources along the bay has been high due to the ongoing shrimp bottom trawling activity since the last four decades with resultant high rate of fin fish bycatch (Fulanda et al., 2011; Munga et al., 2012). Fin fish bycatch ranged between 432.0t in 2001 to 603.2t in 2004 (Munga et al., 2012). This triggered conflicts between the shrimp bottom trawling and the artisanal fishing activities over the fisheries resources (Munga et al., 2014a). Climate variability in the bay has become an additional threat to fisheries resources (Munga et al., 2014b). Deenapanray and Tan (2011), projected an increase in temperature of 3.3 °C and 21% decrease in rainfall by 2050 in the region.

This study therefore, assesses the vulnerability of the fishing communities to climate variability using selected fin fish species in Ungwana Bay and the Lower Tana Delta, north coast Kenya. On one hand, the fin fish species were used to establish the level of exposure and sensitivity of the ecosystems, and on the other hand, the fishing communities were used to determine their adaptation capacity.

2. Materials and methods

This study focused on three fishing communities namely; Ngomeni, Kipini, and Ozi located within the Ungwana Bay and Lower Tana Delta of north coast Kenya (Fig. 1). Ngomeni and Kipini communities are dominant for estuarine and marine fisheries while Ozi is dominant for riverine fisheries (Kamau, 1998; Abila, 2010). In Ngomeni and Kipini, the contribution of economy from fisheries resources is estimated to be 90% and 70% respectively (Kitheka, 2002). The ecosystem of the study area is enriched with nutrients from upstream supplied by River Tana and River Sabaki thus supporting the diversity of fisheries resources. We used a set of methods that are commonly applied in ecological vulnerability assessment of fishing communities according to Cinner et al. (2011) and Metcalf et al. (2015).

Firstly, we adopted the method of ecological sensitivity assessment used by Metcalf et al. (2015) in vulnerability measurement of marine socio-ecological systems. The method relies on fish species biological information existing in literature to evaluate species' sensitivity to environmental variables and establish the ecological sensitivity index. We used the available literature to identify key commercially important fin fish species as well as developing their biological profiles describing the species' life history, habitat usage, and levels of environmental tolerance conditions (WWF, 2014). The species' biological profile was then assessed from a set of environmental indicators developed by Pecl et al. (2014) to determine their sensitivity level using a scale of 1–3, where 1 indicated low and 3 high sensitivity (Table 1). Five demersal fin fish species were identified from the study area which met the desired criteria and these were: blackspotted rubberlip (*Plectorhinchus gaterinus*), pinkear emperor (*Lethrinus lentjan*), dory snapper (*Lutjanus fulviflamma*), marbled parrotfish (*Leptoscarus vaigiensis*), and shoemaker spinefoot (*Siganus sutor*) (WWF, 2014). We perceived fishing demand, fishing pressure, and human population as important factors contributing to sensitivity of fin fish resources. These parameters were therefore included in determination of ecological sensitivity index in the study area.

Secondly, we identified temperature, rainfall and perception of the fishing communities on the impact of climate variability to fin fish production as exposure indicators based on the available data and applicable to the study area. Data on the perception of fishing communities was collected through socio-economic survey (method described in the next paragraph). A scale of 1 – low, 2 – medium, and 3 – high was used to measure the perception of the fishing communities on the impact of climate variability in fin fish production for the last 10 years. Two sets of temperature data were analysed. Terrestrial Temperature (TT) for the riverine study site (Ozi), and Sea Surface Temperature (SST) for the estuarine and marine study sites (Kipini and Ngomeni). The SST was derived from National Oceanic and Atmospheric Administration (NOAA) for a 30 year period (1983–2015), while TT as well as rainfall data were obtained from the Kenya Meteorological Department, Malindi Station for the same period. The mean increase of SST, TT, and rainfall were computed and compared against maximum and minimum threshold values (projected maximum and minimum of temperature and rainfall in the area) to estimate the exposure level (Deenapanray and Tan, 2011). Fritzsche et al. (2014) indicated the need to introduce threshold values to capture realistic condition of vulnerability of an index particularly for data with minimal or no difference in values. Threshold values are the maximum and minimum range of an indicator and are derived from experts or published literature (Fritzsche et al., 2014).

Lastly, the socio-economic survey was carried out to collect data on artisanal fishing communities addressing the level of fish demand, fishing pressure, climate change impacts on fish production, human population as well as adaptation factors. We defined adaptation capacity as the ability of the fishing communities to cope with the dynamics of fisheries resources due to climate variability impacts. Therefore, we developed and collected data for a set of seven adaptation indicators to assess the strength of the communities to respond to the above condition. The adaptation indicators included household size, education, employment, disease status, access to health services, access to portable water, and alternative sources of livelihood. All the indicators were measured in a scale of 1–3 (1 – low, 2 – medium, and 3 – high).

The sample size for the study was determined by the infinite Cochran (1977) formula. This is because the overall population of the entire region was more than 50,000 people (Government of Kenya, 2009). Any population above 50,000 is considered infinite. Therefore, the sample size for infinite population was computed using the Cochran's infinite formula whereby:

$$n_0 = \frac{z^2pq}{e^2} \tag{1}$$

Where:

n_0 = sample size,
z = is the selected critical value of desired level of confidence,
p = is the estimated proportion of an attribute that is present in the population,
q = 1-p,
e = is the desired level of precision

In social sciences, 95% level of confidence is an acceptable accuracy level and a precision value of 15% and below is acceptable level of variability in sample size determination.

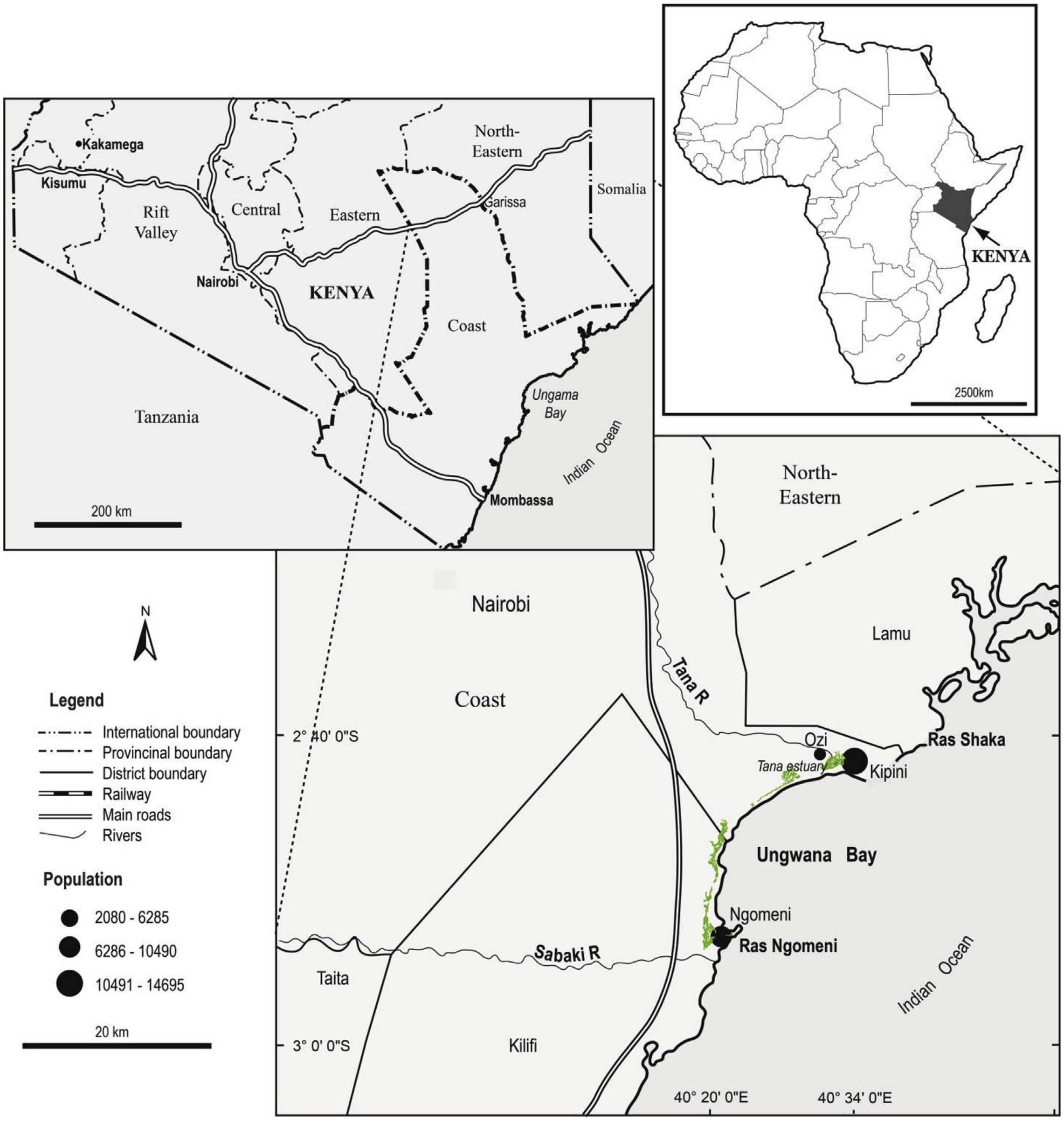

Fig. 1. Map showing fishing communities (Ngomeni, Kipini, and Ozi) in Ungwana Bay and Lower Tana Delta, north coast, Kenya.

Table 1
Definition of sensitivity indicators and criteria for measuring fin fish species'sensitivity to climate variability in Ungwana Bay and Lower Tana Delta, Kenya (Adopted from Pecl et al., 2014). Scale of measurement ranges from 1 to 3, where 1-indicates low, 2-medium, and 3-high sensitivity level to climate variability.

Sensitivity indicators		High sensitivity (3)	Medium (2)	Low sensitivity (1)
Abundance	Fecundity (egg production)	<100 eggs per year	100-20, 000 eggs/year	>20, 000 eggs/year Low sensitivity (3)
	Successive recruitment events sustaining the fish abundance	Highly episodic	Occasional & variable	Consistent every 1–2 years
	Age at maturity	>10 years	2–10 years	<2 years
	General *versus* specialist habitat	Reliance on both habitat and prey	Reliance on either habitat and prey	Reliance on neither habitat and prey
Distribution	Capacity of larval duration - hatching to settlement	<2 weeks or no larval stage	2–8 weeks	>2 months
	Physiological tolerance-latitudinal coverage of adult species as an indicator for environmental tolerance	<10° latitude	10–20° latitude	>20° latitude
Phenology	Environmental variable as a phenological cue for breeding – cues include salinity, temperature, currents and freshwater flows	Strong correlation of spawning to environmental variable	Weak correlation of spawning to environmental variable	No apparent correlation of spawning to environmental variable
	Migration (seasonal or spawning)	Migration is common for the whole population	Migration is common for some of the population	No migration

Therefore, level of confidence was set to be 95% hence $z = 1.96$, desired precision was set to be $\pm 5\%$ hence $e = 0.05$, infinite population is normally set to be 50% hence $p = 0.5$, $q = 1–0.5 = 0.5$.

Sample size $n_0 = \frac{(1.96^2)(0.5)(0.5)}{(0.05)^2} = 384.16 \approx 384.$

When excluding other parts of the region, the specific population size for the study area was 27,020 people which comprised of Ngomeni, Kipini and Ozi only. Therefore, Cochran (1977) suggested a correction formula for the sample size calculated by infinite formula when specific population size is known. Thus the sample size in equation (1) was corrected by Cochran's correction formula (1977) as follows:

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}} \tag{2}$$

Where:

n = new sample size to be determined,
n_0 = sample size derived from eq. (1),
N = actual population size of the subjects

$$n = \frac{384}{1 + \frac{(384 - 1)}{27020}} = 378.6 \approx 379$$

Specific sample size in each study area was determined by the following formula:

$$w = n/N \times sample\ size \tag{3}$$

Where: w = weight.

n = Population for each stratum
N = Total population for the three strata

Thus the sample size for Ngomeni, Kipini and Ozi were determined as follows:

$$\text{Ngomeni} = \frac{10241}{27020} \times 379 = 143.6 \approx 144$$
$$\text{Kipini} = \frac{14695}{27020} \times 379 = 206.1 \approx 206$$
$$\text{Ozi} = \frac{2084}{27020} \times 379 = 29.2 \approx 29$$

Semi structured interviews with questionnaires were used to collect data. Respondents were engaged on one to one interview during the data collection. Purposive sampling was used to identify fishing communities, and then simple random sampling was used to select the respondents. The respondents were identified through a simple random process which was conducted through the help of chief administrators and village elders in the respective areas. All the names of household heads of fishing communities were assigned numbers and then a table of random number generator was used to produce the numbers to be included in the sample size. The corresponding household names on the random numbers generated were then identified and engaged in the semi-structured interviews.

2.1. Normalization of indicators

Different scales of units were used in measuring sub-indices of sensitivity, exposure, and adaptation capacity. These sub-indices were then normalized into a common scale ranging from 0 to 1. Where 0 indicates low level of vulnerability while 1 indicates critical level. The method of Equal Weights (EW) was applied to all indicators. This method is simple due to the assumption that all indicators under consideration have equal contribution to the vulnerability (Fritzsche et al., 2014). Based on the functional relationship of indicators with vulnerability (Table 2), formulae (i) and (ii) were used to normalize the indicators with (↑) and (↓) functional vulnerability relationship accordingly (Fritzsche et al., 2014; Žurovec et al., 2017). The overall average of exposure, sensitivity, and adaptation index was then computed from their respective sub-indices as follows:

$$X_{ij} = \frac{Xi - MinXij}{MaxXij - MinXij} \tag{4}$$

Where:

X_{ij} is the normalized value of ij data set for a specific indicator,
Xi is the actual value to be normalized,
X_{Max} and X_{Min} are the maximum and minimum values of the indicator.

$$y_{ij} = \frac{MaxXij - Xi}{MaxXij - MinXij} \tag{5}$$

Where:

Yij is the normalized value of ij data set for a specific indicator,
Xi is the normalized actual value,
X_{Max} and X_{Min} are the maximum and minimum values of the indicator.

2.2. Framework of vulnerability analysis

We applied the IPCC (2007) model of vulnerability assessment to calculate the final vulnerability level (Fig. 2). This model was also

Table 2
Definition of functional relationship of indicators with vulnerability used for normalization of data. (↑) – Positive, (↓) – Negative relationship with vulnerability.

	Sub indicators	Vulnerability functional relationship with the indicator
Exposure Indicator	Temperature	(↑) - The higher the indicator the higher the vulnerability (Žurovec et al., 2017)
	Rainfall	(↑) - The higher the indicator the higher the vulnerability (Žurovec et al., 2017)
	Climate impact on fin fish production	(↑) - The higher the indicator the higher the vulnerability (This study)
Sensitivity indicator	Abundance	(↓) - The higher the indicator, the lower the vulnerability (Pecl et al., 2014)
	Distribution	(↑) - The higher the indicator the higher the vulnerability (Pecl et al., 2014)
	Phenology	(↑) - The higher the indicator the higher the vulnerability (Pecl et al., 2014)
	Fin fish demand	(↑) - The higher the indicator the higher the vulnerability (This study)
	Fishing pressure	(↑) - The higher the indicator the higher the vulnerability (This study)
	Human population	(↑) - The higher the indicator the higher the vulnerability (Žurovec et al., 2017)
Adaptation capacity indicator	Household size	(↑) - The higher the indicator the higher the vulnerability (This study)
	Education	(↓) - The higher the indicator, the lower the vulnerability (Žurovec et al., 2017)
	Employment	(↓) - The higher the indicator, the lower the vulnerability (Žurovec et al., 2017)
	Disease status	(↑) - The higher the indicator the higher the vulnerability (This study)
	Access to health services	(↓) - The higher the indicator, the lower the vulnerability (This study)
	Access to water services	(↓) - The higher the indicator, the lower the vulnerability (This study)
	Alternative sources of livelihoods	(↓) - The higher the indicator, the lower the vulnerability (This study)

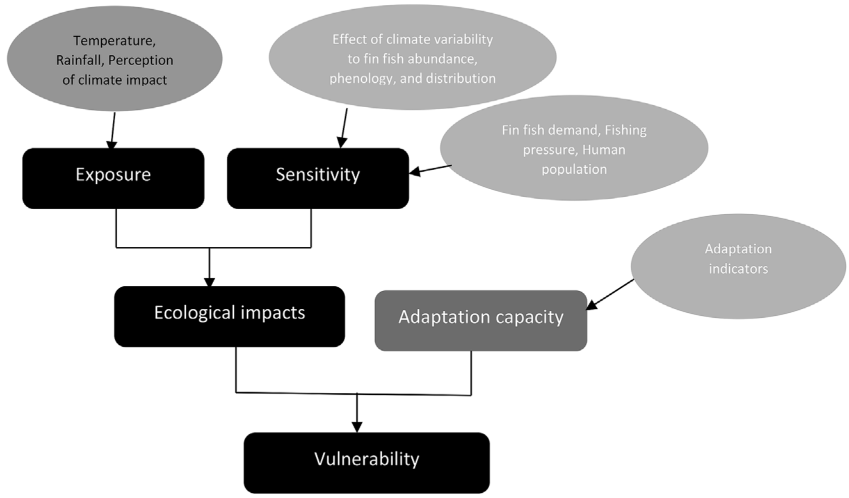

Fig. 2. Frame work of vulnerability measurement (Adopted from IPCC, 2007).

adopted by Cinner et al. (2013) in assessing the vulnerability of coastal communities to impacts of climate change on coral reef fisheries. In this study, the indicators were aggregated using the formula below:

$$VI = (E + S) - AC \tag{6}$$

Where:

VI = Vulnerability index;
E = Exposure;
S = Sensitivity;
AC = Adaptation capacity.

3. Results

3.1. Exposure indicators

All indicators were normalized between 0 and 1, where 0 implies low level of vulnerability and 1 high level of vulnerability. This interpretation is used across all the results presented. Overall average exposure index for Ozi, Ngomeni, and Kipini was 0.70, 0.63, and 0.33 respectively (Table 3). The high vulnerability exposure in Ozi and Ngomeni was due to high exposure of the impact of climate variability in the perceived fin fish production of 1.00 and 0.88 for the two sites,

Table 3
Normalised values for exposure, sensitivity, and adaptation capacity indicators in Ungwana Bay and Lower Tana Delta, Kenya. Index measurement scale range from 0 to 1, where 0 - low vulnerability while 1 - critical level.

Indicators		Sub-indices	Ngomeni	Kipini	Ozi
Exposure		Temperature	0.00	0.00	0.12
		Rainfall	1.00	1.00	1.00
		Impact of climate on fin fish production for the last 10 years	0.88	0.00	1.00
		Average	**0.63**	**0.33**	**0.70**
Sensitivity	Abundance	*Plectorhinchus gaterinus*	0.75	0.75	0.75
		Lethrinus lentjan	0.63	0.63	0.63
		Lutjanus fulviflamma	0.25	0.25	0.25
		Leptoscarus vaigiensis	0.25	0.25	0.25
		Siganus sutor	0.25	0.25	0.25
	Distribution	*Plectorhinchus gaterinus*	0.25	0.25	0.25
		Lethrinus lentjan	0.75	0.75	0.75
		Lutjanus fulviflamma	0.75	0.75	0.75
		Leptoscarus vaigiensis	0.25	0.25	0.25
		Siganus sutor	0.75	0.75	0.75
	Phenology	*Plectorhinchus gaterinus*	0.50	0.50	0.50
		Lethrinus lentjan	0.50	0.50	0.50
		Lutjanus fulviflamma	0.50	0.50	0.50
		Leptoscarus vaigiensis	0.50	0.50	0.50
		Siganus sutor	0.50	0.50	0.50
	Anthropogenic pressure to fin fish resources	Fin fish demand	0.29	0.00	1.00
		Fishing pressure	0.37	0.00	1.00
		Human population	0.65	1.00	0.00
		Average	**0.57**	**0.55**	**0.60**
Adaptation capacity		Household Size	1.00	0.00	0.86
		Education	0.00	1.00	0.30
		Employment	0.00	0.14	1.00
		Health status	0.00	1.00	0.13
		Access to health services	0.43	1.00	0.00
		Access to portable water	0.41	1.00	0.00
		Alternative source of livelihoods	0.00	0.08	1.00
		Average	**0.26**	**0.60**	**0.47**

Table 4
Sensitivity of selected fin fish species to climate variability in Ungwana Bay and Lower Tana Delta, Kenya. Index measurement scale range from 0 to 1, where 0 - low vulnerability while 1 - critical level.

Fin fish species	Abundance	Distribution	Phenology	Average sensitivity level
Plectorhinchus gaterinus	0.75	0.25	0.50	0.50
Lethrinus lentjan	0.63	0.75	0.50	0.63
Lutjanus fulviflamma	0.25	0.75	0.50	0.50
Leptoscarus vaigiensis	0.25	0.25	0.50	0.33
Siganus sutor	0.25	0.75	0.50	0.50

respectively. Temperature recorded minimal vulnerability levels across all the study sites of 0.00 in Ngomeni and Kipini, and 0.12 in Ozi. Unlike temperature, rainfall recorded high vulnerability levels of 1 across all the study sites (Table 3).

3.2. Sensitivity indicators

Overall average sensitivity index was high in all the study sites with the highest value of 0.60 in Ozi, followed by 0.57 in Ngomeni, and 0.55 in Kipini (Table 3). Fin fish demand as well as fishing pressure contributed to high vulnerability level of 1 in sensitivity indicator in Ozi, while population pressure contributed to high vulnerability of 1 in sensitivity indicator in Ngomeni and Kipini (Table 3). The selected fin fish species recorded similar sensitivity levels of abundance, distribution and phenology indices in all the study sites (Table 3). However, analysis of individual species' sensitivity to climate variability revealed variations where *Lethrinus lentjan* showed high vulnerability level of 0.63. *Plectorhinchus gaterinus*, *Lutjanus fulviflamma* and *Siganus sutor* showed moderate vulnerability (0.50 all cases), while *Leptoscarus vaigiensis* indicated low vulnerability (0.33) (Table 4).

3.3. Adaptation capacity indicators

In adaptation capacity index Kipini, Ozi and Ngomeni depicted an overall index value of 0.60, 0.47 and 0.26 respectively (Table 3). The high vulnerability in adaptation capacity in Kipini was as a result of low education, poor health status, low access to health services, and low access to portable water which all depicted an index value of 1 (Table 3). On the other hand, the low vulnerability in adaptation capacity in Ngomeni was as a result of better education, higher employment opportunities, better health status, and availability of alternative sources of livelihood which all recorded an index value of 0.00 (Table 3).

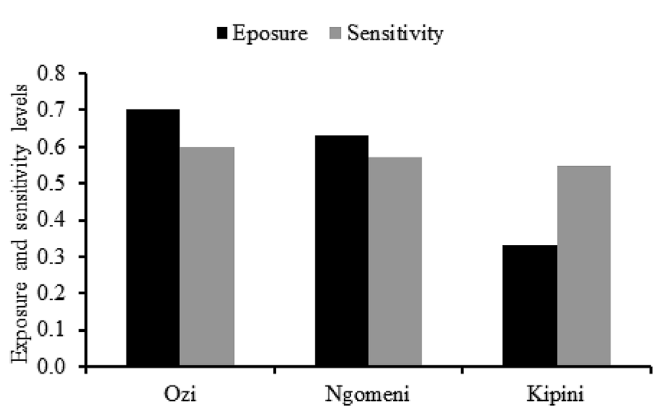

Fig. 3. Comparison of exposure and sensitivity levels of the selected marine fin fish species among the fishing communities in Ungwana Bay and Lower Tana Delta, Kenya.

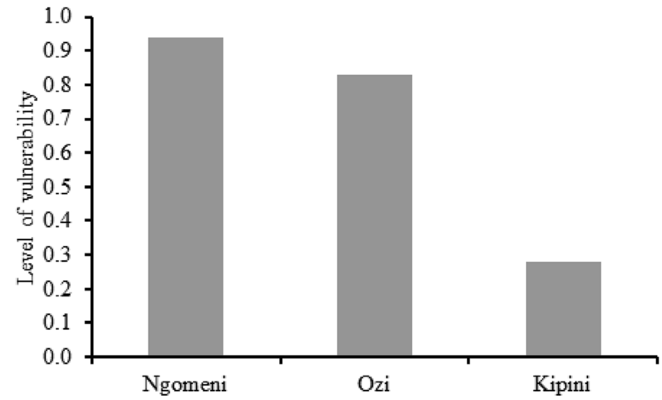

Fig. 4. Comparison of vulnerability of fishing communities in Ungwana Bay and Lower Tana Delta, Kenya.

3.4. Vulnerability of fishing communities in comparison with exposure and sensitivity of the selected fin fish species

In the Ungwana Bay and Lower Tana Delta, Ngomeni and Ozi fishing communities showed high levels of vulnerability of 0.94 and 0.83, respectively. The Kipini fishing community indicated relative low level of vulnerability of 0.26 (Fig. 3). The exposure of climate variability to the selected fin fish species was also high in Ozi (0.70) and Ngomeni (0.63) compared to Kipini (0.33) while sensitivity of the species to climate variability was high across all the sites (Fig. 4). The sensitivity index for Ozi, Ngomeni and Kipini was 0.60, 0.57, and 0.55, respectively (Fig. 4).

4. Discussion

Sustainable sources of livelihood for artisanal fishers largely depend on the sustainability of ecosystem services including provisioning for fisheries resources. Thus understanding the ecosystem vulnerability to climate variability is critical for ensuring food security to communities who primarily depend on natural resources, particularly the coastal and marine resources. Fisheries resources tolerate specific environmental conditions suitable to their biological functioning (Welch et al., 2014). Consequently, climate variability affects these environmental conditions thereby threatening fisheries resources globally (Chowdhury et al., 2010).

Infrequent and reduced rainfall is a key threat to fisheries resources in Ungwana Bay and the Lower Tana Delta. These areas are continuously supplied with freshwater from rivers Tana and Sabaki which form an important estuarine ecosystem that supports fisheries production. In line with the rainfall variability observed in this study, Deenapanray and Tan (2011) projected a 25% reduction of rainfall by the year 2050 in Malindi-north coast of Kenya within where the study area is located. This will intensify reduced water supply from the rivers thus resulting to decreased estuarine ecosystem, low nutrient supply and change in environmental conditions hence affecting fisheries production (Kibria et al., 2017).

Ngomeni and Ozi are particularly at a high threat in fisheries production compared to Kipini. This may be attributed to the location of these sites, Ngomeni being a purely marine environment and Ozi being a riverine environment. Kipini harbours both estuarine and marine environments thus providing a wide spatial adaptation to fin fish species against climate variability. Generally, the tropical regions are characterized by reduced rainfall with low water availability in fisheries habitats causing changes in environmental conditions as well as loss of fisheries resources (Kibria et al., 2017).

In most cases, fisheries (ecological) sensitivity is assessed using environmental indicators for selected specific species (Pecl et al., 2014). However, ecosystem functioning is affected by both natural and anthropogenic factors. Thus, apart from biological sensitivity of fisheries, Metcalf et al. (2015) noted there is need to capture important socio-economic factors that directly affect fisheries resources for sensitivity assessment. With this regard, the sensitivity of the selected fin fish species (biological) to climate variability across the study sites indicated slight variations. This is because the Ungwana Bay and Lower Tana Delta experience similar climatic conditions. Fin fish species in a similar ecosystem that experience similar climatic conditions tend to show minimal differences in sensitivity exposure. This was confirmed by Pecl et al. (2014), who conducted sensitivity assessment of fisheries to climate change in south-eastern Australia. All the species observed showed moderate sensitivity to climate change with slight variations that ranged between 2.75 and 1.25.

In this study, however, the overall sensitivity level was highly influenced by differences in anthropogenic pressure exerted on fisheries resources at Ngomeni, Kipini and Ozi. Ozi experiences high demand for fisheries resources, therefore, exerting high fishing pressure to the resources. On the other hand, Ngomeni and Kipini experience the challenge of population increase thereby escalating the demand for fisheries resources with time. In a study for measuring the vulnerability of marine socio-ecological systems, Metcalf et al. (2015) found similar results in Australia where the level of vulnerability was partly influenced by high dependency of humans on natural resources in Bowen community. Therefore, these socio-economic factors may aggravate sensitivity threat to fisheries resources in the long run. Overall, fisheries sensitivity level is relatively high in the study area.

Vulnerability of coastal and marine artisanal fishing communities to climate change may be manifested by reduction in fish catches (Salim et al., 2014; Bhatta et al., 2016). Sowman and Raemaekers (2018) observed catch reduction in Angola, Namibia and South Africa due to the impacts of climate change. Eventually, catch reduction may cause poverty as well as food insecurity (Nayak et al., 2014). Likewise, climate change impacts to fin fish production is extremely high in Ungwana Bay and the Lower Tana Delta. This suggests reduction in catches among the fishing communities thus increasing their vulnerability.

In addition, the study area is also characterised by low adaptation capacity. Generally, the vulnerability of coastal and marine artisanal fishing communities is highly associated with low level of adapation capacity in most developing countries (Islam et al., 2014; Adelekan and Fregene, 2015). Kipini fishing community is highly vulnerable to adaptation capacity compared to Ngomeni and Ozi. This was as a result of low education, low health status, poor health services, and limited portable water accessibility. Islam et al. (2014) closely confirmed this observation in Bangladesh where the vulnerability of the coastal fishing communities was associated with low level of education. Kipini is characterized by the presence of both local and foreign migrant artisanal fishers (Munga et al., 2012). These foreign migrant artisanal fishers move from the neighbouring Tanzania seasonally depending on fish availability thus being incapable from accessing education and health services appropriately (Wanyonyi et al., 2016). The migrant artisanal fishers may have also resulted to the population increase thus exerting pressure on education and health facilities available.

On the other hand, Ngomeni and Ozi with lower populations are mostly composed of local resident fishing communities thus having relatively better access to education and health services. Better education and health services are the most important adaptation factors that contributed to low vulnerability in Ngomeni and Ozi. Wamsler et al. (2012) confirmed this in their work which demonstrated that education plays an important role in enhancing adaptation capacity to climate change among poor communities. In addition to relatively better education and heath services, Ngomeni is also characterized by availability of alternative sources livelihood and portable water.

Though Ngomeni and Kipini indicated better adaptation capacity, this study generalized most of the adaptation indicators. For example, employment status did not differentiate among permanent, casual, and contract basis. Permanent employment present better adaptation capacity to climate variability than casual and contract employment types. This is due to the constant income earning among the permanent employed group which enable them to plan in advance for appropriate coping actions as opposed to those in causal and contractual basis.

5. Conclusion

The Ungwana Bay and Lower Tana Delta ecosystem experiences both high exposure to climate variability and increased anthropogenic pressure to fisheries resources. In addition to these threats, the artisanal fishing communities are characterized by low adaptation capacity for the selected indicators. Strengthening the adapation capacity would lower their vulnerability level. Consequently, there is need for increased awareness creation on fin fish climate variability impacts. There is also need to raise the health and education standards by increasing the number of health facilities and training institutions in the area. The available facilities are inadequate considering the vast geographical area and the increasing human population.

Acknowledgement

Our thanks go to the National Research Foundation (NRF), South Africa (SFH150922142954) for supporting this study by awarding a PhD scholarship to Mr. Dzoga in 2016 International NRF Doctoral Scholarship. We thank the National Research Fund (NRF) of Kenya for awarding a research grant which additionally supported the research process. We would also like to thank Mr. Jonathan Ngayai of the Kenya Meteorological Department (KMD), Msabaha Station in Malindi for providing the long term data sets of rainfall and temperature.

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