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Effect of Meteorological Parameters on Mullet Recruitment Patterns in Bagamoyo Mangroves Ecosystem, Tanzania

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Abstract
We studied the annual distribution patterns and size structure of mullet fish in Ruvu Estuarine Mangrove (REM) and Mbegani non Estuarine Mangroves (MnEM) areas of Bagamoyo Tanzania in relation to meteorological parameters. Mullets were collected during low tide using beach seine of 20 m long, 2 m wide with a stretched mesh size of 1.6 cm towed over an area of about 100 m^2. Two mullet species, *Mugil cephalus* and *Valamugil buchanani* were found in study area varied significantly in terms of abundance between sites and between seasons. The *M. Cephalus* abundance was signicantly higher in REM site than in MnEM sites (Kruskal Wallis, $p < 0.024$). The abundance of *M. cephalus* and *V. buchanani* were significantly higher during rainy season than dry season ((Kruskal-Wallis, $p < 0.020$; $p < 0.001$) respectively. The mullet collected on mangroves area were all juveniles and were positively correlated (($p < 0.05$) with rainfall and dissolved oxygen. However, they were indirectly correlated (($p < 0.05$) with atmospheric temperature which significantly affects other environmental parameters and in turn affect mullet recruitment patterns. Understanding the relationships among meteorological factors, environmental parameters and mullet recruitment patterns can be useful for forecasting future success of fishery and mariculture progress in Tanzania.

Keywords: Climate variability, Mangroves ecosystems, Mullet fish, Recruitments patterns

Introduction

Mullets are widely spread coastal pelagic fish occurring in the mangroves and estuaries areas of tropics and sub tropics. They are commercially important fish throughout the world, supporting many coastal communities both from capture fisheries and aquaculture industries (Pillay and Kutty, 2005). Mullets are the most important forage fishes representing significant food source for upper-level piscivores (Mwandya *et al.,* 2010). They grow up to a maximum of 120 cm SL and weigh up to 8 kg. The length at first maturity is 36 cm SL (Froese, *et al.,* 2014). They are catadromous fish and therefore recruit in lagoons, coastal waters, mangroves and estuarine areas following a period of offshore spawning (Ditty and Shaw, 1996).

Recruitment is an important component of population dynamics and plays an essential role in the abundance of organism because the survival of juveniles influences adult population (Aburto-Oropeza, *et al.,* 2007). Understanding and predicting recruitment pattern of fish larvae is considered as stepping-stone for appropriate and effective fisheries management (Svendsen *et al.,* 2007; Botsford *et al.,* 2009) and biodiversity conservation (Jones *et al.,* 2007; Almany *et al.,* 2009). The recruitment variability in life history of pelagic fish, especially those with short life spans and plankton feeders, makes their populations sensitive to climate fluctuations (Aburto-Oropeza, *et al.,* 2007). Recruitment variability plays a principal role in determining patterns of population density and community structure (Svensson *et al.,* 2006).

Meteorological parameters such as rainfall and atmospheric temperature are highly correlated with marine environmental variables (Meynecke *et al.,* 2006; Lagade *et al.,* 2011). These are associated with marine fish recruitment variability (MacKenzie and Koster 2004), distribution and abundance of fish (Weijerman *et al.,* 2005; Heath, 2007).

Several efforts have been made to recognize the association between physical changes in ocean environment and biological processes which affect fish stock (Byrne *et al.,* 2002). However, the association has been difficult to understand as large numbers of environmental variables which have been tested for correlation with recruitment resulted into highly spurious correlation (Mwandya *et al.,* 2009). The impacts of rise in sea surface temperature (SST) and sea level have been noted in Tanzania marine waters. It was projected that the atmospheric temperature at Bagamoyo will increase by 0.85 – 1.65^{0}C, and the long rains occurred between March to May will decrease significantly in 2020-2040 (Besa, 2013).

Currently, little is known on how meteorological parameters affect mullet abundance on mangrove habitat areas as rainfall lowers marine salinity. In addition, runoff water brings nutrients to the mangroves area which in turn favours growth of micro and macro algae which are essential food for mullet and other organisms. Also through photosynthesis, dissolved oxygen (DO) in mangrove environments increases which is important in supporting marine life. Therefore, it is important to evaluate the effects of meteorological parameters to both mullet abundance and environmental variables, and how they affect mullet recruitment.

The current study examines distribution pattern and size structure of mullets in Ruvu estuarine and Mbegani non-estuarine mangroves ecosystems in relation to environmental conditions and meteorological parameters.

Material and Methods

Study Area

The study was conducted at two mangrove systems of Bagamoyo District, namely Ruvu which is an estuarine Mangroves area (REM) (6^{o}22'S, 38^{o}51'E) and Mbegani which is non Estuarine Mangroves (MnEM) (6^{o}27'S, 38^{o}58'E) sites (Figure 1). Bagamoyo District usually experiences two rainy seasons, namely heavy and long rains that occur from March to May and short and light rains from October to December. The rest of the months are dry. During this study (2012) there was no rainfall recorded from

October to December and therefore the dry season was prolonged.

Prior to the establishment of permanent sampling stations, determination of coverage of the major bottom substrate types (seagrass, macroalgae, sand and/or mud) was done using a square frame of 1 m^2 that was randomly placed on each site (n = 50). The water depth during high and low tides were recorded and thereafter the seining areas were established (Table 1).

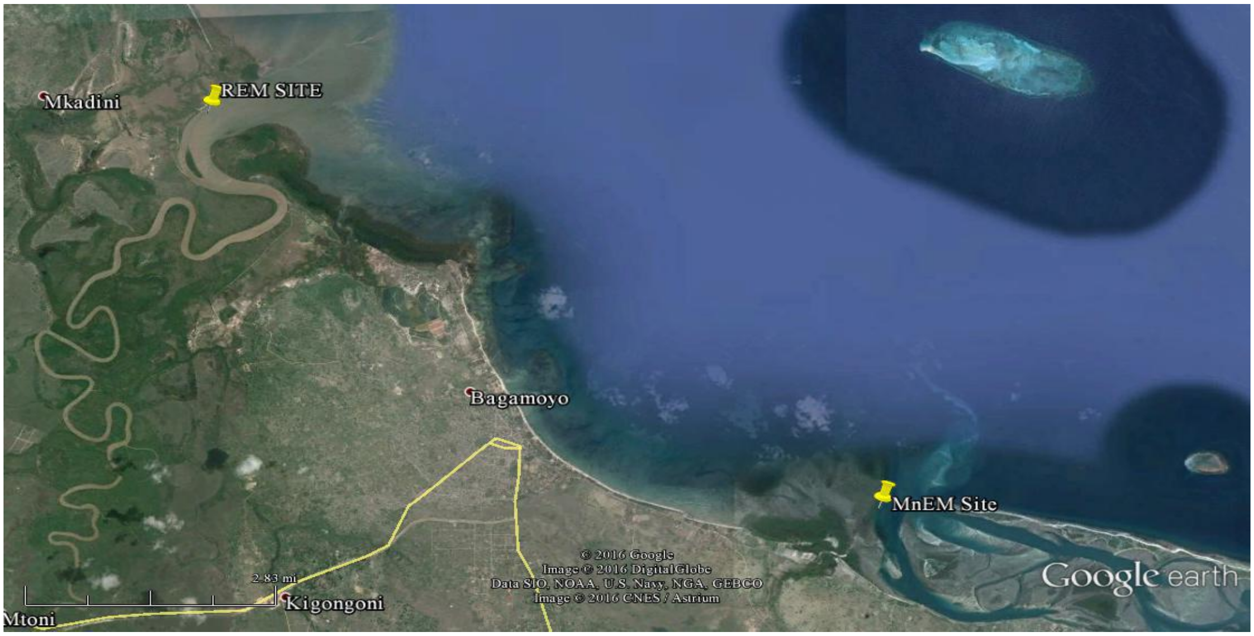

Figure 1: The Mbegani non estuarine and Ruvu estuarine mangroves area, Bagamoyo

Sampling Procedure

Mullet fish were caught using a beach seine of 20 m long, 2 m wide with a stretched mesh size of 1.6 cm. The beach seine was towed during the low tide over an area of about 100 m^2 in each haul. This was done each month from January to December 2012 (except July).

Two replicate hauls were taken at every site during each sampling trip. To minimize the effect of consecutive sampling, the second haul was taken 10 minutes after the first haul. The catches of each haul were placed in separate labeled plastic bags and transported in an ice-box to the laboratory for identification. The mullets were distinguished from each species according to morphological identification as described by Bianchi, (1985). *Mugil cephalus* (Stripped mullet) juveniles were characterized by olive-green dorsally, sides silvery shading to white ventrally; lateral stripes sometimes distinctive and pectoral fins short when folded forward does not reach eye. *Valamugil buchanani* (Blue tailed mullet) were characterized by greenish dorsally, flanks and abdomen silvery, small gold patch on upper operculum, caudal fin bright blue, pectoral fins yellow with dark blue spot dorsally. The caught fish were counted and standard length (SL) of each individual for each species was measured using measuring board to the nearest 0.1cm. The fish were further divided into size class intervals of 2 cm and grouped for each site i.e. REM and MnEM to assess spatial distribution patterns in size frequency. Fish abundance was calculated by taking average number of fish harvested divided by a total seined area.

Water quality variables which included dissolved oxygen (DO), salinity, water temperature and pH were measured prior to fish sampling at each sampling station by using YSI 6600 V2-4 water-quality multi-probe (YSI, Yellow Springs, Ohio, USA). The monthly atmospheric (Atm) temperatures and rainfall data for Bagamoyo during 2012 were obtained from Tanzania Meteorological Agency (TMA), Dar es Salaam. At each sampling site, samples were collected for two consecutive days per month.

Data Analysis

The variations in number of individuals and abundance of two mullet species between sites and seasons (rainy/wet and dry) were analyzed by using T-test. The differences in DO, salinity, temperature and pH between sites and seasons were also analyzed by using t-test due to heterogeineity of variance some of the collected data, non parametric test i.e. Mann-Whitney and Kruskal Wallis test were used. The relationships between *M. cephalus*, *V. buchanani*, environmental variables and meteorological data were analyzed using Principal Component Analysis (PCA) using MiniTab 15.03 program.

Results

Habitat characteristics

Habitat characteristics of the study sites within mangroves area, the data are average values from 50 quadrate of 1m2 in replicates conducted in each site i.e. MnEM and REM.

Table 1: Habitat characteristics of the study sites within mangroves area. (Data are average values from 50 quadrate replicates conducted in each site i.e. MnEM and REM)

Variables	MnEM Site	REM Sites
Depth at high tide	1.2m	1.3m
Depth at low tide	0.6m	0.7m
% Seagrass cover	20	25
% Macroalgae	20	35
% Sand and shells	50	10
% Mud	10	30

REM = Ruvu Estuarine Mangrove, MnEM = Mbegani non Estuarine Mangrove

Environmental variables

Dissolved Oxygen (DO) and salinity varied between sites and seasons. The DO was higher at Ruvu Estuarine Mangrove (REM) site compared to Mbegani non Estuarine Mangrove (MnEM) site whereby salinity was higher at MnEM site. The DO and salinity showed significant difference between sites (t-test; df = 20, p = 0.030) and (t-test; df = 20, p = 0.02) respectively (Table 2). In terms of seasons, DO was higher during wet period whereas salinity and pH were higher during dry season. DO, salinity and pH showed significant differences (t-test; df = 20, p = 0.001; df = 20, p = 0.003 and df = 20, p = 0.000) between wet and dry period respectively (Table 2).

Seasonality within sites showed the same trend that DO was higher during wet period whereas salinity and pH were higher during dry season for REM and MnEM sites. The DO, salinity and pH showed significant differences (t-test; df = 10, p < 0.001) for each tested parameters and for both sites.

Temperature was relatively stable across sites and seasons, with slightly higher by seasons (Table 2).

Table 2: The means (± Standard deviation, SD), minimum and maximum values of environmental variables (n = 11) between sites and seasons

Parameters	Sites							Seasons						
	REM			MnEM				REM			MnEM			
	Mean	Min	Max	Mean	Min	Max	*p*-value	Mean	Min	Max	Mean	Min	Max	*p*-value
DO (mg/l)	5.08 (0.35)	3.8	5.8	4.7 (0.37)	3.8	5.7	0.030	4.72 (0.30)	3.8	5.5	5.36 (0.18)	4.2	5.8	0.000
Salinity (psu)	27.95 (5.02)	13.9	33.5	32.66 (3.43)	19.6	36.1	0.020	32.49 (2.85)	20.3	36.1	24.48 (3.6)	13.9	24.3	0.000
Temp (°C)	30.42 (1.21)	28.2	31.8	30.79 (0.80)	28.5	32.1	NS	30.52 (1.14)	28.2	32.1	30.83 (0.60)	29	31.7	NS
pH	8.09 (0.13)	7.65	8.3	8.12 (0.14)	7.83	8.37	NS	8.17 (0.10)	7.75	8.37	7.95 (0.07)	7.65	8.08	0.000

REM = Ruvu estuarine Mangrove, MnEM = Mbegani non Estuarine Mangrove, Max = Maximum, Min = Minimum, DO = Dissolved Oxygen, Temp = Temperature

Species Occurrence and Distribution Patterns in the Study Area

A total of 494 individuals of *M. cephalus* and 226 of *V. buchanani* were collected in the study areas.

The abundance *M. cephalus* was significantly (Mann-Whitney U, $p < 0.009$) higher than that of *V. buchanani* at REM and MnEM sites. The results showed that abundance of *M. cephalus* was significantly higher (Kruskal Wallis, DF = 1, $p < 0.024$) in REM site which has relative higher percentage of seagrass cover, macroalgae and muddy sediment than in MnEM sites whereas *V. buchanani* showed no significant difference (Kruskal Wallis, DF = 1, $p > 0.847$) in abundance between REM and MnEM sites.

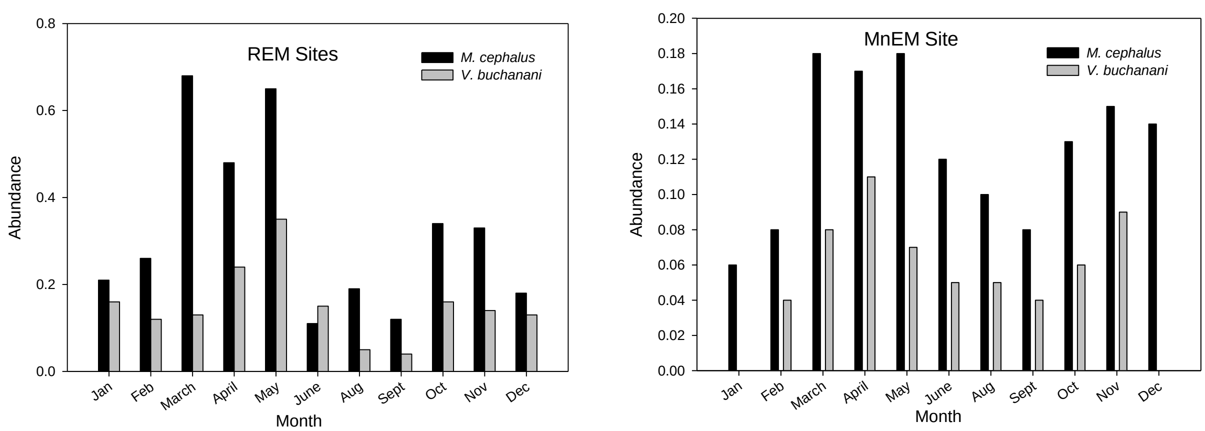

Figure 2: Seasonal abundance of *M. cephalus* and *V. buchanani* in the study areas.

The abundance of *M. cephalus* and *V. buchanani* were significantly higher (Kruskal-Wallis, df= 1, $p < 0.020$; df=1, $p < 0.001$) respectively during wet season than dry season (Figure 2). Both *M. cephalus and V. buchanani* occurred throughout the year with high peaks at the start and end of wet season for both sites.

Size Class Distribution

The size of *M. cephalus* found in REM and MnEM sites ranged from 0.1 to12 cm SL and while *V. buchanani* range from 2.1 to 12 cm SL with mean length size of 4.9 cm and 4.8 cm SL respectively. These size ranges include all juveniles (Bianchi, 1985). In general, the frequency percent contribution in class size was dominated by 4.1-6.0 cm SL size class for both sites in both species *M. cephalus* and *V. buchanani* (Figure 3).

Correlation between mullets Abundance, Environmental and Meteorological Parameters

The first three axes of a PCA of environmental and meteorological factors contributed to a significant part (82.7%) of the total variance (Table 3). The first three Eigenvalues PC1 = 3.0, PC2 = 2.4 and PC3 = 1.2 in PCA indicating the high proportional of variation in *M. cephalus and V. buchanani* data could be explained by hypothetical axes.

Table 3: Eigenvalues and percentage of variation of first four principal factors

Variables	PC1	PC2	PC3	PC4
Eigen-value	3.0	2.4	1.2	0.5
Total (%)	37.8	29.9	15.0	6.7
Cumulative %	37.8	67.7	82.7	89.3

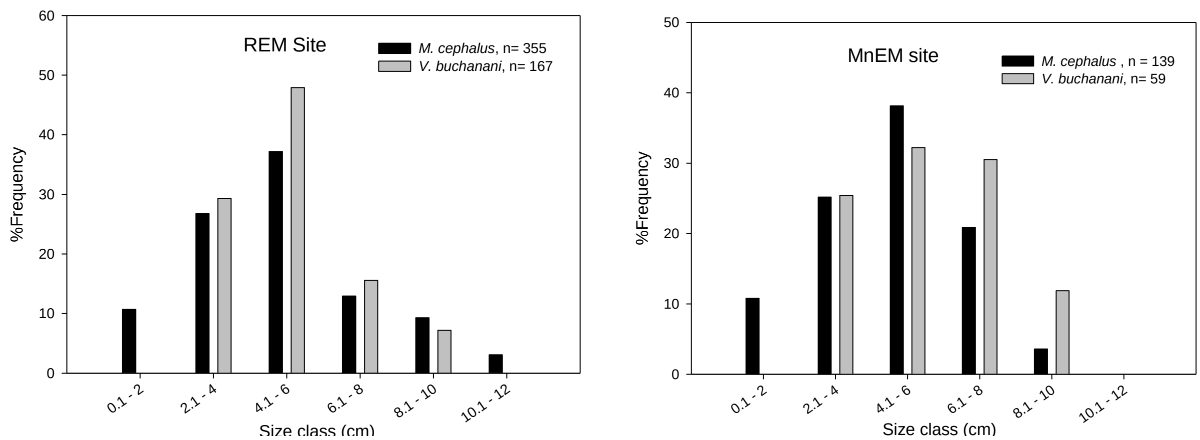

Figure 3: Frequency Percentage distribution of *M. cephalus* and *V. buchanani* in class size in each site

The first axis was negatively correlated with *M. cephalus, V. buchanani*, rainfall and DO whereas was positively correlated with atmospheric temperature, salinity, environmental temperature and pH. Second axis was positively correlated to all tested parameters while the third axis was negatively correlated with *M. cephalus, V. buchanani*, salinity but pH was positively correlated to rainfall, atmospheric temperature, DO and environmental temperature (Table 4).

Table 4: The correlation between variables and principle factors

Variable	PC1	PC2	PC3	PC4
M. cephalus	-0.231	0.512	-0.271	0.301
V. buchanani	-0.263	0.491	-0255	0.363
Rainfall (mm)	-0.456	0.107	0.335	-0.139
Atm temp (^oC)	0.339	0.258	0.512	0.212
DO (mg/l)	-0.411	0.242	0.036	-0.723
Salinity (psu)	0.471	0.235	-0.262	-0.322
Env temp (^oC)	0.122	0.390	0.605	-0.020
pH	0.385	0.390	-0.225	-0.293

PC= Principle component, Atm= Atmospheric, Env= environment, DO = Dissolved Oxygen

PCA graph showed clear the association between mullet species with environmental and meteorological variables. *M. cephalus* and *V. buchanani* abundance was positively correlated with rainfall and DO whereas other environmental variables salinity, environmental temperature, pH and atmospheric temperature were negatively correlated (Figure 4).

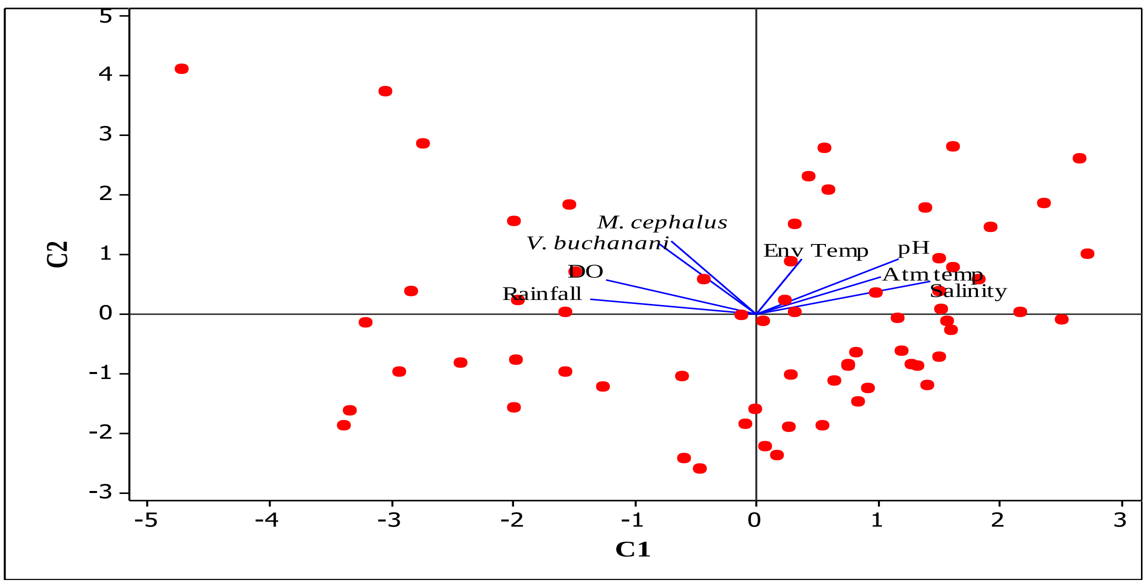

Figure 4: Principal Component Analysis graph showing correlation between striped mullet abundance and environmental and meteorological variable. Atm= Atmospheric, Env= environment, DO = Dissolved Oxygen

Discussion

Our results indicated that estuarine mangrove (REM) site had higher mullet abundance compared to non estuarine mangrove (MnEM) site. This could be due to environmental factors like low salinity which is well tolerated and favoured by juveniles (Wenner and Beatty, 1993) and therefore acts as a barrier to large predators. Habitat characteristics like muddy substrate, seagrasses and macroalgae which are relative high in REM site could be favourable habitat for *M. cephalus* juvenile. The high abundance of *M. cephalus* than *V. buchanani* in Bagamoyo mangrove area could be linked with migration patterns of those species during spawning and fry settling time. In addition, it may be as results of reduced environmental quality of the spawning grounds of the two species hence favouring the more adapted species i.e. *M. cephalus*. The low salinity and high pH in REM compared to MnEM sites favour growth of most fish species especially the juveniles hence the abundance of the mullets at the REM. Therefore increased rainfall will favour the recruitment of these species.

Results from current study revealed that mullet enter non estuarine and estuarine mangroves throughout the year, with intensive recruitment into the surveyed sites during the wet season. This is reflected by a significant positively relationship between mullet catch, DO and rainfall in the study area (Figure 4). The observed results are in line with other studies that showed high fish abundance during rainfall has been recorded at lower Caete estuary in Northern Brazilian coast (Barletta *et al.,* 2003). However, spawning and recruitment peaks may be initiated by environmental cues (Redding and Patiño, 1993). The variation in recruitment pattern within a year could probably be due to variation in the timing of favorable conditions that enhance survival. Such conditions may include environmental factors such as DO for supporting life, hydrographic mechanism which facilitates larval transportation to mangroves nursery grounds Other factors include meteorological factors such as rainfall which enhances primary production (Muller-Karger *et al*., 1989) as well as increased water turbidity which provides camouflage from predation (Mwandya *et al.,* 2009).

The atmospheric temperature did not show any significant link with mullet recruitment, although it showed significant association with environmental parameters such as water temperature, salinity and pH and therefore indirectly affecting mullet recruitment. A similar finding was reported in tropical Australia of having no significant association between water temperature and fish catch (Meynecke *et al.,* 2006). It is well known that global warming/temperature are closely associated with rainfall amount and distribution patterns (Marvel and Bonfils, 2013; DOE/Lawrence Livermore National Laboratory, 2013) leading to biological response of fish species (Meynecke *et al.,* 2006). When the environment is not favourable, fish larvae could actively avoid the nursery place or indirectly by increased mortality rate and hence no recruitment (Robins *et al.,* 2005) or changes fish assemblage (Whitfield, 2005), shifting of nursery habitat due to high temperature as reported in Australia (Meynecke *et al.,* 2006). Similarly, elsewhere, temperature has been reported to have an influence on Sprat, *Sprattus sprattus* recruitment (Mollman *et al.,* 2008), Mackerel, *Scomber scombrus* (ICES, 2007) Sole, *Solea solea* (Darnaude *et al.,* 2004); spawning in Atlantic cod, *Gadus morhua* (Heath, 2007).

Precipitation in Tanzania and its natural variability are distributed differentially in the different regions of the country and seasons or the year. The complex rainfall patterns have been reflected in the FEWS NETS (2012) forecast models of precipitation change, showing the annual rainfall for the northern coastal plain in Tanzania, including Bagamoyo to be below the average value. Results suggested that rainfall plays an important role on modifies DO and salinity in mangroves ecosystem which has an impact recruitment patterns of mullet. These findings are in agreement with modeling experiments which showed fisheries recruitments to have direct links with meteorological forces (Meynecke *et al.*, 2006; Ottersen *et al.*, 2010). The water runoff from rainfall lowers marine salinity and brought nutrients to the mangroves area which favours growth of micro and macroalga essential food for mullet and other organisms. Also through photosynthesis DO in mangrove environments increases which support marine life.

Conclusion and Recommendations

Understanding the complex effects of meteorological parameters on mullet is of vital importance for the sustainability of coastal fisheries. In addition, the study has demonstrated the importance of mangroves ecosystem as an important area in which *M. cephalus* and *V. buchanani* recruit and hence require protection from habitat degradation. Further, this recruitment is influenced by a combination of environmental and meteorological parameters.

Therefore, information on recruitment patterns of juvenile mullets as related to meteorological and environmental parameters is crucial for effective fisheries management. In addition, it is important information to aquaculture managers to inform decision on where to put mullet farms, as the farm should be near to seed source for easy collection and stocking.

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