AACL BIOFLUX

Aquaculture, Aquarium, Conservation & Legislation
International Journal of the Bioflux Society

The ecological impact of tidal pond channelization on the distribution of tilapia species (Perciformes: Cichlidae) on Buguma creek, Rivers State, Nigeria

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Abstract. A study of the tilapia species (Perciformes: Cichlidae) of a tidal creek in the Southeast of the Niger Delta, Nigeria was conducted to assess the ecological impact of tidal pond channelization. There was no significant difference ($p>0.05$) in the values of the physical and chemical parameters, except for transparency, water level and salinity ($p<0.01$). Orthogonal comparison using Duncan's Multiple Range test showed that station 2 (the tidal pond channel) was the cause of the observed difference in transparency and water level. Two tilapia species comprising *Sarotherodon melanotheron* and Tilapia *guineensis* were recorded during the studies, with *S. melanotheron* being the dominant species. Orthogonal comparison using Duncan's Multiple Range test showed that *S. melanotheron* was the cause of the observed difference in the tilapia population. Although there was positive correlation between salinity and the tilapia species at all stations, there was no significant correlation between tilapia species and the environmental variables. The findings of this study showed that channelized water bodies have lower qualify fish assemblage when compared to natural water bodies due to a loss of heterogeneous habitat. Although channelization is inevitable in the development of brackishwater fish ponds, amelioration measures of its adverse effects deserve high priority. However since no significant difference ($p>0.05$) existed in the distribution of *T. guineensis*, this study indicated that not all species are impacted by tidal pond channelization.

Key Words: *Sarotherodon melanotheron*, *Tilapia guineensis*, physical and chemical parameters, Niger Delta.

Introduction. The principle of brackish water pond aquaculture is based on tidal water supply through channelization. Recent studies have shown that channel morphology accounts for recurring patterns and large differences in fish use among intertidal creeks (Visiintainer et al 2006; Allen et al 2007; Stevens et al 2010) for estuarine species. Stream channelization has a negative influence on the fish assemblage (Lau et al 2006). On a subsiding coast, channelized coastal marshes tend to become open water habitats. Lack of freshwater and increased salinity through saltwater intrusion results in complete shift of vegetation (Darnell et al 1976). Habitat loss, decreased food supply, increased salinity and reducing conditions severely affect invertebrate and fish populations (Smith 1970; Darnell et al 1976). In some cases, altered life cycles of water shed species occur (Livingston 1977).

There is paucity of data on the ecological impact of tidal pond channelization on tidal creek fish populations or communities. However, dredging to deepen the channel of Cross River Estuary (the largest in Africa) resulted in increased sedimentation of silty components in the neighbouring tidal creeks and water pools destroyed and reduced niche species of native fish and in turn reduced production and diversity (Holzlohner et al 2002; Spalding 1997). Prolonged siltation degrades spawing grounds, causes behavioural changes in spawning fish, increases egg mortality, decreases larval growth, and affect rate of larval development and survival of larval fish (Muncy et al 1999). Tilapia are the first fish-culture candidates in West Africa (Abban & Agyakwa 2004). *Sarotherodon* *melanotheron* Rüppell, 1852 occur naturally and abundantly in the coastal waters of West Africa (Trewavas 1983; Trewavas & Teugels 1991). *Tilapia guineensis* (Günther, 1862) represents the third most important lagoon tilapia in West Africa coastal areas occurring sympatrically with *S. melanotheron* and *Sarotherodon nigripinnis* (Guichenot, 1861) (Falk et al 2004). *S. melanotheron* and *T. guineensis* constitute the dominant cichlids of Buguma Creek, Rivers State, Nigeria. They are presently the most cultured of brackish water fish species in the Niger Delta, Nigeria, aftermath of FAO/Nigeria Federal Department of Fisheries development in 1963, in collaboration with Niger Delta Development Board.

Although the fish ponds of Nigerian Institute for Oceanography and Marine Research tidal ponds receiving water from Buguma Creek are occasionally used as recruitment ponds for tilapia broodstocks and fingerlings, the impact of the pond channelization on the water quality and distribution of the tilapia species is not scientifically documented. However, studies on the acid sulphate soil have been documented (Dublin-Green 1986; Dublin-Green & Ojanuga 1988). The use of tidal flushing in the management of the fish ponds has also been investigated (Dublin-Green et al 2003). Notable among earlier studies on brackish water tilapia are those of Fagade 1971 and 1978; Pauly 1976; Oribhabor et al 2009; Oribhabor & Adisa-Bolanta 2009.

The purpose of this paper was to present a general account of the water quality and tilapia species in the tidal pond main channel, and to give a comprehensive account of the same ecological characteristics in the mangrove creek, with a view to identifying significant changes that could be attributed to the fish pond channelization.

Material and Method. The study was carried out in the Buguma Creek which is located southeast of the Niger Delta between longitude 6°47' and 4°59' N in Asari-Toru Local Government Area of Rivers State, Nigeria (Fig. 1). A more detailed account of the study area and water quality have been given by Oribhabor & Ogbeibu (2009a, 2009b).

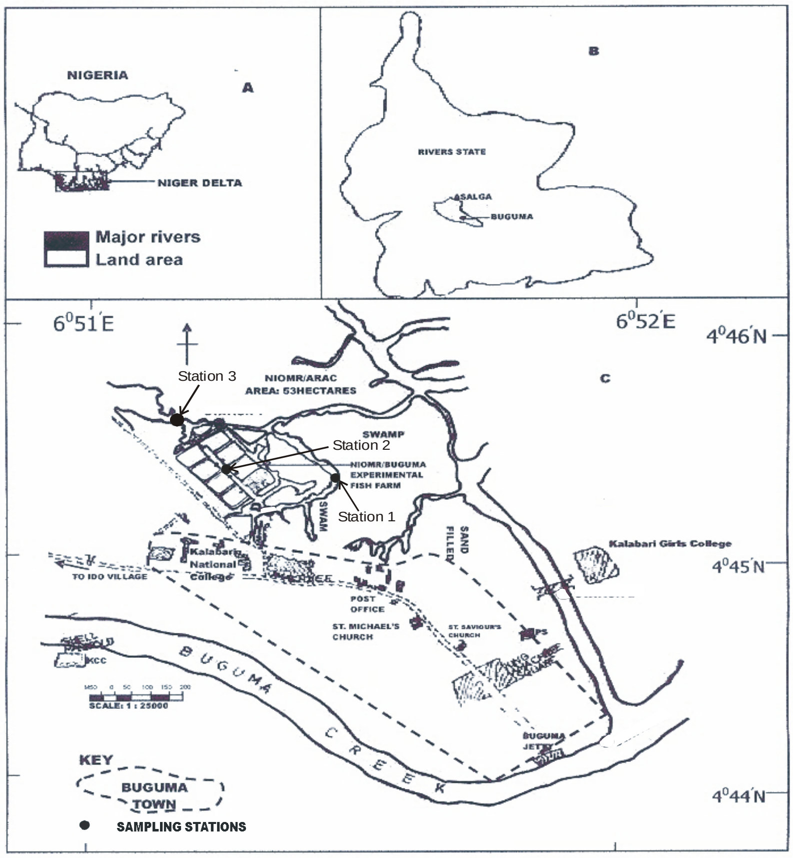

Figure 1. Map of the Study Area: A – Nigeria showing Niger Delta,
B – Rivers State showing Buguma, C – The study creek showing sampling stations.

Three sampling stations were chosen in the adjoining creek to the main creek channel where the fish pond is located: the experimental brackish water fish pond channel (station 2), its upstream (station 1) and downstream (station 3) (Fig. 1).

Sampling for water quality parameters and fish fauna was conducted in the three study stations at fortnightly intervals between August and December 2005, during flood tides. Sampling was conducted at all stations between 08:00 and 17:00 on each sampling day within duration of 4–5 hours, depending on the flow and ebb of tide.

Physical and chemical analysis of water was based on Lind (1979) and APHA et al (1985). Fishing was conducted using baited funnel-entrance traps (Holden & Reed 1978). The fishing effort was the same in each station.

In the laboratory, fish were identified using the keys and descriptions of Olaosebikan & Raji (1998).

All statistical methods used in analyzing the water quality parameters and fish species were adapted from Zar (1984) and Ogbeibu (2005). Data were summarized using basic parametric statistics for measuring central tendency and dispersion. One way Analysis of variance (ANOVA) was used in the test of significance (at 1% or 5% level of significance), while points of significant differences were detected by Duncan's Multiple Range Test. Pearson's correlation analysis was used in relating some environmental variables and tilapia species.

Results. Table 1 summarizes the physical and chemical conditions of the study stations. The range in air temperature for all stations was 26-32°C, water temperature ranged from 26-30°C, transparency 0.6–1.6m, water level 0.8–1.9m, flow velocity 0.02–0.09m/s, salinity 7–10%, pH 6.72–7.35, dissolved oxygen 0.8–2.6 mgL^{-1}, BOD 0.7–1.6 mgL^{-1}, Alkalinity 13-19 mgL^{-1} $CaCO_3$, EDTA hardness 76–200 mgL^{-1} $CaCO_3$, Calcium 19.2–42.5 mgL^{-1}, Magnesium 41.5–1.76.8 mgL^{-1}, and Sulphide 8.1–23.2 mgL^{-1}. Only transparency, water level and salinity were significantly different. Orthogonal comparison using Duncan's Multiple Range test showed that station 2 (the pond channel) was the cause of the observed difference in transparency and water level.

Two tilapia species (*S. melanotheron* and *T. guineensis*) comprising 442 individuals were recorded during the study (Table 2). The total number of individuals of a pool of the two species present at stations 1, 2 and 3 were 192, 90 and 160 respectively. The total number of individuals per species at each station are shown in Table 2.

S. melanotheron was the dominant species. Spatial and temporal variation in the relative abundance of the overall tilapia species at the study stations is shown in Fig. 2, while those of individual species are shown in Fig. 3 for *S. melanotheron*, and Fig. 4 for *T. guineensis*. Orthogonal comparison using Duncan's Multiple Range Test showed that *S. melanotheron* was the cause of the observed difference in the tilapia population (Table 2).

Fig. 2 showed that the highest overall record of tilapia species was October for station 3 (55 individuals); the least was August in station 2 (31 individuals); while October in station 1 had 52 individuals. Fig. 3 indicated the same trend for *S. melanotheron* with highest record for September in station 3 (43 individuals); the least was December in station 2 (21 individuals); while October in station 1 had 38 individuals. Fig. 4 indicated different trend for *T. guineensis* with overall highest record for August (24 individuals) and least record for November (0 individual) in station 1. Highest and least records were August (11 individuals) and October (1 individual) for station 2 respectively. While for station 3, it was August (15 individuals) and October (4 individuals) respectively.

Table 1

Summary of the physical and chemical parameters of the study stations, Buguma Creek, August–December, 2005

Parameter	*Station 1*	*Station 2*	*Station 3*	*Statistical significance*
	Mean ± SE (min – max)	Mean ± SE (min – max)	Mean ± SE (min – max)	
Air temperature (°C)	29.4 ± 0.71 (26 – 32)	28.6 ± 0.68 (26 – 32)	28.5 ± 0.57 (26 – 31)	$p > 0.05$
Water temperature (°C)	28.1 ± 0.35 (26 – 29)	28.1 ± 0.35 (27 – 30)	28.4 ± 0.38 (28 – 30)	$p > 0.05$
Transparency (m)	1.3 ± 0.09 (0.9 – 1.6)B	0.96 ± 0.04 (0.8 – 1.1)A	1.0 ± 0.09 (0.6 – 1.3)A	$p < 0.01$*
Water level (m)	1.5 ± 0.08 (1.3 – 1.9)A	0.96 ± 0.04 (0.8 – 1.1)B	1.2 ± 0.06 (0.9 – 1.3)C	$p < 0.01$*
Flow velocity (m/s)	0.05 ± 0.02 (0.02 – 0.08)	0.05 ± 0.01 (0.02 – 0.08)	0.05 ± 0.01 (0.04 – 0.09)	$p > 0.05$
Salinity (‰)	9.8 ± 0.25 (8 – 10)A	9.6 ± 0.26 (8 – 10)A	8 ± 0.38 (7 – 10)B	$p < 0.01$*
pH	6.85 ± 0.13 (6.72 – 7.26)	6.79 ± 0.06 (6.67 – 7.23)	6.86 ± 0.07 (6.81 – 7.35)	$p > 0.05$
Dissolved oxygen (mgL^{-1})	1.7 ± 0.17 (1.2 – 2.5)	1.5 ± 0.18 (0.8 – 2.6)	1.5 ± 0.16 (1.0 – 2.4)	$p > 0.05$
BOD (mgL^{-1})	1.1 ± 0.35 (0.7 – 1.6)	1.0 ± 0.11 (0.9 – 1.6)	0.99 ± 0.07 (0.8 – 1.3)	$p > 0.05$
Alkalinity (mgL^{-1} $CaCO_3$)	17.5 ± 0.27 (17 – 19)	16.8 ± 0.49 (15 – 19)	15.8 ± 0.70 (13 – 19)	$p > 0.05$
EDTA hardness (mgL^{-1} $CaCO_3$)	130.5 ± 9.94 (76 – 156)	155 ± 10.41 (116 – 200)	133 ± 5.94 (116 – 156)	$p > 0.05$
Calcium (mgL^{-1})	28.8 ± 2.26 (20.8 – 41.2)	31.5 ± 2.49 (22.7 – 42.5)	29.3 ± 2.94 (19.2 – 40.9)	$p > 0.05$
Magnesium (mgL^{-1})	101.7 ± 9.98 (41.5 – 132.8)	123.5 ± 10.21 (89.5 – 176.8)	103.7 ± 6.31 (79.9 – 133.6)	$p > 0.05$
Sulphide (mgL^{-1})	12.8 ± 1.12 (9.2 – 23.2)	11.0 ± 0.69 (8.8 – 13.5)	10.8 ± 0.81 (8.1 – 14.6)	$p > 0.05$

*$p<0.01$ = significant

•Similar letters indicate means that were not significantly different from each other.

Table 2

Summary of the tilapia species relative abundance of the study stations, Buguma Creek, August–December, 2005

Tilapia species	*Station 1*	*Station 2*	*Station 3*	*Statistical significance*
	Relative abundance (min – max)	*Relative abundance (min – max)*	*Relative abundance (min – max)*	
S. melanotheron	136 (Mean = 15) (7 – 22)A	57 (Mean = 6) (1 – 19)B	113 (Mean = 13) (5 – 28)A	$p < 0.05$*
T. guineensis	56 (Mean = 6) (0 – 24)	33 (Mean = 4) (0 – 14)	47 (Mean = 5) (1 – 15)	$p > 0.05$
Pool of the two species	192 (Mean = 21) (7 – 34)A	90 (Mean = 10) (1 – 24)B	160 (Mean = 18) (6 – 31)A	$p < 0.05$*

*$p<0.05$ = significant

•Similar letters indicate means that were not significantly different from each other.

Although Pearson's correlation coefficient showed positive correlation between salinity and the tilapia species at all stations, there was no significant correlation between tilapia species and the environmental variables (Table 3).

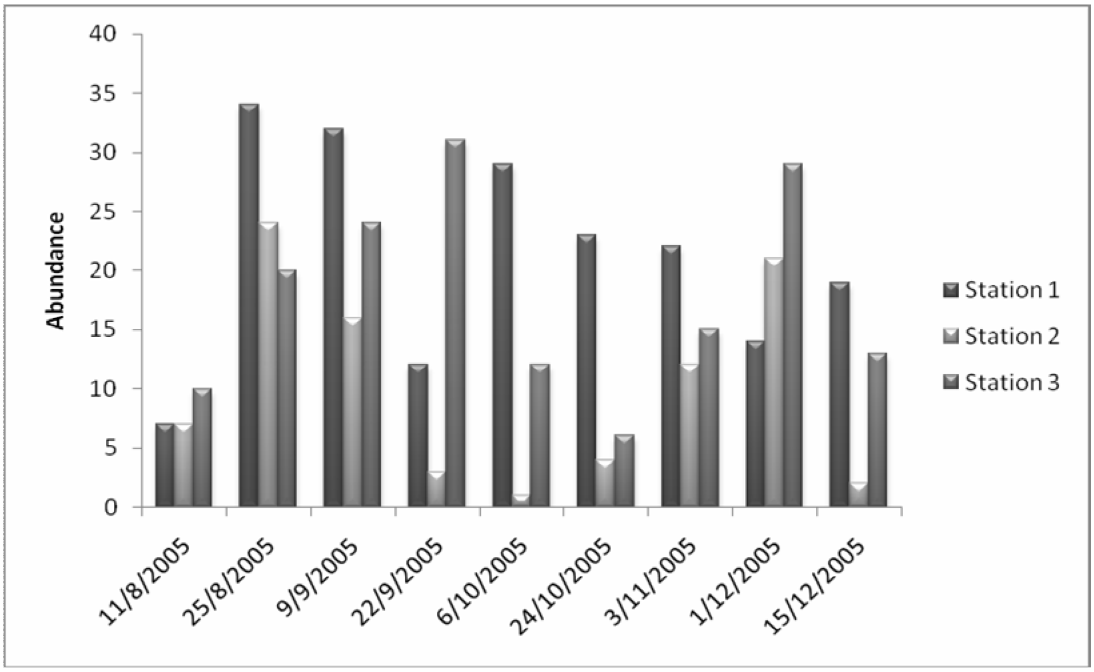

Figure 2. Spatial and temporal variations in the abundance of the overall *Tilapia* species at the study stations.

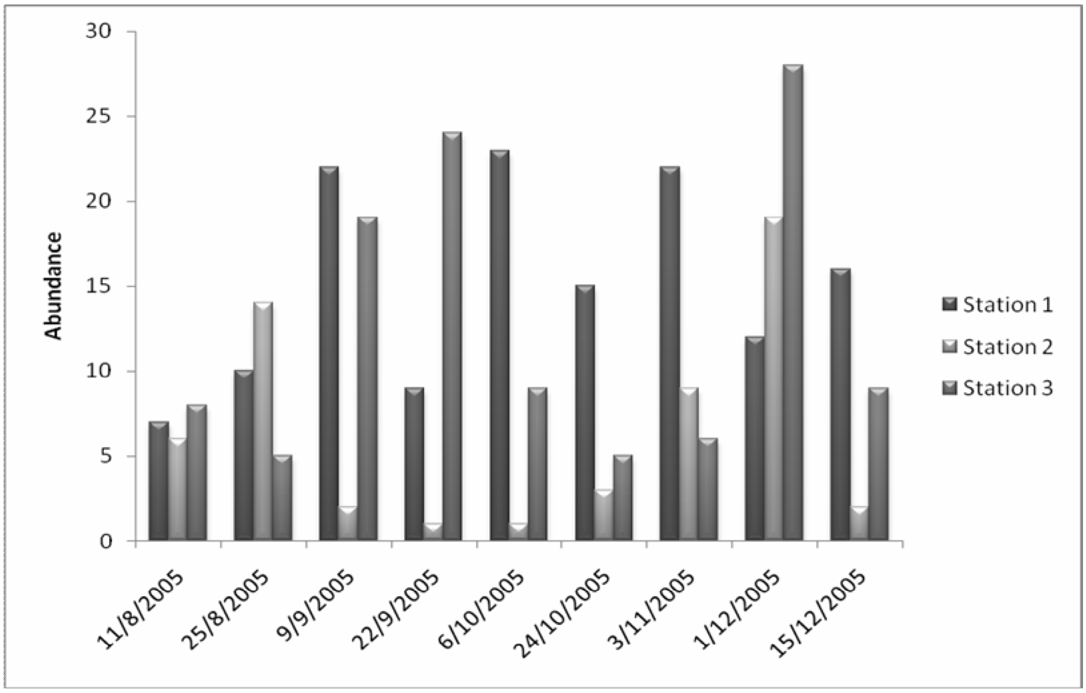

Figure 3. Spatial and temporal variations in the abundance of *S. melanotheron* at the study stations.

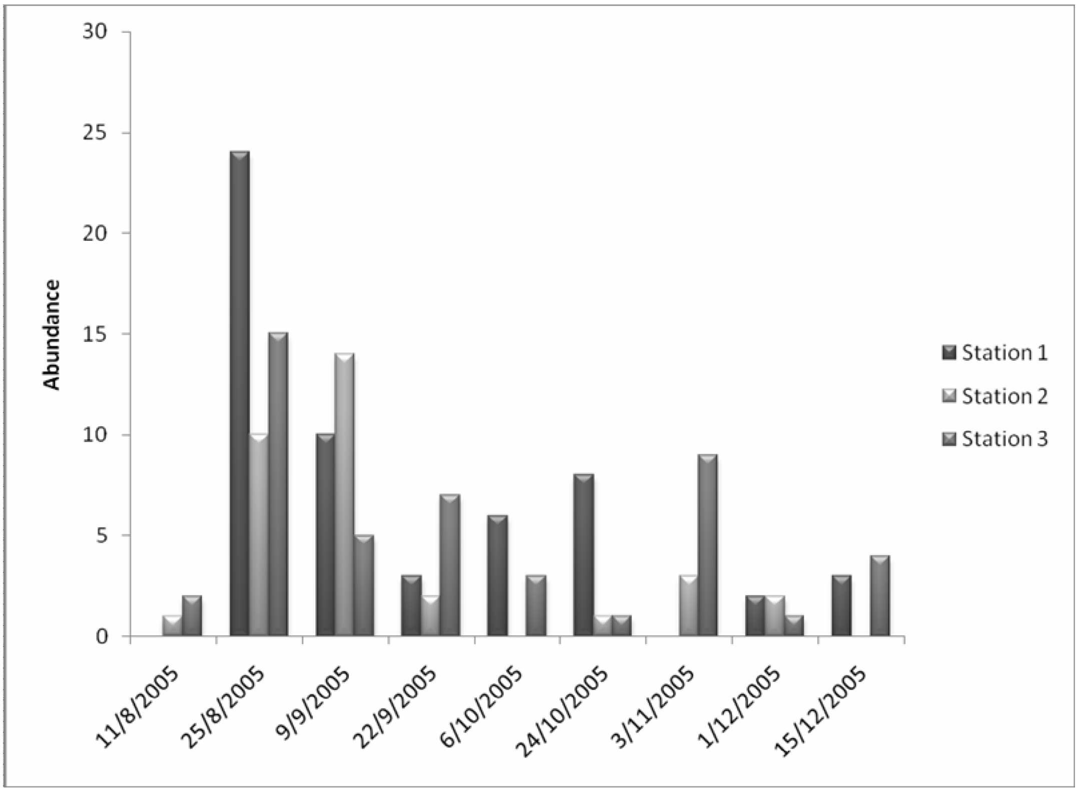

Figure 4. Spatial and temporal variations in the abundance of *T. guineensis* at the study stations.

Table 3

Correlation coefficient (r) values between some environmental variables and tilapia species at the various sampling stations.

Station	*Water temperature*	*Water level*	*Salinity*	*Dissolved oxygen*	*pH*	*Alkalinity*	*EDTA*
Station 1	–0.447	0.308	0.599	–0.488	–0.115	0.010	–0.041
Station 2	–0.598	–0.070	0.189	–0.104	–0.092	–0.137	–0.491
Station 3	–0.076	–0.014	0.278	0.021	0.416	0.306	–0.077

Discussion. The physical and chemical parameters are within the range earlier reported for the same creek (Oribhabor & Ogbeibu 2010). Ogbeibu & Oribhabor (2008) posited that the water is not polluted, based on the generally low biochemical oxygen demand, chemical oxygen demand and extremely low total hydrocarbon content (THC) (< 10 mg L^{-1}).

The impact of anthropogenic alterations such as dredging, channelization, river straightening, bank stabilization and vegetation removal have been analyzed by different papers (Copp & Bennets 1996). Although no data exist on the ecological impact of tidal pond channelization on fish species, the decline of tilapia population in the pond channel is in conformity with Oscoz et al (2005) who reported slightly lower fish density in a channelized section of Larraum River (Nortern Spain) than in the unaltered points.

Funk & Ruhr (1971) observed that changes associated with chanellization have far-reaching ecological effects, some of which may be disastrous. The deterioration, and in some instances elimination of fish stocks and shift in species composition to less desirable species is, due to channelization. Channelization is responsible for the decline in diversity of fish in the pond channel, the predominant habitation by tilapia and the decline in tilapia population at the pond channel.

The observed differences in transparency and water level caused by station 2 (the pond channel) is due to reduced water level caused by siltation, resulting in the water always transparent to the bottom. This could have contributed to the decline of tilapia population in station 2, caused mainly by the significant decline in the population of *S. melanotheron.* This conforms with the fact that certain physical characteristics such as depth, substrate type and flow pattern have been related to fish diversity in estuarine systems (Gorman & Karr 1978; Ewa-Oboho 2006). The abundance of benthic invertivore and herbivore fish groups decline significantly, as the percentage of silt increases for channel fish dwellers. Salinity was positively correlated with the tilapia population, but not significant meaning that transparency, water level and channelization were the most significant factors influencing the distribution of tilapia.

The findings of this study conforms with that of earlier workers that channelized water bodies have lower quality fish assemblage when compared to natural water bodies due to a loss of heterogeneous habitat (Hortle & Lake 1983). It appears that the absence of suitable habitat (viz, areas of snags, area of slack water length of bank fringed with vegetation) accounts for the lower abundance and lower species richness of fish after channelization. In channelized coastal marshes, invertebrates and fish communities may be partially or totally eliminated (Cottam & Borne 1952). Although channelization is inevitable in the development of brackishwater fish ponds, amelioration measures of its adverse effects deserves high priority.

Conclusions. Brackish water aquaculture is in its infancy in Africa, with no information on the ecological impact of tidal pond channelization on the fish species. Information about the position of fishes along the river under specific flow regimes is critical to resource managers developing minimum flows for the river (Flannery et al 2002; Greenwood et al 2007). This investigation revealed that tidal pond for aquaculture was the cause of significant differences ($p<0.01$) in transparency and water level. It also revealed that channelized water bodies have lower quality fish assemblage when compared to natural water bodies. It is therefore important to give special attention to tidal channelization as one of the factors responsible for negative impacts of brackish water aquaculture, when considering amelioration of adverse effects of brackish water aquaculture on the ecosystem. However, since no significant difference ($p>0.05$) existed in the distribution of *T. gunieensis*, this study indicated that not all species are impacted by tidal pond channelization.

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Received: 07 September 2011. Accepted: 28 September 2011. Published online: 14 November 2011.

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How to cite this article:
Oribhabor B. J., Opara J. Y., Ansa E. J., 2011 The ecological impact of tidal pond channelization on the distribution of tilapia species (Perciformes: Cichlidae) on Buguma creek, Rivers State, Nigeria. AACL Bioflux **4**(5): 651-659.