



EMIGRATION OF JUVENILE BONGA, *Ethmalosa fimbriata* FROM THE CROSS RIVER ESTUARY, NIGERIA

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ABSTRACT

Studies were conducted to identify and quantify the proximate factors responsible for the emigration of juvenile bonga from Cross River Estuary for two bonga seasons between January and June 2004 and January and May 2005. Time series of juvenile bonga catch-per-unit-effort was carried out simultaneously with plankton abundance, salinity, turbidity, rainfall and temperature. Emigration of bonga was preceded by heavy and sustained rainfall. A rainfall of above 263 mm in April resulted in the depression of the salinity to fresh water levels in May. At the same time there was increase in plankton abundance. At this time the CPUE of juvenile bonga in the estuary rose to 1.02 kg per unit effort in 2004 and about 0.238 kg in 2005. Within the same period, the condition factor of the fish increased from 0.97 to 1.07 while the modal length decreased to 11 cm. All these events occurred in May. It is concluded that rainfall, with a concomitant depression of salinity is the major proximate factor, which triggers the emigration of juvenile bonga from the estuary while plankton bloom sustains the emigration along the estuary.

Keywords: fish ecology, environmental influence, commercially important fish species, stock recruitment.

INTRODUCTION

Cross River Estuary is a nursery for many commercially important fish species, including bonga (Ama-Abasi & Holzloehner, 2002). Bonga spawns in the near coast waters off Cross River Estuary and hatch therein. The larvae from this spawn are transported to the mouths of estuaries by meteorological and oceanographic events, such as rainfall, waves and current, occurring over variable time scales (Freidland & Haas, 1988). Once in the estuary, bonga larvae grow and metamorphose into juveniles, which are filter feeders. During its annual migration, juvenile bonga enters the Estuary from November/December and departs to the sea in May. Ama-Abasi (2002) observed that emigration of juvenile bonga from Cross River Estuary in May is a spontaneous event with massive congregations of the fish while in the downstream movement. The proximate factors responsible for this emigration and their levels at which the emigration is initiated have not been studied.

Many physico-chemical parameters are known to exert varying influence on the fish distribution and migration. Blaber and Whitefield (1977a, b) showed that the presence of calm waters and suitable food in estuaries were probably the most important factors influencing the distribution of juvenile sparid species, juvenile Mugilidae and a species of goby. Blaber and Blaber (1980) identified salinity, calm waters, turbidity, food and predator as having varying degrees of influence on more than 10 species of fish in the Indo-pacific waters of East Africa. Talbot (1955) found that the

supply of suitable and sufficient food was found to be at least partially responsible for restricting juveniles of *Rhabdosargus globiceps* and ten species of Mugilidae mainly to estuaries. Fagade and Olaniyan (1972) stated that bonga of different size group responded differently to varying salinity. Talarczare & Mizuishi (1976) stated that the species inhabit waters ranging in salinity from 2‰ to 35‰. Ama-Abasi (2002) stated that the juveniles migrate out of the estuary when the salinity is depressed; but the level of salinity at which the emigration is initiated is not known. However, Bronmark *et al.* (2010) and Skov *et al.* (2010) have demonstrated how various environmental cues including habitat familiarity and seasons influence fish migration.

Although the Cross River Estuary is one of the major habitats of bonga in the Gulf of Guinea, there is little information on the distribution of bonga relative to prevailing physical and biological factors in the Estuary. This work was done to identify and quantify the proximate factors that trigger off the spontaneous emigration of juvenile bonga from the Cross River Estuary.

STUDY AREA

The study area is Cross River Estuary and the sampling sites are the waters easterly of Parrot Island and the waters of Calabar River at Adiabo. Adiabo is on the Calabar River 40 km from Parrot Island (Fig 1). Cross River estuary is situated between latitudes 4° and 5° N and longitudes 8° and 8° 30' E.

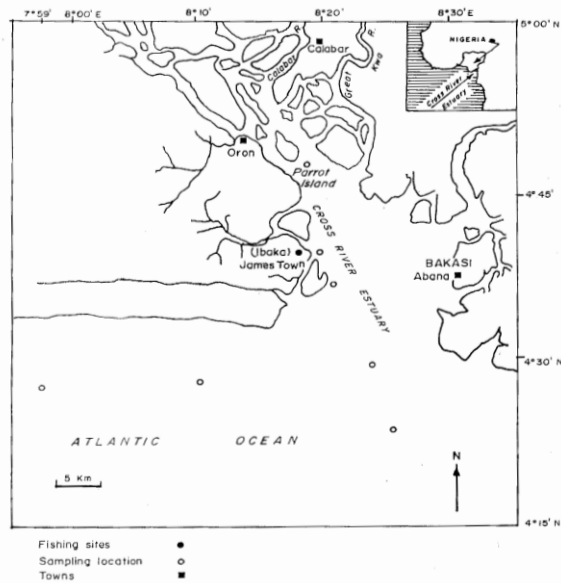


Fig. 1: Map of Cross River Estuary showing the study sites

Parrot Island was chosen because the oceanographic parameters here represent midway between the marine conditions and the fresh water conditions. From April of 2004 we decided to go further into Calabar River and established another sampling station at Adiabo when we discovered that bonga were no longer found in the Estuary easterly of Parrot Island.

Cross River Estuary takes its rise from Cameroon Mountains. It meanders westwards into Nigeria and then southwards through high rainforest formations before discharging into the Atlantic Ocean at the Gulf of Guinea. Within the lower brackish water reaches of the River, the vegetation changes to mangrove forest. The Estuary is the main shipping route to the Eastern Port of Calabar and the associated Export Processing Zone. Several tributary rivers inundate the Estuary, the most important ones being the Calabar, Great Kwa and Akpa Yafe. The Estuary and its tributaries represent the largest source of inland fisheries in Nigeria (Enin *et al.*, 1989) with bonga *Ethmalosa fimbriata* as one of the most important species of artisanal fishery (Moses 1979).

The climate of the study area has been described previously (Akpan & Offem 1993). It is characterized by long wet season from April to October and a dry season from November to March. Mean annual rainfall is about 2000 mm. There is usually a cold, dry and dusty period between December and January referred to as the harmattan season. Temperatures generally range from 22 °C in the wet to 35 °C in the dry season. Relative humidity is generally above 60% at all seasons with close to 90% during the wet season.

Rainfall has a great impact on the hydrography of the river system including its estuary. During the rains the salinity of the Estuary is depressed to freshwater levels. While in the dry season the salinity level increases as high as 30‰ (Lowenberg and Kunzel, 1992).

MATERIALS AND METHODS

Time series of juvenile bonga catch-per-unit effort for the months of January – June of 2004 and January – May of 2005, were determined by sampling drift gill net catches. Driftnets of length 100 x 2 m length were used. These are fishing gear that effectively traps juvenile bonga of emigrational size (10 - 18 cm) total length. The net was made of 25 pieces each of 4 m length. The pieces were of two different mesh sizes. The piece of 35 mm mesh size was alternated with that of 40 mesh size. This was to ensure that all juveniles of emigrational size were caught. The nets were set perpendicular to the shore and allowed to drift for 40 minutes after which it was hauled into the boat for sampling. Fish caught were analyzed to determine the species composition. Bonga samples were measured with spring balance to obtain the total weight. The length of the juvenile was measured with measuring board to get the total length. The total weight of bonga caught was divided by the number of cast to estimate the catch-per-unit effort of the species.

Physico-chemical parameters measured included water temperature, turbidity, and salinity. Salinity was measured as conductivity because the use of conductivity allowed for measurement of salt content below zero salinity. Samples were collected from the surface using plastic bucket and sub-sampled into polythene bottles for laboratory analysis. Temperature and dissolved oxygen were measured electrometrically using SCHOTT I instruments model CG867. Conductivity was measured with field conductivity meter model WTW LF 90. Turbidity was measured in the laboratory using HACH 3000 direct reading spectrometer. Rainfall data was obtained from the Meteorological department of the University of Calabar.

Time series of phytoplankton count data from stations near the net were collected simultaneously with the CPUE. Samples were collected from surface using plastic bucket and filtered with 30 µm mesh Nitex net. The residue was washed with the filtrate into glass vials to which was added clean tap water and Lugols reagent for preservation.

Stomach contents of juvenile bonga were evacuated from fresh stomachs into glass vials to which was added clean tap water and Lugols reagent for preservation. Qualitative and quantitative plankton analyses for water and

stomach contents were performed using Zeiss Inverted Plankton microscope. Sub-samples were mixed with gentle swirling and filled into 5 ml Plankton chambers to which was added one drop of Lugol's solution, which served as a fixative and also aided sedimentation of organisms. After allowing for complete sedimentation (≈ 4 hours) microscopic analysis was performed according to UNESCO (1978) using identification schemes of Edminton (1959, Prescott (1970) and Sharma (1986).

RESULTS

Meteorological and Oceanographic parameters

The environmental parameters of the study area are given in Figs 2 - 5 with the superimposition of the catch-per-unit-effort (CPUE) of bonga and plankton abundance. Surface water salinity in Parrot Island ranged from 4 ‰ in January to the highest of 15.4 ‰ in April of 2004. It fell to zero in June. In Adiabo, the salinity was 1.78‰ in April and fell to 0‰ on June 9. In 2005 the salinity of the water easterly of Parrot Island was 3‰ in January and rose to the highest of 8.6 ‰ in March. The lowest salinity was 0.59 ‰ on May 12. In Adiabo, the salinity was at zero levels all through the period with the exception of March when it was 0.4‰.

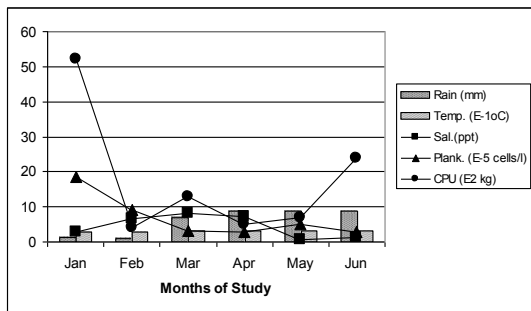


Fig. 2: Environmental parameters of the Cross River Estuary during 2004 at Parrot Island

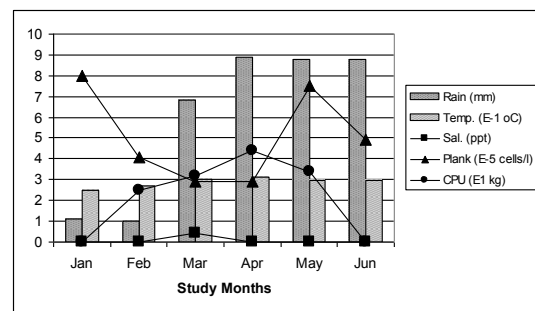


Fig. 3: Environmental parameters of the Cross River Estuary during 2004 at Adiabo

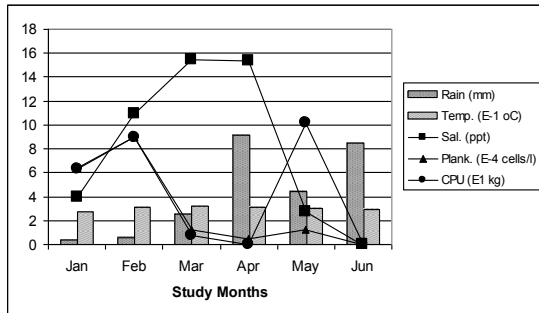


Fig. 4: Environmental parameters of the Cross River Estuary in 2005 Parrot Island

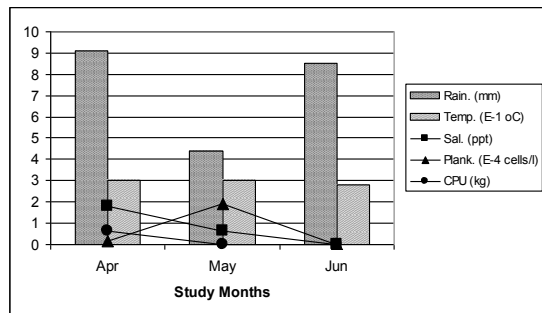


Fig. 5: Environmental parameters of the Cross River Estuary in 2005 Adiabo

In 2004, there were 30 rain-days between January and May with a mean monthly value of 103.1 mm. The highest rainfall was in April with a total of 274.3 mm. In 2005 there were 44 rain-days with mean value of 151.1 mm. The highest rainfall was in April with a total of 265.6 mm. Generally, there were more rains between January and June of 2005 than the corresponding period in 2004. Turbidity and temperature did not show any correlation with the juvenile bonga abundance.

Plankton Abundance

Up to 20 species of plankton from seven families were identified in the stomach content of juvenile bonga. Of all these, diatoms formed the

dominant species accounting for over 96% of the total food content. Of the family of Bacillariophyceae (diatoms) the following were identified, *Actinocyclus*, *Cyclotella comta*, *Nitzschia*, *Skeletonema costatum*. They were present in both water samples and stomach content from January to May.

Of these diatoms, the most dominant species was *Skeletonema costatum*, accounting for more than 40% in the stomach while *Actinocyclus* accounted for about 35%. The remaining 30 % comprised *Cyclotella comta*, *Eucampia viridis*, *Melosira granulata*, *Gyrosigma* sp.

The population of the dominant plankton in the stomach collapsed in June. Species of plankton not dominant in early months were seen thriving in May and June. These included *Gyrosigma accuminata* and *Coscinodiscus* spp.

In Parrot Island, plankton in the stomach was on the average of 3, 944 cells/stomach in February of 2004. The highest plankton abundance in the stomach was recorded in the month of May with an average of 1, 353, 564 cells/stomach. Plankton abundance in water was highest in February with an average of 89, 218.5 cells/l. Then it fell to 4, 611.5 cells/ l in April. It rose again to 12,188.5 cells/l before final collapse in June to 186 cells/l. The lowest concentration of plankton in the stomach was also in June with an average of 1,530 cells/stomach. Total number of species identified in the stomach decreased from 15 in January through March to 7 in June. Also species in water decreased from 17 to 11 in June.

Plankton peak in Parrot Island was in the second week of May in 2004 while the peak was first week of May in Adiabo. In 2005 the peak was in second week of May in Parrot Island as well as in Adiabo.

Juvenile Bonga Abundance

The monthly abundance of juvenile bonga in the two stations is given in Figs 2 - 5. In Adiabo the highest CPUE was 1.158 kg/unit- effort in May and

was zero in June of 2004. In Parrot Island it was 1.02kg/unit- effort in May and zero in June.

In 2005 the CPUE was extremely low with the highest being 0.439 kg/unit-effort in April in Adiabo while there was zero CPUE in January and last week of May. In Parrot Island the CPUE was highest in January with a value of 0.518 kg/unit effort while it fell to 0.065kg/unit-effort in last week of May.

The abundance of bonga was higher in Adiabo than in Parrot Island for the two years and in all the months. From the Figures it is clear that there are two peaks of bonga CPUE in Parrot Island for the two years while in Adiabo there is only one peak.

The modal lengths of juvenile bonga for the two stations in both years are given in Tables 1 and 2. In January, the modal class was 14 cm in Parrot Island and this fluctuated between 14 and 13 cm in the subsequent months, but in May the modal length dropped to 11 cm. That was the same case for Adiabo specimens. However in 2005, the modal length for Adiabo specimens was 11 cm all through the study period.

The condition factor of juvenile bonga is also given in the table. A general observation is that fish condition factor increased in the month of May for both Adiabo and Parrot Island specimens.

Table 1: Some biological indices of juvenile bonga during 2004 study period

Indices	Parrot Island						Adiabo				
	Jan	Feb	Mar	Apr	May	Jun	Jan	Feb	Mar	Apr	May
Condition factor	0.97	0.99	0.97	-	1.07	-	-	-	-	0.98	1.04
Modal length(cm)	14.0	13.0	14.0	-	11.0	-	-	-	-	13.0	11.0
Minimum length(cm)	11.0	13.0	11.0	-	10.4	-	-	-	-	10.0	10.3
Maximum length(cm)	16.0	13.0	11.0	-	14.7	-	-	-	-	15.0	12.0

Table 2: Some biological indices of juvenile bonga during 2005 study period

Indices	Parrot Island						Adiabo				
	Jan	Feb	Mar	Apr	May	Jun	Jan	Feb	Mar	Apr	May
Condition factor	0.97	0.99	0.97	-	1.07	-	-	0.99	-	0.93	1.04
Modal length(cm)	13.0	14.0	12.0	15.0	11.0	-	-	11.0	11.0	11.0	11.0
Minimum length(cm)	10	12	11.0	14	8	-	-	11.0	11.0	9.0	10.3
Maximum length(cm)	16.0	16	15.0	15	28	-	-	16	14	15.0	12.0

DISCUSSION

The two peaks of bonga abundance observed in both years at Parrot Island are the results of immigration and emigration of the juvenile bonga in and out of the estuary. While immigration occurs in months preceding January and continues thereafter, emigration is observed to start in May. The following events were observed in May: increase in CPUE of juvenile bonga, increase in plankton build-up, lowering of modal length, salinity depression and increase in fish health. All these are indicators that emigration of juvenile

bonga commences in May. Ama-Abasi (2002) and Ama-Abasi *et al.* (2004) made similar observation. The salinity (conductivity) trend is seen to follow the bonga density. Our 2004 data revealed that juvenile bonga seemed to follow a pocket of salinity approximately 5 ± 4 ‰. They migrate away from salinities outside this range. This is why there was no bonga in April at Parrot Island when the salinities were 15.4‰ but at the same period there were juvenile bonga at Adiabo 40 km upstream when the salinity was 1.78‰. This proposition is supported by our 2005 data at Parrot Island where

at least few bonga juveniles were caught at the corresponding month when the salinity was 7.11 ‰. It was observed that at Adiabo, the lowest salt content measured, as conductivity was 2.5 mS/cm before there was zero CPUE in 2004. Again in 2005, the salt content (conductivity) before the drop in CPUE was 1.2 mS/cm. It therefore follows that within the salt content range of 1.2 mS/cm and 2.5 mS/cm, the emigration of juvenile bonga will commence. Generally speaking emigration commences when the salinity drops to zero. Here the larger size class of bonga will be the first to move. The smaller size class can tolerate lower salt content measured as conductivity, this explains why the modal length was 11 cm in the months of May in Adiabo and June in Parrot Island. This again is the reason why the modal length remained 11 cm all through the year 2005 because of the extremely low conductivity.

This study implicates rainfall as a possible environmental cue that initiates the emigration episode. The influence of rainfall is likely responsible for the low catches of bonga juvenile in the year 2005 with only 11 cm juvenile forming the modal class all through that year in Adiabo. It seems rainfall relay the information about the upcoming salinity depression enabling juvenile bonga to emigrate before the depression of the salinity to freshwater levels. It is difficult to suggest a mechanism by which the juvenile bonga respond to rainfall increase, but even the local fishers do predict heavy catch of juvenile bonga immediately after the rains of April.

We hypothesize that the proximate factor responsible for the triggering of the emigration is rainfall. A period of sustained and heavy rainfall in April acts as a cue for the emigration of bonga. This, coupled with the attendant depression of the salinity triggered the spontaneous and massive emigration. Juvenile bonga follows a certain salinity milieu in and out of the estuary depending on the individual sizes. Tolerance to salinity is clearly dependent on size with bigger fishes unable to tolerate lower salinities. Below a salt content of 1.00 mS/cm even the smallest size are under extreme physiological stress and must return to areas of higher salt concentration downstream. Our observation is in agreement with the report of Fagade and Olaniyan (1972) that bonga response to salinity is size-dependent. As juvenile bonga reaches a certain critical size, it returns to the sea while the smaller size group continues in the nursery until the salinity becomes too low for further penetration upstream.

The impact of salinity on juvenile bonga migration as it relates to climate change is noteworthy. According to FAO (2010), climate

change and global warming will lead to intrusion of saltwater more into the adjoining rivers. This implies that climate change can lead to more of juvenile bonga going farther upstream than in the present study in years to come. But without the corresponding feeding opportunities provided by mangrove vegetation and the plankton, the survival of such juveniles may be reduced.

The single peak of bonga CPUE in Adiabo is attributed to bonga immigration into the River reaching a peak in March /April. It is therefore clear, that bonga does not penetrate inland much further than Adiabo, and otherwise we should have a double peak as seen in Parrot Island. This study therefore indicates that the waters easterly of Parrot Island is more of a migration route of bonga rather than the resident nursery of juvenile bonga as previously believed. Juvenile bonga do penetrate into the River system where they use as their nursery.

The phytoplankton trend is worth noting. The double peak in seasonal trend of phytoplankton is usual in the Cross River Estuary system (Akpan 1993). What is however intriguing is the relationship between the plankton peak and the bonga migration in and out of the estuary. Immigration and emigration of bonga seems to be timed to coincide with plankton bloom so as to have adequate food supply for the energy demanding movement. While the January bloom coincides with immigration into the Estuary the May bloom coincides with emigration out of the Estuary. Plankton bloom may actually play a role in triggering massive emigration out of the Estuary. Similar timing and effects of planktivorous fish migration on plankton organisms has been reported recently on Cyprinid fish in European lakes (Brodersen *et al.*, 2007).

A comparison of the bonga densities and plankton densities at Parrot Island and Adiabo however shows that plankton is not a major cue for the movement of bonga between these two locations. During both emigration and immigration the bonga actually moves away from location of high plankton densities to that of lower plankton densities. For instance, on May 12 of 2005, when we first recorded emigration, plankton density in Adiabo was approximately 8×10^5 cells/l compared to 3×10^5 cells/l when they arrived Parrot Island.

We suggest that there is an emigrational mechanism, which has evolved, in which juvenile bonga and the phytoplankton communities simultaneously respond to the same salinity changes in the estuary. It is hypothesized that enhanced feeding opportunities along the course of migration is another factor, which initiates the emigration of juvenile bonga. Emigration in May may be an evolutionary adaptation for the survival

of juvenile bonga, which makes use of the available food for the energy needed for the downstream movement of the species. Friedland and Haas (1988) made a similar observation on juvenile Atlantic menhaden in the York River System of the United States of America.

What is also evident from the study is the impact of fishing and predation by higher trophic level members on recruitment. The CPUE in January during immigration is higher ($\approx 60\%$) than in May during emigration from Parrot Island. Conservatively then, only about 40% of juvenile bonga successfully emigrate back to the sea for stock recruitment. This is a sizeable depletion on bonga stock and may be used as an index of over-fishing.

CONCLUSION

In conclusion, we advocate the regulation of the fishery in May when juvenile bonga emigrates out of the estuary. Gill net of larger mesh size should be used to encourage the escape of the juveniles in order to make room for stock recruitment in the sea. The protection of the riparian forest adjoining the Calabar River is critical in the sustenance of the bonga nursery of the River system. We also recommend that a strip of land of up to 30 m on both banks of the River should be left unperturbed in order to enhance its ecological productivity.

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