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The migration status of silver catfish, *Chrysichthys nigrodigitatus* (Siluriformes: Claroteidae) of the cross river, Nigeria

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Abstract
Studies were conducted on the migration pattern of the *Chrysichthys nigrodigitatus* of the Cross River, Nigeria. The objectives were to assess the migration status and route, if any, and to proffer conservation advice. A total of 908 specimens of *Chrysichthys nigrodigitatus* were tagged and released from January to July 2017 at two sites separated by a distance of 88km, in the Cross River. Tagging was done using nylon monofilament and monitoring was conducted with the help of artisanal fishers and fish mammies. A total of 61 specimens were recaptured, representing 6.7% of the total fish tagged. Recaptured fish were either around the point of release or some distance far away from the point of release. There was however no evidence of movement to and fro the upstream and downstream sites. The study shows that *Chrysichthys* engages in local wanderings within the freshwater during the breeding season conveying on the species the potamodromous status.

Keywords: Reproductive ecology, freshwater catfish, nuptial swarming, tagging-recapture, cross river

Introduction
Many fishes engage in periodic long distance movements. A vast literature exists on various aspects of migratory behaviour [1, 2, 3]. Migration takes several forms including reproductive migration, feeding migration and environmental migration. Thus the various forms of migration express the reasons inherent in it [4]. *Chrysichthys nigrodigitatus* is a prized food fish and a very important species of commercial interest in the eastern Niger Delta of Nigeria. Some authors refer to it as estuarine catfish with the perception that they inhabit the brackish water [5, 6]. The fish is abundant during the rainy season months of April to September, therefore, it is strongly linked to rainfall with respect to abundance and reproductive activities. These habits therefore can predispose the fish to severe climate change impacts. It is believed that the species migrates from the estuary to the fresh water for spawning. Juveniles migrate to saline waters in lagoons, swamps and estuaries to feed and grow and migrate upstream from the more saline brackish waters to fresh waters to spawn [6, 7]. This supposition has however not been studied. This also became a discouragement on any attempt to domesticate the species due to perception that the species has affinity to salinity. It was this perception that prompted [8] to undertake a study on growth performance of silver grey catfish, fingerlings fed salt-rich diets in freshwater system.

Usually, brackish water species recede further into the estuary and marine environment during the rainy season as a result of the depression of the estuarine salinity while during the dry season such species moves further into the freshwater environment with elevation of salinity [9, 3]. The theory that a supposed brackish water species such as *Chrysichthys nigrodigitatus* moves into the freshwater for spawning during the rainy season was rather an enigma, warranting this study. The objectives of the work were to investigate the reality of *Chrysichthys nigrodigitatus's* migration from brackish water to freshwater, and demarcate the migration route, if any. If *Chrysichthys nigrodigitatus* is a migratory species, the basic questions this work shouldz answer are: where do they migrate from and where do they migrate to? Why do they migrate? The study is our own contribution to the ongoing quest for the domestication of the species.

Materials and Methods

Study Area

The study area is the Cross River. The river takes its origin from Cameroon mountains and meanders westward and then southward through rainforest vegetation and mangrove swamp before emptying its waters at the Bight of Biafra in the Gulf of Guinea. The climate of the study area is characterized by two seasons. The wet season from April to October and the dry season from November to March. There is a short period of drought in August referred to as 'August break'. Detail of the limnology and the hydrography of the area was reported by ([10]). The major occupation of the people in the riverine community is fishing with fishers coming from different tribes in Nigeria, including the Tivs, Ijaws, Igbos, Hausa and the Ibibios. Farming along the river floodplain is carried out by the people also. Two sampling locations were chosen. These were Umon Island at the upstream and Akani Obio Uruan in the downstream closer to the Cross River Estuary (Fig 1). The two locations are separated by a distance of 88km. The choice of the two sites was informed by the assumptions that the fish moves from the estuary to fresh water to spawn and that they return to estuary after spawning [6, 7]. In this case species tagged at the downstream would be recaptured while on upstream movment for spawning while species tagged at the upstream would be recaptured on its downstream return from spawning.

Tag-recapture method

Tagging–recapture method was employed in the study. A total of 908 specimens of *Chrysichthys nigrodigitatus* were tagged and released from January to July 2017. Fish were bought from commercial fishers at capture-tagging. Fish were tagged using nylon monofilament size 2/0 lot ww-AG-16035 from Agary pharmaceuticals. For proper tracking of the fish and its origin, fish from riverine waters of Akani Obio Uruan, downstream Cross River, were tagged on the caudal peduncle while specimens from the waters of Ikot Okpara, the upstream, were tagged on the pectoral or dorsal spine fin ray. Any recaptured fish was re-tagged and released. The tagging was done in such a way that the nylon did not apply pressure on the skin of the fish while allowing for growth of the flesh and skin. Fish tagged were promptly released into the water.

Measurement of hydrographic parameters

Some environmental parameters of the ambient water were recorded. The salinity and the turbidity of the surface water were monitored during the study period. Salinity was measured using hand refractometer, model 2441W05, while turbidity was measured using turbidimeter model TBN-WGZ 911001. Water depth was measured using echo sounder. Rainfall data were provided by the Meteorological Unit of Department of Geography and Environmental Management of the University of Calabar, Calabar.

Awareness creation and participation by the Fisherfolks

Prior to the commencement of tagging, a large scale awareness creation was embarked on in the different fishing communities along the river system. Information flyers were printed and distributed through community leaders and youths. The flyers contained not only information on the project but also the phone numbers of the researchers. Different fishers and fish mammies were also contacted. They were strongly encouraged to take part in the research with the specific responsibility of reporting any tagged fish in their catches and purchases. Any reported tagged fish attracted a reasonable amount of money higher than normal price. We therefore monitored the movement of the tagged fish for two *Chrysichthys* seasons (2017 and 2018), but received additional report in 2019. Both the fishers and fish mammies reported each time a tagged fish was seen in their catch and purchases respectively. Confirmation of their report was made in two ways including taking photograph of the recaptured tagged fish and keeping it until the arrival of the researchers.

Statistical analysis

Student's t-test was employed to determine for any significant difference between the hydrographic parameters between the upstream and the downstream section of the river. Chi-square test was used to find out if there was any significant difference in the recovery rates of the tagged fish between the upstream and downstream sections of the river, using the formular:

$$\chi^2 = \sum (O-E)^2/ E$$

Where O is observed values and
E =expected values.

Results and Discussion

Recaptured specimens

Of the 908 specimens tagged and released, 387 were from the downstream, representing 42.6% of the total number tagged while 521 specimens representing 57.4% of the total were tagged and released in the upstream section. Table 1 shows the monthly recaptured fish from 2017-2019. A total of 61 recaptured fish were reported between March 2017 and May 2019. This represents 6.72% of the total number of specimens tagged. Of the number of specimens tagged in the downstream, 27 were reapyured representing 6.98% while in the upstream 34 specimens were recaptured representing 6.53%. Thus relatively almost the same percentage of individuals tagged were recovered from both the upstream and the downstream. While the ratio of tagged fish in downstream to upstream was 0.74:1, the ratio of recaptured fish in downstream to upstream was 0.79:1. However, Chi-square test of the downstream - upstream ratio of recaptured fish did not differ statistically ($\chi^2 = 0.07$, 1df, $p > 0.05$) from zero, thus indicating equivalent fishing pressure at both streams.

Figure 1 also indicates the route of the recaptured fish. Some tagged specimens were recaptured at upstream points away from the location of release. Two fish were recaptured twice while one fish was recaptured thrice. The fish recaptured thrice was caught around the point of release while one of the fish recaptured twice was caught about 20km from the points of release. Throughout the period of study, no fish tagged at the upstream section of the river was caught downstream and vice versa. That our tagged fish were recaptured to the value of 6.71% is a very encouraging result [11]. reported of 0.04% (only 2) recaptured fish out of 4,075 fish tagged in the coastal waters of the United States of America [12]. reported 1.8-3.9% recapture of total fish tagged. The low values for Secor and Chapman are possible because they were working in the sea while this study report is on a river with very comparatively narrow width and directional flow. That the tagged fish were caught at a point upstream from their location of release shows that *Chrysichthys nigrodigitatus* does engage in a kind of migration. That some specimens were recaptured more

than once within the region of their release shows that they did not migrate. As indicated in Table 1, majority of the tagged fish (85.2%) were recaptured during the rainy season months of April to October. A monthly trend of the recaptured fish for the first 7 months of 2017 is given in Fig.2 a. There is a positive correlation between the amount of rainfall and the number of recaptured specimens (Fig. 2 b). A match of rainfall data with the number of recaptured specimens indicated that highest number of recaptured fish was in the peak of rainy season month of July, then the months of May and April in that order. It was observed that after the heavy rains in the night of 2nd April, 2017, the following morning there was a recapture of 6 specimens, the highest in a day throughout the sampling period.

Table 1: Monthly recapture of the tagged fish from 2017 to 2019

Month	2017	2018	2019	Total
January	0	0	0	0
February	0	0	0	0
March	5	0	0	5
April	12	0	0	12
May	13	0	1	14
June	4	0	0	4
July	15	1	0	16
August	1	0	0	1
September	3	0	0	3
October	2	0	0	2
November	2	1	0	3
December	0	1	0	1
Total	57	3	1	61

Comparison of the hydrography of the Upstream and Downstream rivers.

A comparison of the water parameters between the two sites is given in Table 3. A t- test analysis did not reveal any significant difference between the water parameters of the upstream and downstream sections of the river (p>0.05). The turbidity of the water and river depth, salinity, currents and temperature were not significantly different between the two sites, showing that the river system is homogenous. Moreover, the adult of *Chrysichthys* were caught in both the upstream and downstream sections of the river throughout the year. This would not have been so if the species were present in one section of the river at a particular period and absent in the other section then, a likely scenario in the face of migration. This observation does not support [5, 7] that the adults migrate to the fresh water to spawn and return to the more saline water after spawning. That report had portrayed *Chrysichthys nigrodigitatus* as estuarine species. However, from our study as demonstrated in Table 2, the salinity of the river system is purely freshwater. Therefore the presence of this species in both upstream and downstream all year round in the freshwater does not support the proposition that *Chrysichthys* migrates from estuary to freshwater for spawning. It was this supposition that had discouraged the attempt on the aquaculture of the species. By our result we confirm that *Chrysichthys nigrodigitatus* is a freshwater species and thus can be cultured in the hatchery.

Table 2: Mean monthly salinity values of the Cross River in 2017 (‰)

Months	Upstream	Downstream
January	-	0.03
February	0.05	0.04
March	0.01	0.03
April	0.06	0.05
May	0.02	0.02
June	0.02	0.02
July	0.02	0.02
August	0.01	0.02
September	0.02	0.02
October	0.02	0.02
November	0.01	0.01
December	0.01	0.01
Mean	0.02± 0.02	0.03 ± 0.01

Table 3: Mean hydrographic parameters between the upstream and downstream of the Cross River with calculated t-values.

Parameters	Upstream	Downstream	t_{cal}
Temperature	28.8±1.88°C	28.9±2.05 °C	0.025
Current	0.50 ± 0.38ms^{-1}	0.45± 0.29ms^{-1}	1.4
Turbidity	46.2± 38.4NTU	43.3±46.2 NTU	0.24
Depth	4.44±2.3m	4.93±1.4m	0.90
Salinity	0.02±0.02‰	0.03±0.01‰	0.69

There was no significant difference in the hydrographic parameters between the upstream and downstream of the Cross River ($p \geq 0.05$)

Migration status of *Chrysichthys nigrodigitatus*

For migration to take place a species is taken away from one locale to another and from one population to another or from one habitat to another. Migration affects the population size at a particular point in time. The process of leaving one locale to another is termed emigration while the process of arriving a new locale is termed immigration. In *Chrysichthys* there is no such phenomenon as emigration and immigration. The population appears to be one. Uyoh *et al*. (pers comm.) reported more than 99% homology in molecualar characterization of *Chrysichthys* from the upstream and the downstsream of the Cross River. The species do actually move especially upstream, but with the homogeneity in the hydrographic parameters one should rather consider this as local wanderings in search of a breeding place. This is especially so as some specimens were recaptured two to three times within the region of release. Since *Chrysichthys* inhabits the entire length of the Cross River, both the upstresam and downstream individuals may be regarded as members of the same population. Hence such displacement during breeding cay not be regarded as migration but a search for a favourable breeding ground against competition for space. That several of the recaptured specimens were preponderant during the breeding season months of May to July suggests that they were involved in reproductive swarming. This supposition is accentuated by the presence of many gravid females in our samples during the rainy season months from April to August. Consequently it can be argued that *Chrysichthys*

nigrodigitatus of the Cross River engages in nuptial swarming similar to the nuptial flight of termites at the onset of rains or the reproductive swarming of marine sandworms *Nereis diversicolor* and *Nereis nuccinea* during full moon [13, 14].

This movement as shown by specimens recaptured far away from their points of release though not outright migration, serves some biological purposes like any reproductive migration [4]. acknowledged that many species undergo reproductive migrations within freshwater, the so called potamodromous fishes. According to [16], by this movement life cycles of many fishes remain unhindered-spawning, foraging and refuge. The volume of favourable habitat is enhanced or unimpeded; gene flow is unperturbed between conspecific fish populations. Consequently, many fish species are not confined to small and often isolated habitat patches that can sustain only a limited number of individuals. In their study of the molecular and morphological characterization of two species of *Chrysichthys* in the Cross River, Uyoh *et al*. (pers comm) observed high similarity between the specimens from the downstream and upstream Cross River as an indication of a high degree of gene flow. Specimen recaptured in 2018 in Itu far away from Akani Obio Uruan (Fig 1) gives a clue that this constant movement may take them after some years to the upstream location. Such development can lead to interbreeding and gene flow with a resultant high degree of homology in their genetic composition.

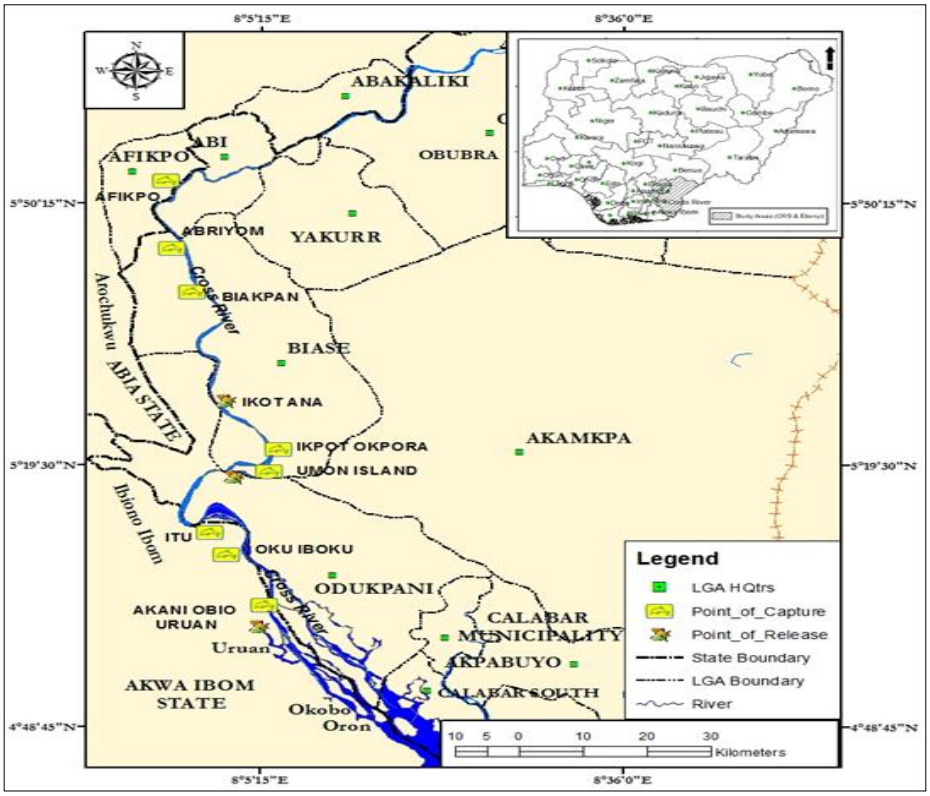

Fig 1: Map of the Cross River showing the sampling locations and fish migration pattern

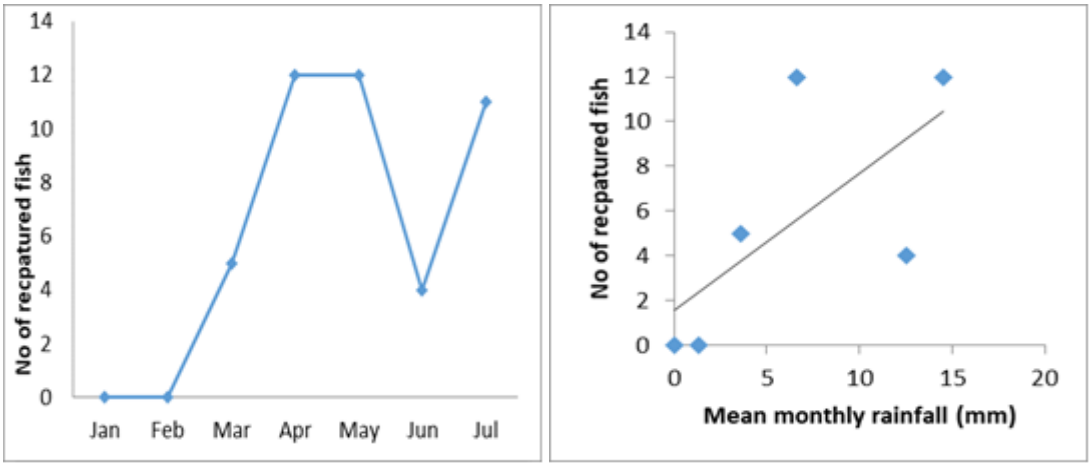

Fig 2: Relationship between number of recaptured *Chrysichthys nigrodigitatus* and (a) month of the year (b) mean monthly rainfall

That one species was recaptured twice (tagged thrice) around the point of initial release shows that some of the specimens are actually confined/restricted to their natal sites. In the first year of sampling, species released at Akani Obio Uruan were caught only 20km upstream at Oku Iboku. But in the second year report of specimen caught about forty kilometres at Itu was received. None from the downstream has been reported yet at Ikot Okpara which is about 88 km upstream from Akani Obio Uruan. This further opens door to more research as to the stock identity of the species of *Chrysichthys* in the Cross

River system. This movement of fish species gives important clue as to the need for concerted effort in the management of the species along the river system [4]. Stated that migration both in and out of population greatly complicates any attempt at predicting future population size A increase. Future work should investigate whether the downstream individuals ever wander beyond Itu to Ikot Okpara or whether there is an underwater barrier like sand mound that can obstruct the crossing of this benthic species to upstream. It is known that some underwater mound/sill prevents the crossing over of some fish species from the Mediterranean Sea into the Atlantic Ocean at the Strait of Gibraltar [4]. A similar phenomenon may happen along the Cross River which is made up of high underwater sand mound at some points along the river. Species upstream movement may not merely be because of search of breeding ground, but constant swimming against current is a strategy to enhance optimum oxygen uptake in the water which is very important for the survival of this species. *Chrysichthys* does not like confinement but prefers constant movement. This habit may also be taken into cognizance as critical in the aquaculture of this species.

This study has not seen any evidence of the migration of the species from the estuary to upstream- anadromous phenomenon, else specimens tagged at Akani Obio Uruan, lower Cross River, close to the estuary would have been recaptured at Ikot Okpara upstream. Unlike in American shad's migration where [17] observed clear prespawning and post spawning movements upstream and downstream respectively, and *Ethmalosa fimbrita* where [3, 9] and observed massive congregations during emigration from the Cross River Estuary, there was no observable prespawning and post spawning movements in *Chrysichthys nigrodigitatus* that could point to outright migration. For migration to occur there must be a distinct immigration and emigration. The hydrographic parameters of temperature, currents, turbidity, depth and salinity, investigated and analysed did not show any significant difference between the upstream and the downstream sections which could warrant migraton. Secondly, if *Chrysichthys nigrodigitatus* was engaged in anadromous migration, they would not have been found all year round in both upstream and downstream sections of the river. For anadromous species like American shad and salmon, the adults are found in the ocean prior to Spring and they migrate to freshwater for spawning at Spring. They are not found all year round in the fresh water. For both adult and juveniles *Chrysichthys* to be found all year round in the freshwater shows that they are indeed true residents in the freshwater. Thirdly, both gravid and spent females found at both upstream and downstream shows that spawning also occurs in these two regions. This would not have been so if the species were migrating upstream for spawning.

Therefore, *Chrysichthys nigrodigitatus* is not anadromous species that migrate from the estuary to the freshwater for spawning. Rather the species is potamodromous and swarm within freshwater for the purpose of reproduction. That such swarming commences at the onset of rains demonstrates the dependence of reproductive activities on seasonally driven climatic variation [4]. In *Chrysichthys nigrodigitatus* spawning appears to be synchronized with periods most favourable for the survival of the young and the possibility of the spawning females and other reproductive activities not being perturbed [18]. reported that during the breeding season, the water depths in the Cross River becomes very high. Consequently the species being benthic organisms, are out of the reach of catch by the fishers. Secondly spawning coincides with seasonal blooms of zooplankton and other allochthonous food materials from the floodplain maximizing the chances that larvae and juveniles encounter prey during the critical period shortly after they use up the energy stores of their yolk supply. This period is also characterised by rise in water volume into adjoining riparian and terrestrial vegetation providing habitat expansion and shades, for protection of the young ones from predators in the main river where the mothers are [5].

Tagging – Recapture method

Ours is the first documented report of tagging-recapture method in Nigeria. The authors are not aware of any previous work on tagging experiment. That we can rely on nylon monofilament for the tagging is an innovation which of course has saved some money from the importation of Visible Implant Elastomer (VIE). This method also ensures that any tagged fish can be consumed at the end of the experiment as opposed to the colouring injector of VIE that leaves a permanent mark on the tagged fish rendering it unfit for consumption. There is an ecological advantage with respect to species conservation with our method. By tagging and releasing about 1000 specimens of fish purchased from commercial fishers, we have rescued them from destruction and returned them into the water. Thus our study method is environmental friendly and enhances conservation.

Review of the name "Estuarine catfish"

The presence of *Chrysichthys nigrodigitatus* in water with salinity range from 0.02‰ to 0.06‰ as seen in our records calls for a review of the name 'estuarine' catfish since these salinity values are associated with freshwater. Our observation is in agreement with [4] who identified that there are 6 freshwater families of siluriformes and that only 2 families are marine. The family claroteidae is not mentioned among the two families. Consequently *Chrysichthys* in the family claroteidae of the order siluriformes is a primary freshwater fish.

Conclusion

We conclude that *Chrysichthys nigrodigitatus* inhabits the freshwater of the Cross River and does not migrate from the Estuary to the freshwater. Consequently, the fears associated with its aquaculture in freshwater ponds should be dispelled. Domestication is highly germane, with the linkage of the species to rainfall. This would shield the fish from the vagaries of climate change impacts, thus enhancing its sustainability, and food security. The aquacuclture of the *Chrysichthys nigrodigitatus* will form another subject of communication.

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