LIFE HISTORY CHANGE IN SILVER CATFISH, *CHRYSICHTHYS NIGRODIGITATUS*, FAMILY BAGRIDAE, IN OGUN STATE COASTAL ESTUARY, NIGERIA

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ABSTRACT

Fishing has been hypothesized to cause changes in life history traits of exploited commercial fish stocks. Hence, this study examined the life history change in of silver catfish *Chrysichthys nigrodigitatus* collected from commercial landings in Ogun State coastal estuary, Nigeria during the period of six consecutive months, December, 2012 to May, 2013.The size of fish stock ranged between 7.1cm and 47.0cm and an average weight ranged between 53.76±3.22g and 133.96±9.06g. Asymptotic length ($L\infty$ = 49.88cm), growth curvature (K =1.45yr^{-1}), fishing mortality (F = 2.04yr^{-1}), natural mortality (M = 1.99yr^{-1}), total mortality (Z = 4.03yr^{-1}) and exploitation rate (E = 0.51) were calculated. Length at-first maturity, L_{50}, was 12.88cm at age, A_{50}, 0.21yr. Fecundity of the fish ranged from 557 eggs to 11,607 eggs. The mean condition factor of females was higher in small and juvenile (1.071±0.12– 2.182±0.41g/cm^3) than large size (0.799±0.10 - 1.193±0.11g/cm^3). Potential rate of population increase, γ^1 was estimated as 29.91. This stock of *C. nigrodigitatus* exhibited phenotypic plasticity. It is therefore recommended that management effort be directed towards controlling fishing pressure on the fish stock in the water body.

Keywords: Life history change, Plasticity, Exploitation, *Chrysichthys nigrodigitatus*, Ogun State.

INTRODUCTION

Silver catfish, *Chrysichthys nigrodigitatus* Family: Bagridae), is an important fish species occurring in estuarine water bodies of Nigeria. According to Eyo *et al.* (2013), the fish is highly appreciated by consumers for its taste and meat quality, mostly in smoked form, and is used in traditional and continental dishes. The fish is a highly valued food-fish included among the dominant commercial catches exploited in major rivers in Africa (Offem *et al.*, 2008) and it is known to be the most abundant fish catch in estuarine waters in Nigeria (Eyo *et al.*, 2013). Abdul and Omoniyi (2003) reported that it is one of the preponderant fish species, next to tilapias, harvested by fish aggregating device in the lagoon and the fish has been overexploited in the lagoon (Abdul *et al.*, 2009).

Fishing has been hypothesized to cause phenotypic changes in exploited fish populations (Stokes *et al.*, 1993; Sharpe and Hendry, 2009). In particular, it may lead to changes in the life history traits such as age, size and maturation as well as fecundity; because these traits are sensitive to altered mortality schedules (Stearns, 1983). These changes have been observed in many commercial fish stocks (Stokes and Law, 2000; Hutchings and Baum, 2005; Jorgensen *et al.*, 2007; Fenberg and Roy, 2008). According to Eikeset *et al.* (2013), fish stocks experiencing high fishing mortality show a tendency to mature earlier and at a smaller size. Demographic traits of fishes, such as growth and reproduction patterns may change under fishing pressure as observed in North Sea Sole and Plaice (Rijnsdorp and van Leeuwen, 1996). Changes in size-at-sexual maturity and fecundity have also been reported for Atlantic cod, Atlantic herrings and sea plaice (Beacham, 1983; Rijnsdorp, 1991).

Rochet (1998) has identified three effects of fishing on fish population dynamics. These include direct effects on population density and the mean size of individuals, short – term environmental effects on growth and reproduction (mediated by phenotypic plasticity and density-dependent mechanism) and long-term effects due to the selective pressure imposed on harvesting. The first type of problem is commonly addressed by fisheries assessment models and management policies, and other two types of effects are seldom considered.

Winemiller and Rose (1992) have reported some important life-history parameters that can be used to assess species vulnerability and prioritize stocks for research and management. Musick (1999) identified intrinsic rate of increase and age at maturity as two key traits which strongly influence degree of vulnerability. Others identified size at maturity, potential fecundity, condition factor, population (density/ha), stock biomass and fish body size as essential parameters in fish stock assessment (Jennings *et al.*, 1998; Rideout *et al.*, 2005; Berkeley *et al.*, 2004).

Therefore, the goal of this study was to assess the life - history change in the exploited silver catfish, *C. nigrodigitatus* using length, weight and fecundity data.

MATERIALS AND METHODS

Study Site: The study was carried-out in Ogun State coastal estuary, Nigeria (Fig. 1). It is situated between $004^{0}15^{1}$E – $004^{0}30^{1}$E and $06^{0}20^{1}$N – $06^{0}45^{1}$N and bounded in the East by Lekki lagoon and South by Bight of Benin. The estuary covers an area of 26 km^{2} (Ssentongo *et al.,* 1983). It empties into the Atlantic Ocean through Lagos Harbour. The water is linked to the Lekki and Lagos lagoons. The lack of direct access to the Atlantic Ocean coupled with the discharge of Rivers Osun, Mosafejo and Oni into the water

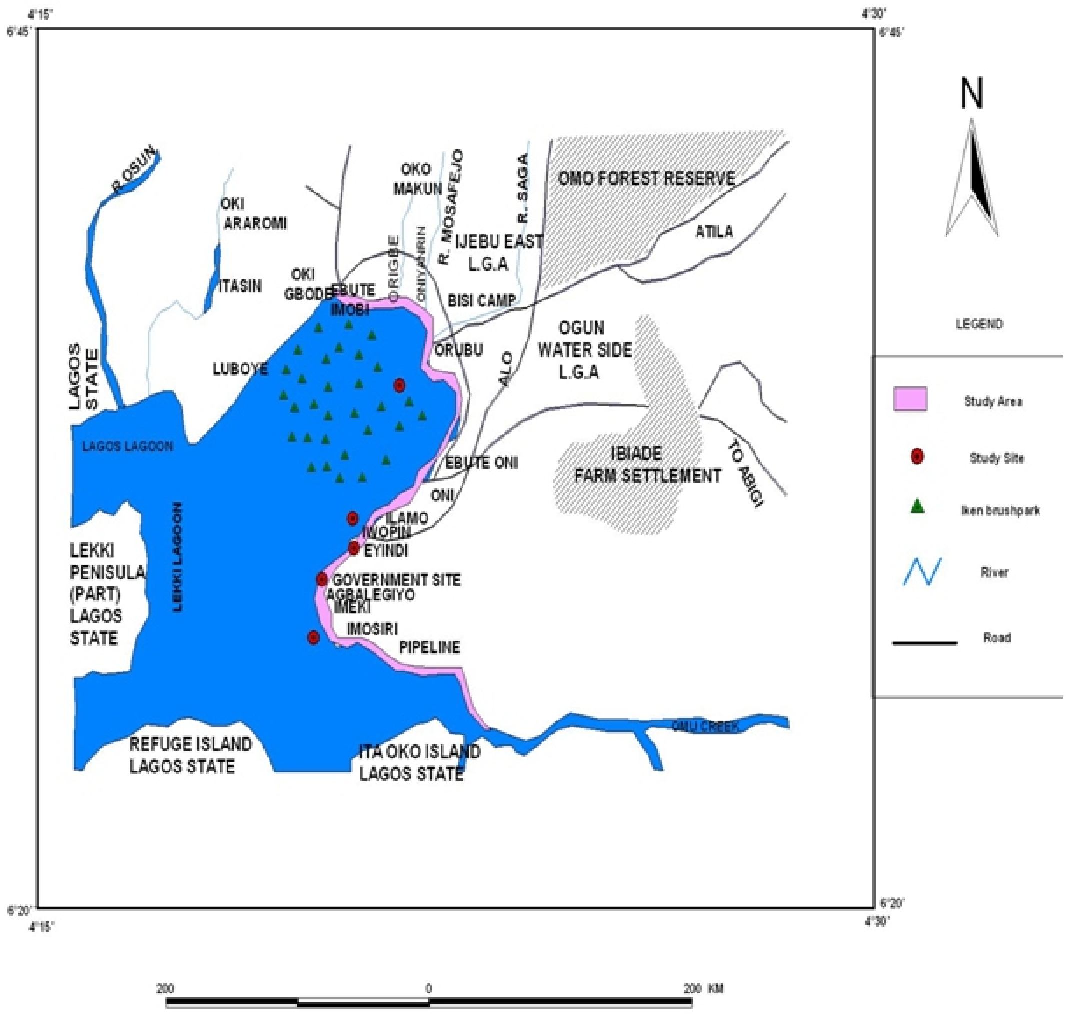


Fig. 1. Map of Ogun State coastal estuary showing the study area

Data Collection and Analysis

A total number of 1671 random samples ranging from 7.1cm – 47.0cm Total Length (TL) of *C. nigrodigitatus* were collected from commercial landings for a period of six consecutive months, December, 2012 to May, 2013. TL of each was measured to the nearest 0.1cm using Ichthyoboard, while body weight (W) was taken to the nearest 0.1 g using Metler balance (Model: HR 2385/A). The length-frequency data were analysed using FiSAT II version 1.2.1, (Gayanilo *et al.*, 2002). The stepwise procedure was adopted for correction of length-frequency data for mesh selection (Pauly, 1986) and the sub-routines of FiSAT II, ELEFAN 0-II, were later used to estimate growth and population parameters, which served as input data for empirical estimation of length and age-at-first maturity, L_{50} and A_{50} respectively. The annual mean temperature of 28.3^0C reported by Abdul *et al.* (2009) was used in this study to estimate natural mortality.

Length-at-first-maturity, $L_{50}$was estimated as: $\text{Log}L_{50} = 0.8776\text{Log}L\infty - 0.38$ (Froese *et al.*, 2000). Similarly, age-at-first maturity, $A_{50}$was obtained replacing the L_{50} in the VBGF and solved for t: $A_{50} = -1/K*In(1 - L_{50}/L\infty)$ (Flores *et al.*, 2013)

Where, $L\infty$ = asymptotic length (cm), K = growth curvature (year^{-1}) and t_0 is negligible.

The length-weight data were used to estimate the length-weight relationship parameters of the stock in the form of Log W = Log a + bLog L where, L = total length (TL, cm), W = weight (g)

For fecundity, egg size and condition factor, 342 females were examined. Ovaries from gravid females were carefully excised from the body cavity of each specimen and preserved in modified Gilson fluid (Simpson, 1951). Absolute fecundity was calculated as the product of total weight of eggs and the number of eggs per gramme body weight.

Fecundity-length relationship was expressed as:$\text{Log}\,F = \text{Log}\,\alpha + \beta \text{Log}\,L$

Where, F = absolute fecundity, L = Total length (cm), α = constant and β= exponent

Condition factor (CF) was estimated as: $CF = 100W/L^3$

The surrogate estimate of intrinsic rate of population increase, γ^1, as used by Jennings *et al.* (1998) was used to determine the resiliency of the fish stock to fishing pressure as:

$\gamma^1 = In(\text{Fecundity at } L_{50}) / A_{50}$

Fecundity at L_{50} was estimated from the derived linear regression equation above and fecundity at L_{50} was estimated from

$F_{L50} = \alpha(L\infty(1 - \exp -k(t - t_0)))^\beta$, where α and β are parameters of fecundity-length relationship.

RESULTS

The length-frequency distribution of *C. nigrodigitatus* in the estuary is shown in Fig. 2. The fish species had a range of total length 7.1cm-47.0cm. A minimum number of two was recorded in36.1cm-37.0cm, 37.1cm-38.0cm, 41.1cm-42.0cm, 43.1cm-44.0cm, 44.1cm-45.0cm, 45.1cm-46.0cm and 46.1cm-47.0cm and a maximum number of 179 fish was recorded in total length class 16.1cm-17.0cm. The monthly mean of TL was also recorded. This ranged between 15.93±1.82cm in May and 21.22±1.61cm in January. The lowest total number of fish, 210, was recorded in April and the highest total number, 319, was recorded in December. The monthly average weight ranged between 53.76±3.22 g in May and 133.96±9.06 g in January (Table 1). From the data, as shown in Fig.2, the small length class of *C. nigrodigitatus* dominated the fishery.

Table 1: Length-frequency Distribution and Mean Weight of *C. nigrodigitatus* in Ogun State Coastal Estuary

Length class(cm)	December	January	February	March	April	May	Total	Mean Weight(g)
7.1-8.0	-	-	2	-	8	-	10	13.9
8.1-9.0	-	-	3	-	10	-	13	17.7
9.1-10.0	4	2	9	-	18	8	41	15.7
10.1-11.0	6	2	9	3	12	8	40	18.1
11.1-12.0	4	2	6	2	8	17	39	22.1
12.1-13.0	24	4	2	17	16	24	87	22.7
13.1-14.0	34	13	22	38	12	27	146	28.2
14.1-15.0	33	21	13	37	12	41	157	35.8
15.1-16.0	46	25	16	37	12	31	167	44.3
16.1-17.0	37	22	38	28	14	40	179	53.2
17.1-18.0	22	10	20	23	20	34	129	62.3
18.1-19.0	21	24	20	13	20	20	118	69.9
19.1-20.0	27	41	22	10	6	20	126	80.8
20.1-21.0	19	21	14	7	4	12	77	86.1
21.1-22.0	9	19	2	12	4	-	46	89.8
22.1-23.0	2	22	2	2	4	2	34	137.8
23.1-24.0	6	22	5	3	8	-	41	122.7
24.1-25.0	6	12	5	3	8	-	34	142.6
25.1-26.0	-	15	3	2	-	6	26	227.1
26.1-27.0	2	6	6	-	2	-	16	267.7
27.1-28.0	3	3	11	-	2	2	21	225.6
28.1-29.0	-	3	11	-	4	-	18	218.4
29.1-30.0	2	3	5	5	2	-	17	280.6
30.1-31.0	-	2	8	2	2	2	16	314.8
31.1-32.0	-	3	2	3	-	-	8	314.8
32.1-33.0	-	3	2	2	-	-	7	276.2
33.1-34.0	-	2	5	3	-	-	10	439.3
34.1-35.0	-	-	8	2	-	-	10	417.6
35.1-36.0	-	2	5	-	-	-	7	527.5
36.1-37.0	-	-	-	-	2	-	2	427
37.1-38.0	-	-	2	-	-	-	2	471
38.1-39.0	-	2	2	-	-		4	667.7
39.1-40.0	-	2	-	2	-	-	4	522
40.1-41.0	-	3	-	-	-	-	3	706
41.1-42.0	-	2	-	-	-	-	2	760
42.1-43.0	2	2	-	2	-	-	6	615
43.1-44.0	-	2	-	-	-	-	2	910
44.1-45.0	2	-	-	-	-	-	2	755
45.1-46.0	2	-	-	-	-	-	2	567
46.1-47.0	-	2	-	-	-	-	2	988
Total	313	319	280	255	210	294	1671	-
Mean Length(cm)	17.25±1.66	21.12±1.61	19.99±1.96	17.62±2.22	16.15±3.02	15.93±1.82	-	-
Mean weight(g)	70.06±5.12	133.96±9.06	123.27±7.93	78.77±6.21	65.64±4.755	53.76±3.22	-	86.03±2.11

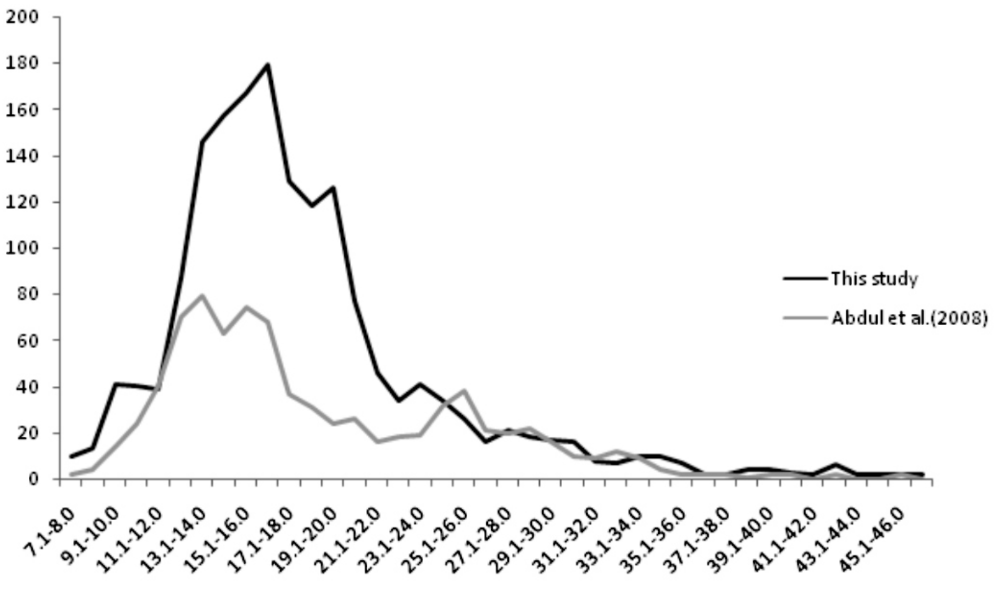


Fig. 2. Change in Size Distribution of *C. nigrodigitatus* in Ogun State Coastal Estuary

The result of growth and population parameters is presented in Table 2 as well as, the LWR for combined sexes was $0.181 L^{2.114}$ ($r^2 = 0.9219$).

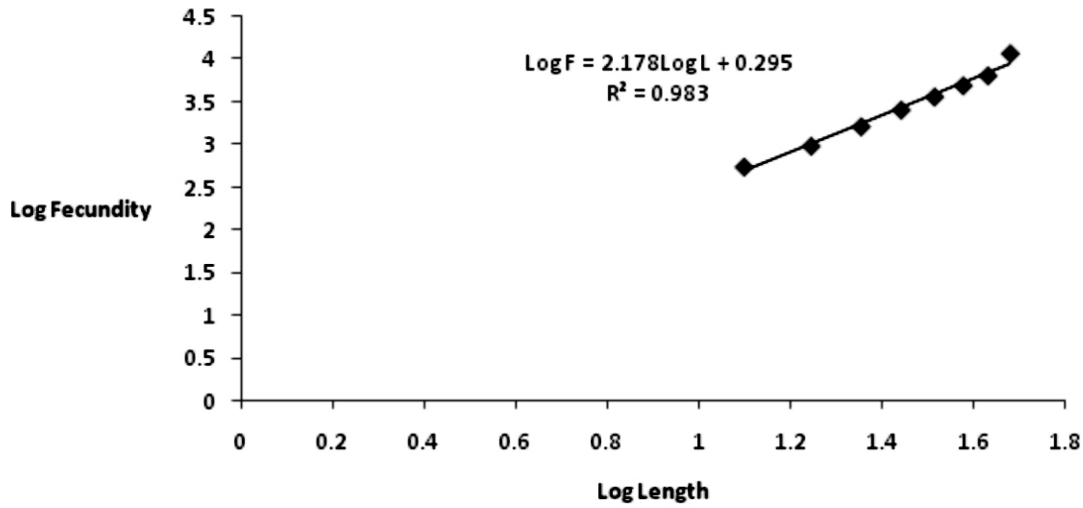
From a total of 342 females (Table 3) randomly selected from commercial landings, 0%, 36%, 40%, 30% and 56% of respective length classes 5.1 cm-10.0 cm, 10.1 cm-15.0 cm, 15.1 cm-20.0 cm, 20.1 cm-25.0 cm and 25.1 cm-30.0 cm were gravid. While 33%, 25%, 17% and 25% were also gravid in the length classes 30.1 cm-35.0 cm, 35.1 cm-40.0 cm, 40.1 cm-45.0 cm and 45.1 cm-50.0 cm respectively. Mean condition factor of female fish ranged between 0.799±0.10 g/cm^3 and 2.182±0.41 g/cm^3. The values were higher in smaller size females than large size females. Mean egg size increased with increased size of female. It ranged between 0.60±0.03 mm (10.1-15.0 cm TL) and 3.18±0.14 mm (45.1-50.0 cm TL). Absolute fecundity of fish increased with size of female samples in the population. Fecundity values ranged from 557eggs (10.1 cm-15.0 cm TL) to 11,607eggs (45.1 cm-50.0 cm) and the fecundity-length relationship is shown in Figure 3, where α=1.972 and β= 2.178(r^2 = 0.983). Potential rate of population increase, γ^1= 29.91, was estimated.

Table 2: Comparison of Growth and Population Parameters of *C. nigrodigitatus* in Ogun State Coastal Estuary

Parameters	Abdul *et al* . (2009)	This study
Mean size-at-harvest, L(cm)	24.3	17.99
Asymptotic Length, L_∞(cm)	52.63	49.88
Growth curvature, K (year^{-1})	1.65	1.45
Length-weight relationship parameters, a	1.994	0.181
b	2.722	2.114
Fishing mortality, F (year^{-1})	2.22	2.04
Natural mortality, M (year^{-1})	1.26	1.99
Total mortality, Z (year^{-1})	3.48	4.03
Exploitation rate, E (year^{-1})	0.64	0.51
Length-at-first maturity, L_{50} (cm)	16.67	12.88
Age-at-first maturity, A_{50} (year)	0.27	0.21

Table 3. Proportion of Ripe Females, Condition Factor, Egg Size and Absolute Fecundity of *C. nigrodigitatus* in Ogun State Coastal Estuary

Length Class(cm)	Number of Females	Proportion of Ripe Females	Mean Condition Factor (g/cm^3)	Mean Egg Size (mm)	Absolute Fecundity
5.1-10.0	15	0.00	2.182±0.41	-	-
10.1-15.0	95	0.36	1.097±0.22	0.60±0.03	557
15.1-20.0	121	0.40	1.206±0.32	1.42±0.06	974
20.1-25.0	40	0.30	1.071±0.12	2.32±0.09	1637
25.1-30.0	23	0.56	1.193±0.11	2.44±0.10	2557
30.1-35.0	10	0.33	1.046±0.30	2.51±0.09	3629
35.1-40.0	19	0.25	1.009±0.10	2.70±0.10	4906
40.1-45.0	15	0.17	0.985±0.09	2.91±0.12	6415
45.1-50.0	04	0.25	0.799±0.10	3.18±0.14	11,607



*Length class 5.1-10.0cm was excluded from a regression analysis

Fig. 3.Fecundity-Length Relationship of *C. nigrodigitatus* in Ogun State Coastal Estuary

DISCUSSION

Fishing has been described to influence life history changes via at least two different mechanisms in addition to the immediate commercial effects of mortality (Law, 2000; Heino *et al.*, 2002). Firstly, fishing may induce plastic changes in life history traits as overfishing most times causes rapid decrease in population size (Hutchings and Baum, 2005), which in turn can lead to relaxation of intra-specific competition, and thus rapid growth rates (as observed in this study where, E= 051, and K= 1.45/year) of survivors. As a result of these rapid growth rates, fish mature at younger ages, and can show associated changes in size at maturity (Kuparien and Merila, 2007). It was observed from this study that length-at-first maturation (L_{50}= 12.88cm)and age-at-first maturation (A_{50} = 0.21year) decreased when compared to those values reported by Abdul *et al.* (2009) (L_{50}= 16.67cm & A_{50} = 0.27year).

The maturity age and size of American Plaice population (*Hippoglossoides platessoides*) estimated by cohort using generalized linear models with a logit link function and binomial error provide an excellent example of decline in both age and size at maturation as population abundance declined (Morgan and Colbourne, 1999). Mean size at harvest (L=17.99cm) as well as asymptotic length (L = 49.88cm) reported in this study against values (L= 24.3cm and L= 52.63cm) that were reported by Abdul *et al.* (2009) in the same water body, Ogun State coastal estuary, is a strong indication of phenotypic plasticity in the *C. nigrodigitatus* population. Changes in the environment have been linked with changes in body-size especially when water temperature is relatively high (Jorgensen, 1992). This simply implies that biotic and abiotic changes taking place in the ecosystem are to be evaluated when stock biomass is fished down. According to Ricker (1981), consistent relationship has not been established between body weight and environmental variables such as temperature and salinity.

Secondly, fishing may also induce evolutionary changes in fish stocks by selecting against particular life histories (Stokes *et al.*, 1993; Tripple, 1995). Rapid divergence in life history traits have been reported in wild population of guppies, *Poecilia reticulate* and mosquito fish, *Gambusia affinis* (Stearns, 1983; Reznick *et al.*, 1990; Reznick and Ghlambor, 2005). Sharpe and Hendry (2009) reported a life history change in commercially exploited fish stocks where rates of phenotypic change were calculated for two traditional maturation indices, L_{50} and A_{50}, and reported that the rates of decline have strong correlation with fishing intensity. Therefore, the exploitation rates, E, reported by Abdul *et al.* (2009) (E= 0.64) and that estimated from this present study (E = 0.51) might be contributory factors to the rapid maturation of the stock.

According to Law (2000), selection of fishing gear and spatial location of fishing are contributory factors to large changes in yield-determining traits such as growth rate, length and age-at-sexual maturity and fecundity of commercially exploited fish. That is through fishing, fishermen generate selection, causing evolution that changes the sustainable yield.

Early maturity observed in this stock could also be attributed to the fact that the fishery generates selection of life history traits simply because fishermen catch more individuals of some ages and sizes than the others. The level of adult mortality relative to juvenile mortality have been reported to affect age and size at maturation (Jorgensen, 1990; Morgan, 2004; Morgan and Lilly, 2006; Grift *et al.*, 2007)

Higher natural mortality, M = 1.99yr^{-1}, estimated from this study when compared to that reported by Abdul *et al.* (2009) (M = 1.26yr^{-1}) might have resorted from intense predation as a consequence of low population of the stock. Parkinson (1990) predicted that lower population levels would result in longer school formation time and small schools, both resulting in higher mortality due to predation. Schooling can provide access to higher quality food, as reported from Lake Malawi by Marsh and Ribbink (1986) showed that individual cichlids were able to gain access to aggressively defended, higher quality grazing sites when they joined a school.

The reproductive biology of fish determines its productivity and the population resilience to exploitation (Morgan, 1990). Studies of fecundity of *C. nigrodigitatus* in Lekki Lagoon is lacking, therefore, data collected from this study were compared with the results of Eyo *et al.* (2013), Offem *et al.* (2008) and Ekanem (2000) from Cross-river estuary, Nigeria. Eyo *et al.* (2013) reported that the fecundity of *C. nigroditatus* in Cross-river estuary ranged between 975 eggs for fish of total length 23.2 cm and 11,280 eggs for fish of total length 50.0 cm. Meanwhile, Offem *et al.* (2008) reported that the species is heavily exploited in Cross-river estuary as commercial resource; therefore, this could contribute to the reduction in the fecundity and mean egg size reported by Eyo *et al.* (2013). Ekanem (2000) had earlier reported that the stock's fecundity varied between 3,046 eggs (TL = 28.5 cm) and 28,086 eggs (TL = 64.0 cm). Lower fecundity range, 557 eggs (TL = 10-15 cm) to 11,607 eggs (TL = 45-50 cm) was recorded in this study. This, obviously, could be attributed to early maturity as a consequence of plastic response to over-exploitation of the stock in the estuary (Law, 2000).

The length-frequency distribution of the present study in Ogun State coastal estuary shows that the population of larger and older fish is low, and this according to Green (2008) has been responsible for the collapse of many important fish stocks. Additionally, the preponderance of smaller size females in the stock may impact negatively on its reproductive success except when there are other compensatory factors in the estuary. Several studies have shown that larger size individuals produce more eggs, better quality larvae and promote survival. Murawski *et al.* (2001) found that fish body size affect larva quality, then removal of larger females from the population may adversely affect reproductive potential. Berkeley *et al.* (2004) found that progeny of older female black rock fish (*Sebastes melanops*) survived starvation over twice as long as progeny from younger females. This might be because the larvae from older or larger females have significantly larger oil globules or reserves (Sogard *et al.*, 2008), and that oil globule size is positively correlated with larval growth rates and median time of starvation. Older and larger females span a longer spawning season, enhancing the probability that progeny will meet favourable environments (Rideout *et al.*, 2005). The low condition factor in large size females might make them show high level of atresia and significantly reduce egg production or make them skip spawning.

The high value of γ^1 shows that the species still has high resilience for the intense fishing pressure estimated in the fishery. The result is similar to those estimated for deep water fish species (Fujiwara, 2012). According to Fujiwara (2012), iteroparous fish like *C. nigrodigitatus* can have high resilience if they mature early and produce a large number of offsprings. If juvenile survival is high and there is greater abundance in the juvenile stage, it may result in enough number of individuals maturing each year to maintain the population. Resilience is also affected by life history traits. It increases with increasing maturation rate and juvenile survival rate. Therefore, the resilience is the property associated with parameters of juvenile stage.

CONCLUSION

Fishing has been known from this study to cause phenotypic plasticity in life history of *C. nigrodigitatus* in Ogun State coastal estuary. These changes are similar to those that have been reported in most commercial fish stocks as a result of intense fishing pressure. Periodic checks on fish stock parameters such as length-at-first maturity, condition factor and fecundity could be used as indicators in fish stock management. It is therefore recommended that fishing pressure be reduced on this stock to ensure sustainability and circumvent extinction.

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