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RECRUITMENT PATTERN, PROBABILITY OF CAPTURE AND PREDICTED YIELDS OF *TILAPIA ZILLII* IN OGUN ESTUARY, NIGERIA

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ABSTRACT

A study was carried out on the stock parameters, recruitment pattern, and probability of capture of *T. zillii* in Ogun estuary, Ogun State, Nigeria using length-frequency and catch-at-length data. The fish stock was assessed using the methods of ELEFAN 0- III of the FiSAT II software. Results showed that the stock has a continuous recruitment pattern. L_{25}, L_{50} and L_{75} were 13.82cm, 15.50cm and 17.19cm respectively. Fish population decreased with increase length class. Average mortality rate was 1.16/ year, and exploitation rates were lower in length class 11-12cm to 26-27cm and large size, 34-35cm, and equal or greater than optimum in others. Steady biomass also increased with length class until 24-25cm. The fishery would attain MSY if the present effort level is raised by 1.6.

Keywords: Recruitment pattern, stock assessment, *Tilapia zillii,* Ogun state.

INTRODUCTION

Fish production by Nigerian maritime states in artisanal sector shows that Ogun State contributed 191 – 5,269 tonnes from a total production of 124,117 – 196,276 metric tonnes between 1985 and 1994 (Sikoki, 2006). This was least contribution among other maritime states in Nigeria. It is opined that effort should be directed towards assessing the fishery of Ogun coastal estuary as the state lacks the data on the status of its brackish water fishery potentials down to fish species landings (Abdul, 2009).

Stock assessment has been defined in many ways, often in terms of its objectives. Sparre and Venema (1992) proposed that the basic purpose of stock assessment is to provide advice on the optimum exploitation of aquatic living resources. Hilborn & Walters (1992) defined it as a method that involves the use of various statistical and mathematical expressions to make quantitative predictions about the reactions of fish populations to alternative management choices.

Currently, there has been great interest in length-based method of assessing fish stock. The reason for this has come from at least three sources- the increasing problems of applying the better known age – based methods (especially in tropical areas where fish do not carry easily –deciphered birth certificates on their hard parts (e.g. scales, otolith, opercula bones, vertebrae, spines). The development of improved method of analyzing length data and the increased availability of computers that put within the reach of all the computational power needed to take advantage of some of the new methods. Among these methods is the most globally accepted, Electronic Length Frequency Analysis, ELEFAN (Pauly & David 1981). The system has been revised, expanded and presented as comprehensive software package which incorporates various new routines, FiSAT (FAO-ICLARM Stock Assessment Tool) for length-based fish stock assessment (Gayanilo *et al*., 1988; Gayanilo and Pauly, 1987, Gayanilo *et al.,* 1996, Gayanilo *et al*., 1997).

Meanwhile, fish species of the major brackish waters in Nigeria have been listed (Williams 1962; Fagade & Olaniyan, 1974; Solarin, 1998; Onazi, 2000). *Tilapia zillii* has been listed as the major cichlid stock of lagoons in Nigeria. It is a true estuarine fish species and dominant all the year round in Ogun estuary of Ogun State, Nigeria. Cichlid tilapias constituted about 50.78 percent to the annual yield of "Iken" Brush Park fish landing which is one of the most popular fishing operations, and *T. zillii* currently contributes over 99.27% of the total weight of tilapias landed from the whole fishery Abdul (2009). It is therefore paramount that study is carried out on the status on the stock, *T. zillii,* to know its recruitment patterns, probability of capture, current level of exploitation and predicts its future yields at varying fishing efforts for a sustainable fishery management.

MATERIALS AND METHODS

Description of study site

The study was carried out in Ogun estuary, Ogun Waterside and Ijebu-East Local Government Areas of Ogun State, Nigeria (Figure 1). It is situated between longitude $4^{0}15^{1}$E – $4^{0}30^{1}$E and latitude $6^{0}20^{1}$N – $6^{0}45^{1}$N and bounded in the East by Lekki lagoon and South by Bight of Benin. The estuary covers an area of $26km^2$ (Ssentongo 1983). The estuary empties into the Atlantic Ocean via Lagos Harbour. It falls into the western littoral area. The climate is tropical with rain (April - November) and dry season (December - March).

The fish landing centres on the water front include Ebute-Imobi, Origbe, Oniyanrin, Orubu, Ebute Oni, Aberu, Papermill, Ilamo, Iwopin, Eyindi, Government site, Agbalegiyo, Imeki, Mosiri and Pipeline. Fishing activities are carried-out with canoes (outboard and non-powered). Gillnet, seine net, cast net, traps and brush park fish aggregator popularly called "Iken" are predominantly the gears used for fishing in the area.

Growth and population parameters estimates

Length-frequency data of *T. zillii* were collected with the different gears; Cast nets, Seine, Gillnet nets, and, 'Iken' fish aggregator at monthly intervals (4 days in a month) for the period at each of the landing centres. Sexual dimorphism was not taken into consideration because preliminary study on the species fish before the commencement of this study did not show any significant difference between the von Bertalanffy growth parameters. The weight of individual sample was also determined to the nearest 1g. Means of the two years' monthly length-frequency distribution, catch-at-length data and price-at -length of *T. zillii* pooled together as an annual data and analysed using the procedure of Gayanilo Jr. *et al*. (2002) of the FiSAT II (version 1.2.0) computer software package of fish stock assessment. ELEFAN I (non-parametric scoring of VBGF Fit) and II subroutines of the software were used to estimate von Bertalanffy growth and mortality parameters, recruitment patterns and probability of capture. Virtual population and yield prediction analyses were determined using ELEFAN III sub-routine of the FiSAT II programme. The number of *T. zillii* caught C (L_1, L_2) in each length class was recorded to calculate natural mortality factor, number of survivors, exploitation rate, fishing mortality, mean body weight (in kilogramme), mean annual number, annual mean biomass, yield-at-length for all length classes. Thompson and Bell prediction model as described by Sparre & Venema (1992) was used to predict the maximum sustainable yield, MSY and maximum sustainable economic yield at varying F-factors X ranging from 0.0 – 4.0 graphically.

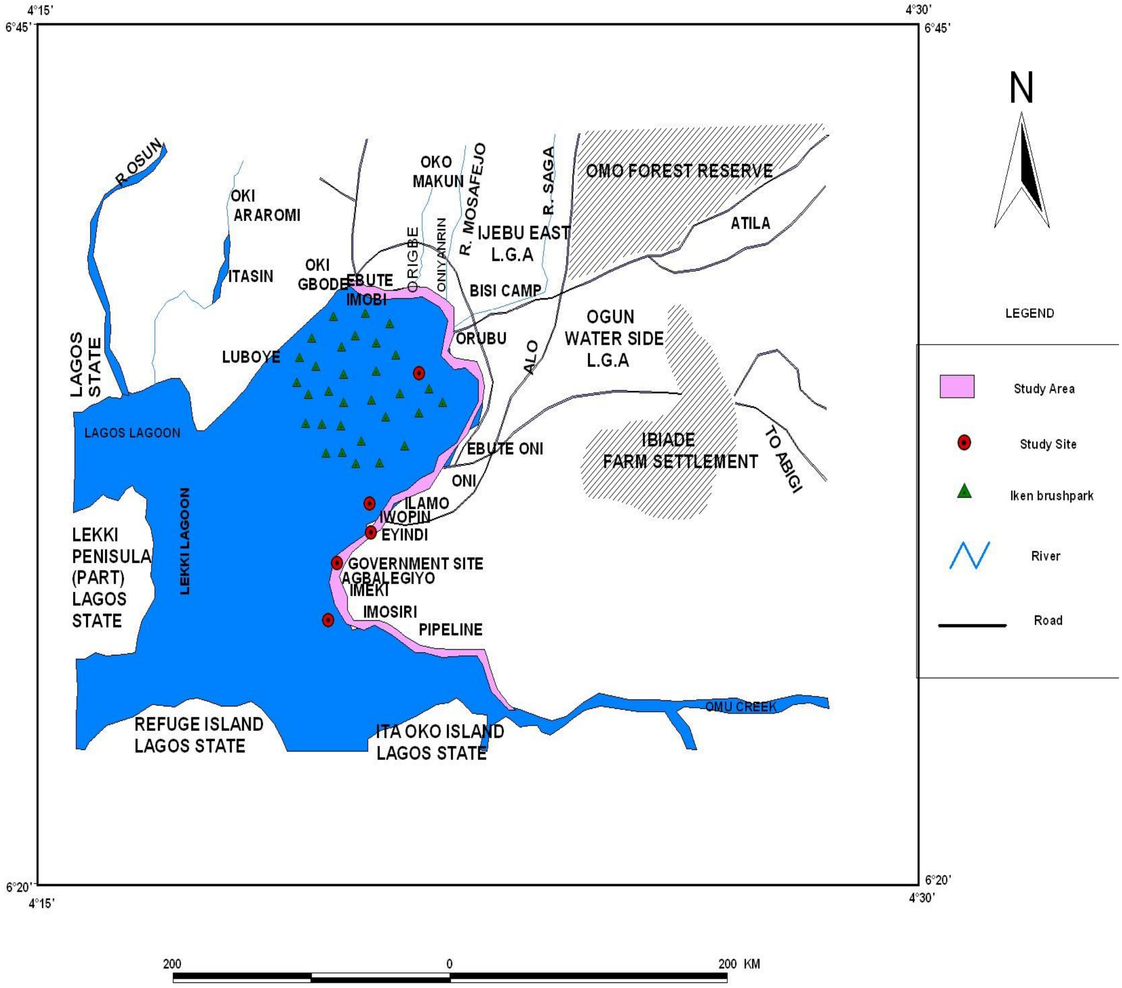

Figure 1: Ogun estuary

RESULTS

Stock parameters, recruitment and probability of capture

It was estimated that asymptotic length, L_∞ and growth curvature, K, were 38.33cm and 0.81/year respectively. From the regression analysis of Z- catch curve, the total mortality was found to be 3.93/year with a class interval of 3.03-4.56/year. Natural, fishing mortalities and exploitation rate were estimated to give 1.46/year, 2.47/year and 0.63 respectively. Results show that August had no (0.00%) recruitment to the fishery, December had the highest level of recruitment (28.27%) followed by November. The values implied that recruitment into the fishery took place for eleven months. September had 3.91%, October had 10.97%, January had 12.38%, and in February, March, April, May, June, and July it was 8.55%, 4.51%, 5.36%, 2.21%, 3.42% and 3.85% recruitment respectively. Figure 2 demonstrates the recruitment pattern of *T. zillii* in the fishery. When decomposed by NORSEP normal distribution procedure, it was found to show one major peak and one minor peak recruitments (December and April respectively).

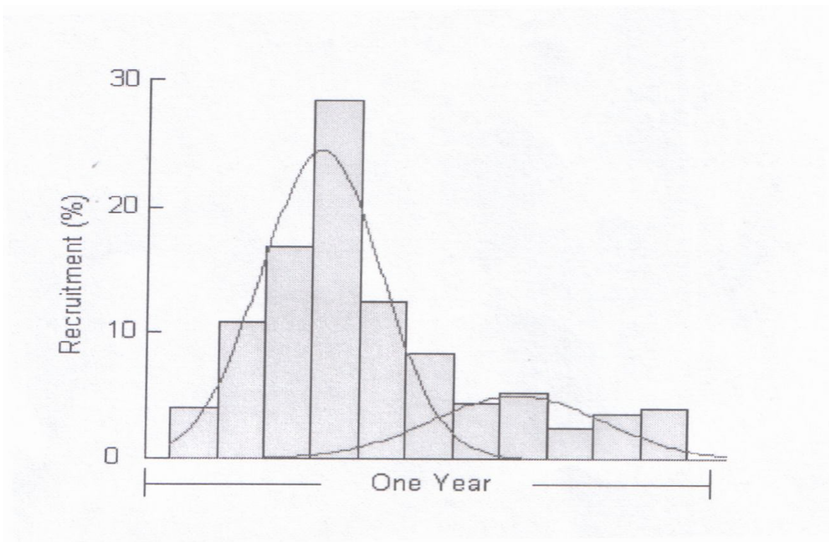

Figure 2: Annual recruitment pattern of *Tilapia zillii* in Ogun estuary

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Table 1 gives the probability of capture of various length classes of *T. zillii* in the estuary. Length classes 11-12, 12-12, 13-14, 14-15, 15-16, 16-17, 17-18, 18-19, 19-20, 20-21, 21-22, 22-23, 23-24 and 24-25cm had the respective probabilities of been captured by gears used, 0.459, 0.412, 0.453, 0.420, 0.551, 0.652, 0.719, 0.782,0.808, 0.812, 0.860, 0.848, 0.897, and 0.922. While 25-26cm and higher length classes had 0.890 and 1.000 probabilities respectively. It was estimated from logistic transformation that L_{25} = 13.82cm, L_{50} = 15.50cm and L_{75} = 17.19cm.

Table 1: Probability of capture to *T. zillii* of Ogun estuary

Length class (cm)	Probability of capture
11-12	0.459
12-13	0.412
13-14	0.453
14-15	0.420
15-16	0.551
16-17	0.652
17-18	0.719
18-19	0.782
19-20	0.808
20-21	0.812
21-22	0.860
22-23	0.848
23-24	0.897
24-25	0.922
25-26	0.890
26-27	1.000
27-28	1.000
28-39	1.000
29-30	1.000
30-31	1.000
31-32	1.000
32-33	1.000
33-34	1.000
34-35	1.000
35-36	1.000
36-37	1.000

Virtual population analysis (VPA)

The result of virtual population analysis, VPA, is presented in Table 2 and Figure 3. The table shows the length classes, catch in number, C, population, N, fishing mortalities based on length classes, and steady-state biomass. The catch ranged between 224, length class 13-14cm, and 8366, length class 24-25cm. The length classes of 16-17cm to 32-33cm were mostly exploited in the fishery. Recruitment into the fishery was estimated at 3,747,328.75. The population of fish decreased with increase length class. Length-classes 11-12cm to 26-27cm and 34-35cm had fishing mortalities, F^1, less than natural mortality, M. The average F^1 value was 1.16/year. This was less than that estimated by catch-curve, 2.47/year. The exploitation rates E^1, were below optimum between length class 11-12 to 26-27cm and 34-35cm. The other length classes exploitation rates that were equal to or greater than the optimum, $E_{0.5}$. The length class 30-31cm had the greater E^1 value. Steady- biomass increased with class length, from 11-12cm to 23-24cm (5.80 -21.25 tonnes), then fell to 20.85tonnes in length class 24-25cm up to 0.25 tonne in length- class 35 – 36cm.

Table 2 : Virtual Population Analysis of *Tilapia Zillii* in Ogun Estuary

Length class (cm)	Catch in Number	Population (N)	Fishing Mortality (F^1)	Steady-state Biomass (tonnes)	Exploitation rate (E^1)
11 – 12	744	3747329	0.0045	5.80	0.0031
12 – 13	447	3503103	0.0028	7.09	0.0019
13 - 14	224	3266524	0.0014	8.51	0.0010
14 - 15	523	3037555	0.0035	10.05	0.0024
15 - 16	2463	2815738	0.0168	11.69	0.014
16 - 17	8067	2599580	0.0572	13.39	0.0371
17 - 18	17257	2385787	0.1279	15.12	0.0806
18 – 19	34562	2171462	0.2696	16.76	0.1763
19 – 20	43850	1949740	0.3639	18.25	0.1995
20 - 21	43103	1729942	0.3832	19.58	0.2079
21 – 22	66932	1522614	0.6466	20.58	0.3069
22 – 23	52662	1304545	0.5593	21.25	0.2770
23 – 24	77091	1114406	0.9155	21.45	0.3854
24 – 25	83666	914377	1.1485	20.85	0.4403
25 – 26	48962	724356	0.7805	20.07	0.3484
26 – 27	75584	583811	1.4368	18.74	0.4960
27 – 28	64767	431422	1.5553	16.45	0.5158
28 – 29	76568	305856	2.533	13.19	0.6344
29 – 30	79183	185155	4.5070	8.44	0.7353
30 – 31	38024	80320	4.6843	4.28	0.7624
31 – 32	8516	30445	2.0949	2.34	0.5893
32 – 33	5081	15993	2.1407	1.49	0.5945
33 – 34	3661	7447	3.3286	0.75	0.6951
34 – 35	598	2180	1.2760	0.35	0.4664
35 –36	449	898	1.4600	0.25	0.5000

M = 1.46/year, Mean F^1 = 1.163, K = 0.81/year, $L\infty$ = 38.33cm, F_t =1.46/year, E^1 = 0.34

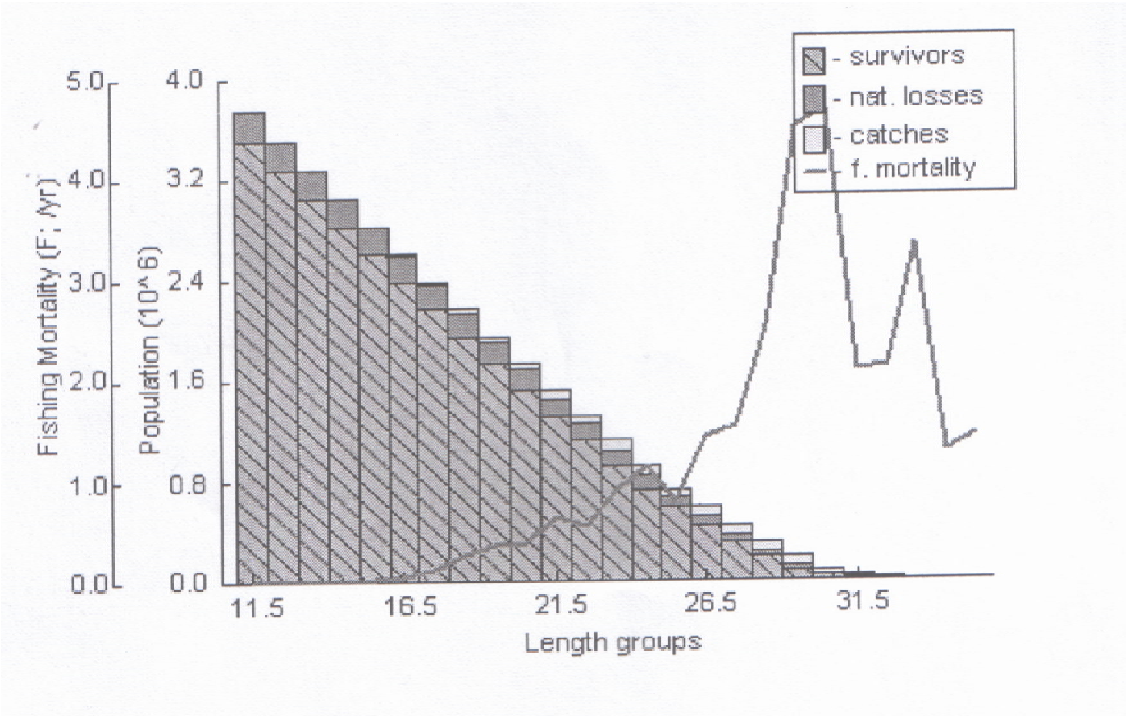

Figure 3: Virtual population analysis of *Tilapia zillii* in Ogun estuary

The Thompson and Bell Yield prediction analysis is presented in Table 3 showing f-factor (various effort levels), the yield, the standing biomass and the monetary value (revenue) of the fishing operation. The prices of fish based on size were used for the analysis. The f-factor ranged between 0.0-4.0 as prescribed by the programme, FiSAT II. Yield of *T. zillii* increased 0.000 – 524.717million tonnes with increased effort level, 0.0 – 1.6, before it started to fall again as the effort was increased to 4.0. The standing biomass had a reverse relationship with increased effort-level (f-factor). As f-factor increased from 0.0 – 4.0, standing biomass reduced from 119.865 x 10^7 tonnes to 13.763 x 10^7 tonnes. The fishery was increasing in value with f-factor from 0.0-1.0 before it started falling till 4.0 f-factor. The value ranged between N0- N143billion.

Table 3: Yield-Stock Prediction Analysis of *Tilapia zillii* in Ogun estuary

f-factor (effort level)	Yield (x 10^6)	Biomass (x 10^7)	Value (x 10^9)
0.0	0.000	119.865	0.000
0.1	139.503	103.050	46.251
0.2	240.616	89.829	78.251
0.3	314.880	79.246	100.476
0.4	369.982	70.639	115.882
0.5	411.172	63.544	126.461
0.6	442.107	57.622	133.558
0.7	465.384	52.626	138.220
0.8	482.878	48.369	141.040
0.9	495.960	44.711	142.536
1.0	505.648	41.541	143.063
1.1	512.706	38.774	142.880
1.2	517.712	36.343	142.179
1.3	521.109	34.194	141.103
1.4	523.239	32.283	139.758
1.5	524.369	30.576	138.224
1.6	524.707	29.042	136560
1.7	524.417	27.659	134.814
1.8	523.630	26.406	133.07
1.9	522.449	25.267	131.197
2.0	520.959	24.227	129.372
2.1	519.225	23.275	127.558
2.2	517.301	22.400	125.764
2.3	515.233	21.593	123.999
2.4	513.054	20.848	122.268
2.5	510.793	20.158	120.576
2.6	508.473	19.517	118.924
2.7	506.116	18.920	117.316
2.8	503.736	18.363	115.751
2.9	501.344	17.842	114.230
3.0	498.952	17.354	112.753
3.1	496.567	16.896	111.319
3.2	494.197	16.464	109.928
3.3	491.846	16.058	108.578
3.4	489.520	15.675	107.269
3.5	487.222	15.313	106.001
3.6	484.954	14.970	104.770
3.7	482.718	14.645	103.577
3.8	480.516	14.336	102.420
3.9	478.347	14.042	101.297
4.0	476.216	13.763	100.208

M = 1.46/year, Mean F^1 = 1.163, K = 0.81/year, $L\infty$ = 38.33cm, F_t =1.46/year, E^1 = 0.34

DISCUSSION

Recruitment is demonstrated with a graph that displays variation in intensity of recruitment with time. In this population there was one major and one minor recruitment peak in a year, and the two overlapped in time to give a continuous year-round pattern. As a general rule, if Z/K ratio <1, the population is growth-dominated, if it is >1, then it is mortality-dominated; if it is equal to 1, then the population is in equilibrium state where mortality balances growth (Barry & Tegner, 1989). In this study, Z/K was 4.86 indicating that the exploitation level was high. This recruitment pattern is typical of short-lived tropical fish species (King & Etim, 2004).

Estimates of probability of capture, Table 1, indicate that 25% (L_{25}) of the fish would be retained in the meshes of the gears if fish of 13.82cm is targeted and the remaining 75% escaped capture. Also if 15.50cm and 17.19cm were targeted 50% and 75% (L_{50} and L_{75}) would be retained respectively in the meshes of the gears used for fishing on the estuary. The L_{50} was referred to as length-at-first capture (L_c). Mess & Rousseau (1996) derived rules of thumb based on certain biological reference points that may be used as indicators of the need for management action. Where L_{50} is greater than Lm (length-at-first maturity) effort controls are less important and overfishing is unlikely to occur. In this study, L_{50} =15.50cm greater than L_m=10.23cm estimated by Abdul (2009) for *T. zillii* in the estuary. This therefore contradicts the estimate of exploitation rate, E given by Abdul (2009), which might have been overestimated from the value of total mortality, Z from the converted catch curve. Z was estimated by assuming that mortality was uniform with age and that the sample was representative of the age groups considered (Lablance & Carrara 1988).

Length–based virtual population analysis (VPA) or cohort analysis (LBCA) has been developed and used extensively (Pauly 1984, Galucci *et al*. 1996, Gayanilo & Pauly, 1997, Huiskes, 1998, Polacheck, *et al.,* 1998, Vaughan, *et al*. 1998). Pauly (1984) conducted some sensitivity analyses to test the robustness of the model. Despite the weakness of this model contrary to the age-based approach, Galucci *et al*. (1996) and Pauly (1984) discussed that the length-based is best for tropical fisheries. The results from VPA, Table 2, were used as input for yields, biomass, value predictions and estimation of maximum sustainable yield, maximum sustainable economic yield, MSE, together with corresponding f-factor and stock biomass (Sparre & Venema 1992; Gayanilo and Pauly, 1997).

The assumption in the analyses (VPA and prediction) is that the stock remains in a steady state, with all parameters (e.g. recruitment) except fishing mortalities are constant and do not change with fishing effort. This model could then be used to predict short and long-term by yield under different fishing patterns and varying effort, which might be changes in minimum mesh size, decreases or increases of fishing effort, or closed seasons. The underlying assumption of steady state is unrealistic considering inter and intra specific interactions that occur within the various stocks for spawning, feeding and breeding habitat in the estuary.

Various setbacks of these methods have been identified (Pauly, 1984, Gayanilo & Pauly, 1997). There include the guessed value of F_t (terminal fishing rate), bias in the estimation of $L\infty$ and K and the need for high F value to cover rapidly towards the "true" value. That is, low fishing pressures would produce unreliable estimates of yield. The mean E^1 and F^1 estimated from VPA were lower than the E and F estimated by ELEFAN sub – routines of FISAT II programme. This difference was probably due to the difference in the two methodologies. The F was estimated from the relationship of F=Z-M and E from the ratio of F and Z (F/Z ratio). The value of Z was variable depending on what portion of the length-converted catch curve is chosen to run the regression for Z. The alterative process of VPA was assumed to provide better estimates based on the directly estimated F^1 by length groups without an overall Z estimate.

The concept of the MSY has a long history in fisheries literature, particularly when stock assessment results have been applied to the problems of managing the fisheries (Gulland, 1968). But the main problem confronting fisheries management is what needs to be optimized? Sometime ago, the epitome of fisheries fashion was to achieve sustainable yield. Later, the alternative technology of maximizing economic returns was strongly advocated. But, recently, the aim has been to achieve optimum sustainable yield (Larkin, 1978).

Yield prediction based on the Thompson and Bell model is susceptible to error when the interactions between the various species in the water body were not taken into consideration. Therefore, Hay *et al.* (2000) suggested that it was necessary to develop adaptive management systems based on monitoring data with important parameters such as community and stock structures and life histories of important species.

Results from this study revealed that *T. zillii* has not been over exploited, E^1 = 0.34/year. The MSY of 524.707 x10^6tonnes was to be achieved when the current effort is raised by 60% (1.0-1.6) (Table 3).While MSE of N143.063billion would be achieved if the current effort level (1.0) was sustained. According to FAO (2006), a good stock assessment would not provide a single right answer, but should rather give a range of choices showing the predicted outcomes and any tradeoffs. The choice between such options should be made by fishery managers, not by stock assessment scientists, guided by their attitudes towards risk and the socio-economic priorities for the fishery. The fishery would be sustained economically if the present exploitation rate was sustained, but to balance growth with mortality, MSY could be a good reference point for management.

The "stock assessment process" goes as far as the provision of stock assessment advice. It may provide both short term (tactical) and the long term (strategic) management guidance. Short term advice might be on the size of the total allowable catch (TAC) next year; long term advice on whether a change in the overall management strategy could give better returns. Any increase in effort level might lead to profit levels that were below the desired maximum. This is referred to as economic overfishing. According to Israel & Banzon (2002), economic overfishing might be of the most interest to fisheries managers and planners because fisheries resources are primarily viewed as economic resources (i.e. generators of food and employment). At MSE, the standard economic condition for profit maximization is met (maximum economic rent, MER). If the fishery is efficiently run, fishing should stop at MSE where profits are at maximum. However, with complete open-access, fishing continues beyond MSE as more fishermen, motivated by profit, get into the fishery. This situation pushes the level of fishing to pass the economic optimum into the next optimum, the MSY, which is the biological optimum of the fishery. According to Isreal & Banzon (2002), at the MSY level, positive profits still exist as total revenue remains greater than total cost. This situation therefore would further induce fishing until, finally, the open access yield (OAY) is reached. At this point, positive profits are gone and, without any incentive to continue fishing, further fishing stops.

CONCLUSION

Investigation from this study showed that recruitment of *T. zillii* in the estuary is continuous with one major and one minor peaks annually. This population of fish is described as being mortality dominated which is a characteristic of a short-lived tropical fish species. Larger fish are more prone to capture by the various gears employed in the fishery to exploit the stock. At present, the fishery is at maximum economic yield and will attain maximum sustainable yield if the current effort is raised by sixty percent. It is therefore recommended from this study that effort be maintained at current level because any further increase will lead to MSY and consequently to what is described as open access yield, OAY which is deleterious to the sector economically

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