Mortality and Exploitation of *Penaeus monodon* in the Andoni River, Nigeria

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Abstract
The mortality and exploitation of the giant tiger prawn (*P.monodon*), an exotic shell fish species whose occurrence in Nigerian coastal waters was first reported in 1999 was investigated in the Andoni River, Nigeria from March 2012 to February, 2013. The stock was determined through data collected from artisanal fishers at Kaa water front on a monthly basis. The weight of each specimen was determined using Ohaus electronic weighing balance while length was measured with vernier caliper. FAO-ICLARM Fish Stock Assessment Tools II (soft ware) was used for data analysis. Population parameters showed that asymptotic length ($L\infty$) and growth rate (K) were 31.5cm and 0.870yr-^{1} respectively. Natural mortality (M) yr^{-1} was equal to 1.64302 while fishing mortality (F) yr^{-1} was 0.38698 and total mortality (Z) yr^{-1} equalled 2.03. The exploitation rate was 0.1906 while the allowable limit of exploitation (E_{max}) was equal to 0.421. The present value of exploitation ratio (E = 0.1906) was lower than that associated with the maximum relative yield per recruit (E_{max} = 0.421). The results indicate that *P. monodon* was under-fished. Consequently, fishing effort exerted on the stock can be increased by 100-120% of its current value to achieve the maximum yield per recruit.

Key Words: Mortality, Exploitation, Shrimps, Prospect, Niger Delta

1.0 Introduction

The invasion of the giant tiger prawn in the coastal waters of Nigeria in 1999 (FAO, 1999) was surrounded with superstitions as fishers wondered where such giant species of shrimps had emanated. No sooner than later the species gained acceptance and became an essential fishery resource in the Niger Delta. Few literature exist on the mortality and exploitation of the species in Nigeria, hence the need for the study. Earlier researches on shrimps reveal that the total mortality coefficients (Z) of shrimps in littoral marine waters of the Mekong Delta, south of Vietnam (using length-converted catch curves) varied from 1.49 to 5.78yr^{-1}. Their natural mortalities (M) ranged from 1.7 to 2. 61yr^{-1}, fishing mortalities (F) and exploitation rate varied from 0.22 to 3.78 yr^{-1} and 0.10 to 0.65 respectively (Dinh *et al*., 2010). Saputra (2010) reported total mortality Z = 8.190 yr^{-1}, natural mortality (M) = 1.430 yr^{-1}, fishing mortality (F) = 6.760 yr^{-1} and exploitation rate (E) = 0.830 for fine shrimp *Metapenaeus elegans* in Segara Anakan Lagoon. When exploitation E = 0.5 and above, the stock is described as over- exploited.

Total mortality coefficients (Z) of *Farfante penaeus notialis* in the Cross River estuary of Nigeria was reported to be 6.86 and 9.37 for 2007 & 2008 respectively while natural mortality (M) = 1.60 and 6.44 yr^{-1} for 2007 and 2008 seasons respectively (Nwosu 2009).

Natural mortality was the major cause of death in *P. gracillima* and *P. cultrirostris* (Dinh *et al.,* 2010) meanwhile predation was reported as the main cause of natural mortality in *F. notialis* as well as most aquatic life within the lower trophic levels (Nwosu 2009).

Between 1984 – 1987 in Bangladesh waters, male *P. monodon* recorded natural mortality (M) = 2.13, fishing mortality (F) = 5.93, total mortality (Z) = 8.06 yr^{-1} and exploitation rate (E) = 0.74. while female *P. monodon* recorded natural mortality (M) = 1.97, fishing mortality (F) = 2.68, total mortality (Z) = 4.65 yr^{-1} with exploitation rate (E) =0.58. Males of *P. semisulcatus* had natural mortality (M) = 2.31, fishing mortality (F) = 5.41, total mortality (Z) = 7.72 yr^{-1} and exploitation rate (E) of 0.70. On the other hand, females of *P. semisulcatus* had natural mortality (M) = 2.19, fishing mortality (F) = 3.81, total mortality (Z) = 6.00 yr^{-1} and exploitation rate of 0.63. *P. mergulensis* (males) had annual mortalities of 2.37, 5.01 and 7.38 yr^{-1} for natural, fishing and total mortalities respectively with exploitation rate (E) of 0.68.

Values for females of same species (*P. mergulensis*) were reported as 2.31, 2.03 and 4.34yr^{-1} for natural, fishing, and total mortalities respectively with exploitation rate (E) of 0.47.

Metapenaeus monoceros (males) was over exploited with exploitation rate of 0.58, natural mortality (M) = 2.59, fishing mortality (F) = 3.52 and total mortality (Z) = 6.11 yr^{-1}. Female *M. monoceros* had natural mortality (M) = 2.47, fishing mortality (F) =2.17 and total mortality (Z) =4.64yr^{-1} with exploitation rate (E) of 0.47 which is close to optimum exploitation rate of 0.50 (Khan *et al.,* 2003).

Nurul Amin *et al*., (2009) reported total mortality coefficient (Z) of *Acetes japonicus* to be 5.16 yr^{-1}. Using length converted catch curve, natural mortality (M) was estimated at 2.35 yr^{-1} and fishing mortality (F) = 2.81 yr^{-1} at an exploitation rate (E) of 0.54 indicating over exploitation.

P. semisulcatus in Bardawil Lagoon, Northern Sinai, Egypt showed males total mortality (Z) of 7.391 yr^{-1} and females (Z) = 6.253 yr^{-1}; Natural mortality for male was 1.956 yr^{-1} while that of female natural mortality (M) was 1.795 yr^{-1}. The corresponding fishing mortalities were F = 5.435 yr^{-1} and 4.458 yr^{-1} for males and females respectively. The exploitation rate was calculated to be 0.735 and 0.713 for males and females respectively. The above reported mortality values also exceeded Gulland (1971) optimum exploitation ratio (E_{opt}) = 0.5, which implied that *P. semisulcatus* was heavily exploited due to high fishing pressure exerted on the lagoon (Yassien 2004).

Lalitha (1987)'s survey of penaeid shrimp mortalities between 1979 and 1983 showed average total mortality of female *P. monodon* to be 5.12 yr^{-1}, natural mortality (M) = 2.02 yr^{-1} and fishing mortality (F) = 3.11 while average mortalities of male *P. monodon* were: total mortalities (Z) = 10.58 yr^{-1}, natural mortality rate (M) = 2.89 yr^{-1} and fishing mortality (F) = 7.69 yr^{1}. *P. monodon* (males) had exploitation rate (E) of 0.7262, and females were exploited at the rate (E) of 0.5897. Table 1 shows the mortality coefficient and exploitation rate of some shrimp species reported by other researchers.

2.0 Materials and Methods

2.1 The Study Area

The Andoni River is located between latitudes $4^{0}28'$ to $4^{0}45'$ N and longitudes $7^{0}45'$ E. It is a major fish breeding and nursery area in the Niger Delta region of Nigeria on the West coast of Africa. (fig 1).

2.2 Data Collection and Fishing Operation

Usually, the fishers set out to the fishing ground (Plate 1) as soon as the tide begins to ebb which may occur during the early hours of the morning, afternoon or late in the night. They return from fishing grounds to land catches as the flood tide sets in. Ebbing and flood tide duration are six hours each. It takes six hours before the flood reaches its maximum height by which time all the fishers must have returned from their fishing operations. The gravitational pull of the moon on the earth and tide are responsible for these cycles (Libini and Khan 2012; Francis 2003).

2.3 Weight Measurement

The weight of each specimen was determined using Ohaus electronic weighing balance as shown on plate 2. Measurement of weight of the shrimp was done by zeroing the weight of a plastic bowl and then placing the specimen in the bowl. Weight was measured in grams.

2.4 Length Measurement

Total length (distance from tip of rostrum to the tip of telson), of each shrimp of the sub-sample were measured using a digital vernier caliper and transparent plastic ruler as shown on plate 3. Measurement of lengths was recorded in centimeter.

2.5 Mortality Rate

The catch curve method Pauly (1983) was used in estimating the total mortality (Z) of the shrimps. This method involved plotting the natural logarithms of the shrimps in various age groups (N) against their corresponding relative age t. Total mortality (Z) will then be obtained from the slope (b) of the descending part of the curve after it has been fitted with a regression line. The equation of the line was then derived from the equation.

Log N = a+ bt …………………………..…………………… …………………(1)

where;
a = Y intercept
b = Slope
t = Relative age
N = Age

Only those values of logN which pertain to the age of the shrimps that were identified as fully vulnerable to the gear were included in the calculation of the linear function. Fishing mortality co-efficient (F) was estimated as:

F = Z – M…………………………………………………………………… .(2)

where;
Z = Total mortality
M = Natural mortality
F = Fishing mortality

Natural mortality (M) was estimated using Pauly's (1980) empirical formula that integrates mortality and size, using the mean temperature (29.4°C) of Andoni River system.

$$Log_{10} M = 0.0066 - 0.279 \, Log_{10} L_{\infty} + 0.6543 \, Log_{10} K + 0.4634 \, Log_{10} T \quad \text{……..(3)}$$

Where:

M = Natural mortality
L∞ =Asymptotic length (i.e., possible length)
K = Growth co-efficient
T = Mean temperature of Andoni River System
Note that:
Z = F + M
The catch curve method has also been incorporated into the FiSAT computer programme (Gayanilo and Pauly, 1997) hence Z was obtained through the computer package.

2.6 Exploitation Rate

Exploitation rate (E) of the shrimps was determined as suggested by Pauly, (1983):

$$E = \frac{F}{Z} \qquad \text{……………………. ……………………. ……………………. (4)}$$

where;
F = Fishing mortality co-efficient
Z = Total mortality co-efficient
E = Exploitation rate
Exploitation rate helps to determine whether or not a fish stock is over-exploited, that is overfished. This is based on the assumption that optimal exploitation (Eopt) value is 0.5. Optimal exploitation value of 0.5 is on the assumption that sustainable yield is optimized when F=M (Pauly 1983, Francis 2003).

2.7 Statistics Analysis

The FAO-ICLARM Stock Assessment Tools 2 (soft ware) a certified tool for the analysis of fish and fisheries data was used.

3.0 Results

3.1 Mortality Rate

Natural mortality (M) was estimated using Pauly's (1980) empirical formula that integrates mortality and size, using the mean temperature of Andoni River system.
The asymptotic length (L∞) was equal to 31.50cm at a growth rate (K/yr) of 0.870 and mean temperature of 29.4^{o}C. Natural Mortality (M) equals to1.64302. Total Mortality Coefficient (Z) was computed using Length-Converted Catch Curve routine (fig.2) with L∞ = 31.50cm, K =0.870/yr. Total Mortality Coefficient **(Z) = 2.03.**

From the value of Z obtained by Length converted catch curve, **fishing mortality was calculated to be 0.38698.**
Fig.3: Showed that survivors of *P.monodon* in the Andoni River System was in descending order of length groups(cm) 10.0 > 15.0 > 20.0 > 25.0 > 30.0 while natural losses(natural mortality) was highest in length group 10.0cm, lowest in length group 20.0cm and absent in length group 25cm and 30cm. Fishing mortality (Catches) was highest in length group 20.0cm

3.2 Exploitation

From Pauly's (1980) empirical formula, natural mortality (M) =1.64302/year.
From Berveton and Holt Model, total mortality (Z) = 2.03/year. Therefore fishing mortality (F) equals 0.38698/year and exploitation rate (E) = 0.38698/2.03 **= 0.1906,** which is approximately **0.2.**

The exploitation rate of *P. monodon* caught from the Andoni River System, Niger Delta of Nigeria was approximately 0.2 which is lower than both the allowable limit of exploitation (E_{max}= 0.421) and the optimum level of exploitation (E = 0.50).

Using the Knife-edge procedure (fig.4), the relative yield per recruit (Y/R) and biomass per recruit (B/R) analysis of *P. monodon* of the Andoni River System was computed. The maximum allowable limit of exploitation level (E_{max}) that gives the maximum relative yield per recruit was estimated at 0.421. The exploitation level ($E_{0.5}$) which corresponds to 50% of the relative biomass per recruit of the unexploited *P. monodon* was estimated at 0.278. Meanwhile, the level of exploitation ($E_{0.1}$) at which the marginal increase in relative yield per recruit is 10% was estimated at 0.355.

The present value of exploitation ratio (E = 0.1906) was lower than that associated with the maximum relative yield per recruit (E_{max} = 0.421). This implies that fishing effort exerted on *P. monodon* at the Andoni River system can be increased by 100-120% of its current value to achieve the maximum yield per recruit of 0.062)at a biomass per recruit of 0.50.

4.0 Discussion

4.1 Mortality and exploitation rate

The natural mortality of *Penaeus monodon* in the Andoni River system with an average temperature of 29.4°C was estimated to be 1.64. Fishing mortality (F) and total mortality (Z) were 0.39 and 2.03 respectively. The implication of the higher natural mortality over fishing mortality is that, this shell fish (*Penaeus monodon*) gets wasted naturally, which could have be harvested sustainably for socio-economic empowerment and development of coastal communities. The present low exploitation rate (0.19) was as a result of low fishing mortality. Fish predation is a factor that may have contributed to the observed high natural mortality (Aleleye-Wokoma and Woke, 2007).

Optimum level of exploitation (E_{opt}) is 0.5 beyond which stock is said to be over-exploited. The present studies on *P. monodon* shows that the stock is under-exploited. Saputra (2010) reported fishing mortality ($F=6.760yr^{-1}$) natural mortality (M=1.430), total mortality ($Z=8.190yr^{-1}$) and exploitation rate (E=0.8830) of *Metapenaeus elegans* which indicated over exploitation of the stock.

Nwosu (2009) reported over exploitation of *P. notialis* with E=0.77 in 2007 and 0.69 in 2008. Most species of penaeid shrimps are over fished (Lalitha, 1987; Yassien, 2004, Nurul Amin *et al.,* 2009; Khan *et al*., 2003). However, female *P. mergulensis* and female *Metapenaeus monoceros* were reported to be close (E=0.47) to optimum exploitation value of 0.5 (Khan *et al*., 2003). Dinh *et al.* (2010) recorded seven species of shrimps that were under-exploited in Mekong Delta Vietnam. Exploitation varies with species, fishing effort and fishing locality. The exploitation rate of *P. monodon* in Andoni River system is useful for management purposes. Intensifying fishing effort will balance loss through natural mortality.

Survivors rate in the Length-based Virtual Population Analysis was in the length group order of 10cm >15cm >20cm>25cm>30cm. Fishing mortality was greatest in length group >15cm<25cm while natural losses were highest in length group 10cm followed by 15cm.

4.2 Contribution to Socio-economic Development

The only country that exports *P. monodon* from West Africa is Gambia, and since it is under exploited here, large scale harvest from the wild can be encouraged for export. The export will contribute to food and nutrition security in addition to contributing to other aspects of socio-economic development, especially in terms of providing employment, income and foreign exchange earnings. Khan and Latif (2003) reported *P. monodon* as one of the most significantly occurring species in Bangladish estuary having asymptotic length of 31.36cm, growth coefficient 0.72 and natural mortality of 1.423 against a very high fishing mortality of 8.377 and exploitation rate of 0.855; indicating a highly over exploited resource. On the contrary, *P. monodon* in Andoni River, presently, is under-exploited, thus highlighting its prospects for socio-economic development.

5.0 Conclusion

The higher value of natural mortality of the giant tiger prawn in Andoni River over the fishing mortality implies under-exploitation of this prawn. Predation and other anthropogenic activities especially from crude oil business could be responsible for such high natural mortality. To achieve maximum sustainable harvest in the River, the exploitation rate can be increased by 100 to 120% of current exploitation rate. The giant tiger prawn (*P. monodon)* being under-fished, presents a prospect for profitability through investment in the fishery. The government and private investors can seize the opportunity to create wealth and job for the coastal dwellers by establishing industries relating to its responsible harvest and post harvest processes. Sustainable exploitation of the fishery resource will increase the country's foreign exchange and the nation`s GDP.

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Table 1: Mortality coefficient and exploitation rate of some Shrimps

S/N	Species	Location	Natural mortality (M)yr^{-1}	Fishing mortality (F)yr^{-1}	Total mortality (Z)yr^{-1}	Exploitation rate (E)	Reference
1.	*Penaeus monodon (F)*	Kakinada India	2.02	3.11	5.12	0.5897	Lalitha (1987)
2.	*Penaeus monodon (M)*	-do-	2.89	7.69	10.58	0.7262	
3.	*Metapenaeus monocerus (F)*	-do-	1.84	3.65	5.49	0.6481	-do-
4.	*M. monocerus (M)*	-do-	1.81	6.17	7.98	0.7716	-do-
5.	*M. dobsoni (F)*	-do-	3.44	9.28	12.72	07289	-do-
6.	*M. dobsoni (M)*	-do-	2.54	9.97	12.51	0.7964	-do-
7.	*P. semisulcatus (M)*	Northern Sinai Egypt	1.956	5.435	7.319	0.735	Yassien (2004)
8.	*P. semisulcatus (F)*	-do-	1.795	4.458	6.253	0.713	-do-
9.	*Acetes japonicas*	Malacca Peninsular Malaysia	2.35	2.81	5.16	0.54	Nurul Amin *et al*., (2009)
10.	*P. monodon (M)*	Bangladesh	2.13	5.93	8.06	0.74	Khan *et al*. (2003)
11.	*P. monodon (F)*	-do-	1.97	2.68	4.65	0.58	-do-
12.	*P. semisulcatus (M)*	-do-	2.31	5.41	7.72	0.70	-do-
13.	*P. semisulcatus (F)*	-do-	2.19	3.81	6.00	0.63	-do-
14.	*P. mergulensis (M)*	-do-	2.37	5.01	7.38	0.68	-do-
15.	*P. mergulensis (F)*	-do-	2.31	2.03	4.34	0.47	-do-
16.	*Metapenaeus monocerus (M)*	-do-	2.59	3.52	6.11	0.58	-do-
17.	*M. monocerus (F)*	-do-	2.47	2.17	4.64	0.47	-do-
18.	*Haliporodes sibogae*	Mekong Delta Vietam	1.88	0.39	2.27	0.17	Dinh *et al*. 2010
19.	*Harpiosquilla harpax*	-do-	1.80	1.43	3.23	0.44	-do-
20.	*Metapenaeus affinis*	-do-	2.00	3.78	5.78	0.65	-do-
21.	*M. brevicorats*	-do-	1.93	1.42	3.35	0.42	-do-
22.	*M. temuipes*	-do-	1.83	0.91	2.74	0.33	-do-
23.	*Parapenaeopsis cultrirostris*	-do-	1.17	0.32	1.49	0.21	-do-
24.	*P. gracillima*	-do-	2.07	0.22	2.29	0.10	-do-
25.	*P. maxillipedo*	-do-	2.61	2.27	4.88	0.47	-do-
26.	*Farfantepenaeus notialis*	Cross River Nigeria	1.60	5.26	6.86	0.77	Nwosu (2009)
27.	*F. notialis*	-do-	1.54	6.44	9.37	0.69	-do-
28.	*Metapenaeus elegans*	Segara Anakan Cilacap Central Java	1.430	6.700	8.190	0.830	Saputra (2010)
29.	*P. monodon*	Andoni River System Nigeria	1.64302	0.38698	2.03	0.1906	Present study

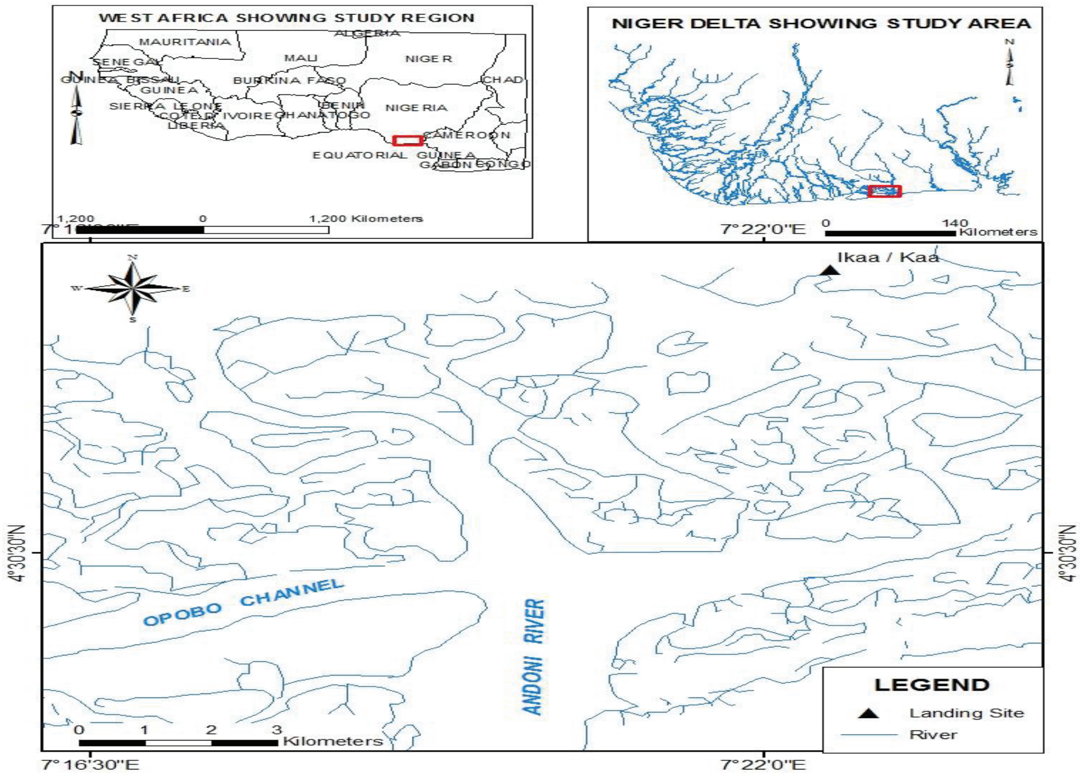

Fig. 1 Map of Andoni River, Southern Nigeria

PLATE 1: Artisanal fishers at Andoni River System, Southern Nigeria

PLATE 2: DETERMINATION OF SAMPLE WEIGHT USING OHAUS ELECTRONIC WEIGHING BALANCE


PLATE 3: RESEARCHER TAKING MORPHOMETRIC MEASUREMENT OF SAMPLES

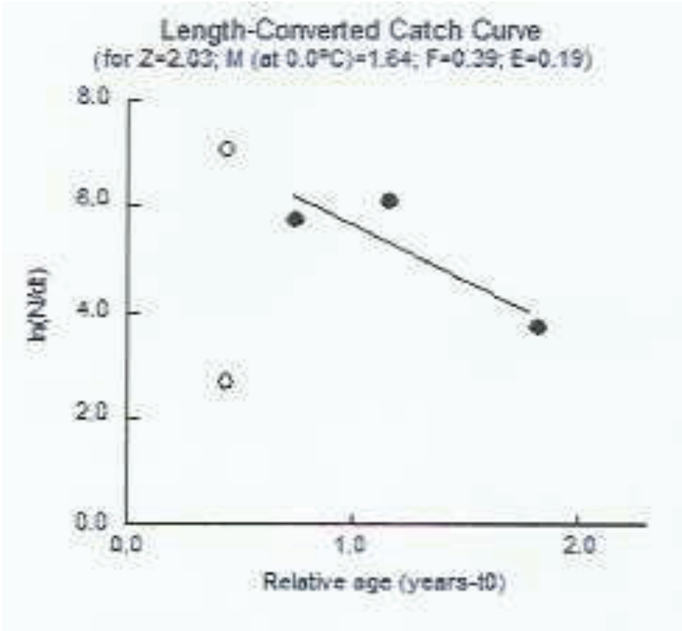

Fig. 2: Length-converted catch curve of *P. monodon* in Andoni River System.

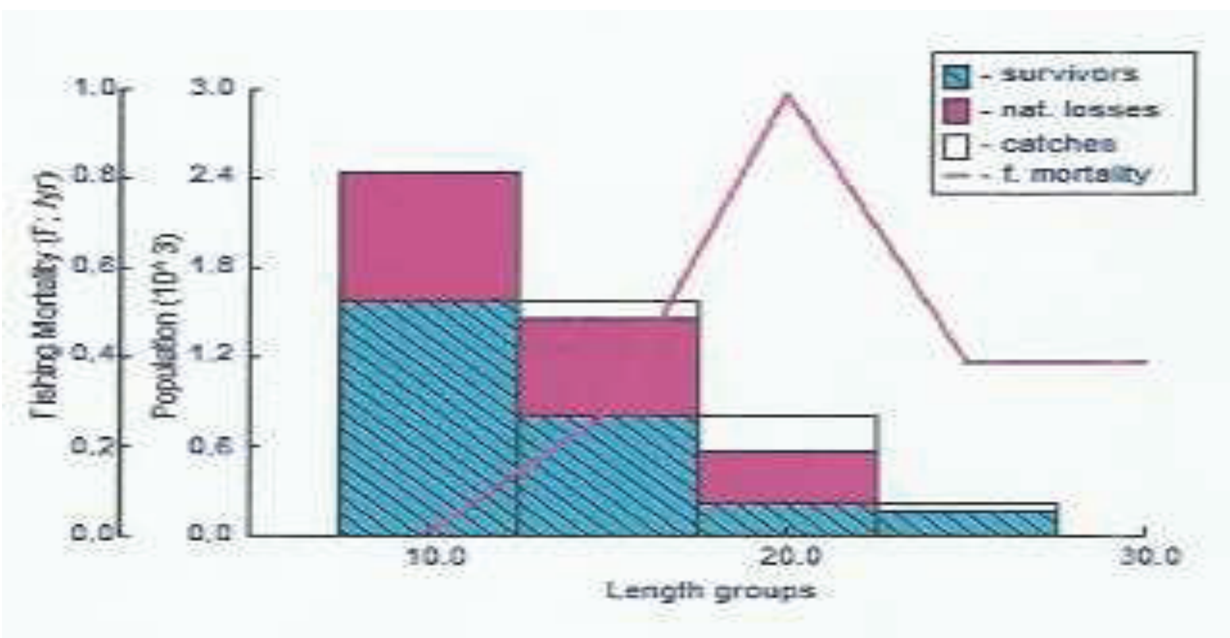

Fig. 3: Length based Virtual Population Analysis of *P. monodon* in the Andoni River System

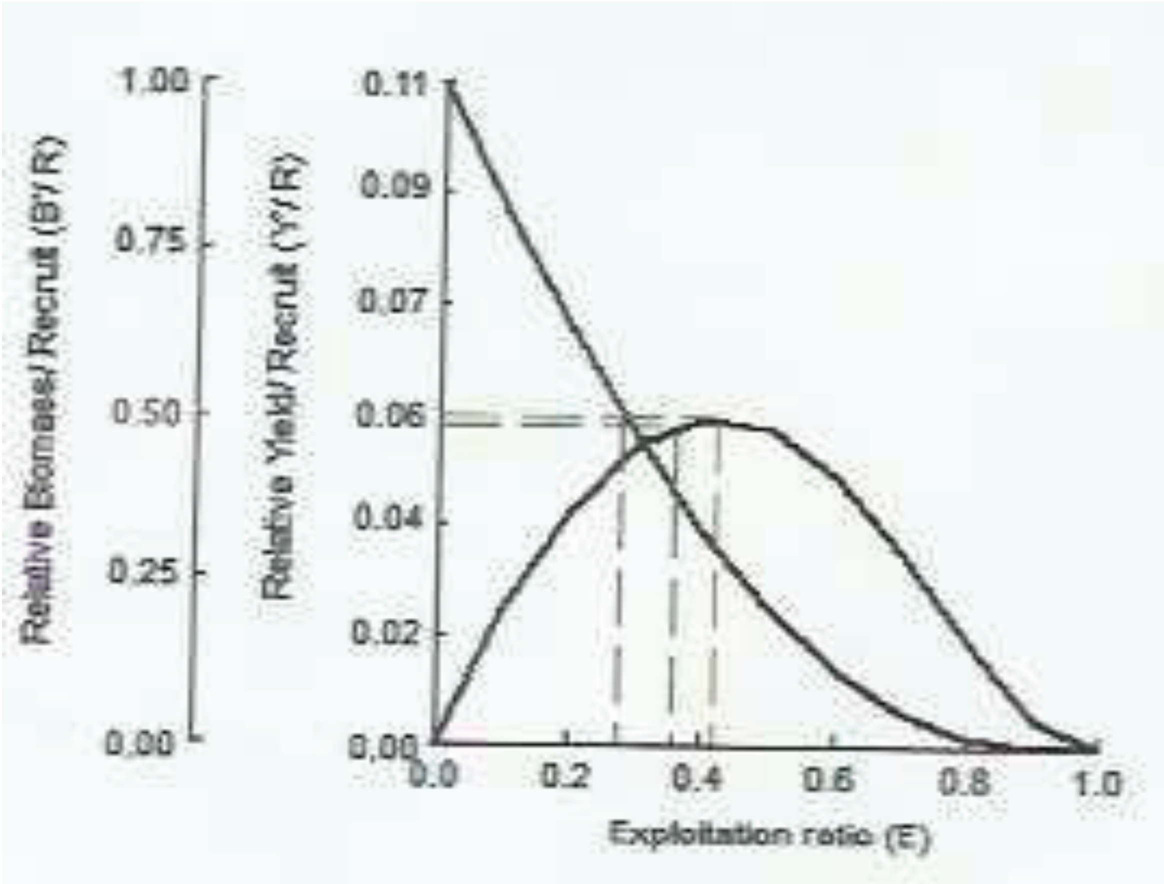

Fig. 4: Relative Y/R and B/R analysis of *P. monodon* of the Andoni River System