Recruitment pattern and catch per unit effort of the Black Tiger Shrimp (*Penaeus monodon*) in Andoni River System, Niger Delta Region of Nigeria

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The investigation of recruitment pattern and catch per unit effort of the black tiger shrimp (*Penaeus monodon*) was conducted from March 2012 to February 2013 in Andoni River System, Niger Delta region of Nigeria. Total weight and length of sampled *P. monodon*, number of fishers, fishing duration and temperature were sampled monthly. Total weight of *P. monodon* landed, number of fishers and fishing duration was used to determine catch per unit effort in kg/man/h. The recruitment pattern was analyzed using the length frequency data of the stock. The result shows that recruitment pattern was continuous and higher during the rainy season, that is from May to October. Catch per unit effort was lowest (46.09Kg/man/h) in January and highest (78.11 kg/man/h) in September. Mean temperature ranged from 27±0.32°C to 31±0.89°C which was suitable for the stock. A positive moderate correlation existed between recruitment and catch per unit effort (r = 0.50056) while a positive weak correlation occurred between recruitment and temperature (r = 0.21102). It is concluded from the study that a rise in the recruitment of *P. monodon* translated into a rise in catch per unit effort and that temperature was not the only factor necessary for recruitment.

**Key words:** Shrimp, recruitment, catch per unit effort (CPUE), Andoni River, *Penaeus monodon*, Nigeria.

**INTRODUCTION**

It is popular that changes in shrimp populations are primarily driven by variability in recruitment—a concept that is defined as the number of shrimps surviving to enter into the fishery or that has grown to maturity which eventually can be harvested at the fishing ground. Recruitment is influenced by the number of offspring produced as well as the effect of density independent (temperature and food condition) and density dependent (competition for food or refuge) factors which occur at different pre-recruit stages (Pablo and Bodmer, 2004).

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Recruitment, being a determining factor on the abundance of a species, influences the efforts exerted by shrimpers in catching the target species of shrimp. Hence, catch per unit effort (CPUE) in fisheries and conservation biology is an indirect measure of the abundance of a target species; and changes in the catch per unit effort are inferred to signify changes to the target species’ true abundance (Pablo and Bodmer, 2004). There is paucity of knowledge on how recruitment of the black tiger shrimp relates with CPUE and temperature largely for the fact that the species is none native to Andoni River systems and such study had never been conducted. This correlation study intends to unravel the underlying relationships. Therefore the study provides a baseline data for the exotic Penaeus monodon in Andoni River Systems, Niger Delta region of Nigeria.

The black tiger shrimp (P. monodon) is a marine crustacean that is highly reared for food (FAO, 2011). It is an invasive species to Nigerian coastal water, first reported in 1999 by a trawl fishing company (FAO, 2000). The natural distribution is Indo-West-Pacific, ranging from the eastern coast of Africa, the Arabian Peninsula, South-east Asia and the sea of Jordan as well as eastern Australia and the Mediterranean Sea. Further invasive populations have become established in Hawaii and the Atlantic coast of the USA – Florida, Georgia and South Carolina (Suthep, 2015; Fuller et al., 2014).

The limitations in this study lie in the assumptions that all shrimp/fish in a given set of data grows as described by a single set of growth parameters; that recruitment occurs in eleven months only, in a-twelve-month data sampling (Pauly, 1986; Gayanilo et al., 1989). Furthermore, sample collection was not replicated to necessitate mean and standard error, and that all artisanal shrimpers operate four active boat days (being the average number of fishing days in a week). When recruitment is juxtaposed with fishing effort otherwise referred to as catch per unit effort, (described in terms of quantity of fish landed by a fisherman over a specified time) an idea of the abundance of the stock, and productivity of a river can be revealed. However, productivity of a river is not in isolation of physical properties such as temperature of the river.

Water temperature is critical in aquatic ecosystems. It limits the migration, spawning, egg incubation, growth and metabolism of aquatic organisms (Kelly and Linda, 1997). The Andoni River, being a system of flowing river tributaries, maintain a suitable surface water temperature for P. monodon at the fishing grounds, though it is not clear what relationship exists between recruitment and temperature of the River. Most aquatic organisms are exothermic and are not able to control their body temperature except by behaviour such as temperature selection. Metabolic rate increases two or four fold for every increase of 10°C (Waterwatch/Namoi CMA, 2013). Increased metabolic rate leads to higher oxygen consumption and waste production of CO₂ and ammonia. Temperature is therefore a significant physical property of water because it affects the amount of dissolved oxygen in the water. Water at 0°C will hold up to 14.6 mg/L while at 30°C it will hold only up to 7.6 mg/L (Waterwatch/Namoi CMA, 2013).

Temperature also affects the rate of photosynthesis of plants, the metabolic rate of aquatic animals, rates of development, timing and success of reproduction, mobility, migration patterns and the sensitivity of organisms to toxins, parasites and disease. Life cycles of aquatic organisms are often related to changes in temperature (Water watch/Namoi CMA, 2013).

As with dissolved oxygen, each aquatic organism has an optimal temperature range for its metabolism. Warmer water promotes higher metabolism and respiration rates. Water temperature indirectly affects lake by influencing the dissolved oxygen concentration. Warm water has less dissolved oxygen than cold water (Water watch/Namoi CMA, 2013; Kelly and Linda, 1997).

This paper therefore aims at filling the knowledge gap on how recruitment of the black tiger shrimp relates with CPUE and temperature in Andoni River Systems, providing a baseline data for the exotic P. monodon in Andoni River Systems of Niger Delta region of Nigeria.

MATERIALS AND METHODS

Study area

The Andoni River system (Figure 1) lies between latitudes 4°28’ to 4°45’ N and longitudes 7°45’ E. It is a major fish nursery in the Niger Delta region of Nigeria, West coast of Africa (Francis, 2003) most probably due to the abundance of mangroves within this brackish water ecosystem.

The climate of the Andoni area consists of a long wet season which stretches from April to October and a short dry season from November to March dotted with rains. Ebbing and flood tide durations within aquatic system are six hours each. The fishers use tide movement to aid their transport during fishing since they primarily use dugout canoe (unmotorized) in fishing. The Andoni River is brackish with annual salinity range of 10 to 28% (Yoloye, 1976), 5 to 22% (Francis, 2003).

Nypa fruticans (an exotic palm), Rhizophora mangle (Red mangrove) and Avicenia marina (white mangrove) and flood plains border the river and its numerous creeks and tributaries and these are well exposed at low tides. The Andoni River system has two main landing sites viz; Kaa water front and Oyorokoto fishing settlement. Kaa water front is located between 4°33.915’N to 4°34.248’N and 7°21.746’E to 7°22.637’E (Figure 1). Kaa (Ika) fish market is the major point of sales of live, fresh and smoked fish products.
Research design

Landing survey, otherwise known as catch assessment survey described by Stamatopoulos (2002) was conducted at Kaa landing site once in every first week of the month for a period of twelve months (from March, 2012 to February, 2013). The data collected included quantity of catch, species composition, associated effort, and other secondary data such as prices, weight and length of the black tiger shrimp landed (Sobo, 2004).

Recruitment pattern

In determining the recruitment pattern of the black tiger shrimp, length-frequency data was produced from the recorded individual weight and total length of the species and used. The length – frequency data collected from sub-sample of P. monodon landed by artisanal fishers of the Andoni River system at Kaa landing site and representative of whole catch were subjected to recruitment procedure. FAO-ICLARM Stock Assessment Tool (FISAT II), a program package developed mainly for analysis of fishery data, was used. The recruitment routine in FISAT was employed for the estimation of the recruitment pattern using the number of recruitment pulses per year and evaluating the importance of this pulses when compared to each other.

The recruitment patterns were analyzed using NORMSEP (SEParation of the NORMally distributed components of length-frequency samples) to fit into Gaussian distribution on length-frequency data for the year, pooled together as described by Pauly (1983), Moreau and Cuende (1991) and Gayanilo and Pauly (1997).

Catch Per Unit Effort (CPUE)

In determining the catch per unit effort of the black tiger shrimp landed in Kaa water front (landing site) of Andoni River system, the daily catch landed were weighed using a weighing balance and measured in kilogram. The numbers; of fishing communities, boats, fishers and fishing duration were noted.

Twenty-five fishing communities land their catches at Kaa water side each day of the survey. An average of seven boats go fishing from each of the fishing communities. Number of boats that land shrimp per day equal 25x7=175 boats. Each boat was operated by two shrimpers; therefore the total numbers of shrimpers per day equals 175x2=350, meanwhile shrimpers spend an average of eight hours for actual fishing of P. monodon, this happened by the early hours of the morning and late evening depending on tidal movement (Awajikarem, Andoni fisherman, personal Communication). Catch per unit effort was determined by dividing the total monthly catch by the effort (number of fishers per boat) and by the number of hours of fishing.

\[
\text{CPUE} = \frac{\text{Total catch}}{\text{number of fishers/fishing hours}}
\]
CPUE=kg/man/h (King, 1995; Francis, 2003). This formula was multiplied by four days being the average number of fishing days in a week and further multiplied by four weeks being the average number of weeks in a month as estimated by artisanal fisher folks.

Therefore,

Monthly Catch per unit effort (MCPUE) = (kg/man/h) x 16

Where M = monthly active boat days = 16 (number of active boat days),
kg = Weight of black tiger shrimp landed
Man = No. of fishers involved
h = fishing hour.

Temperature

A total of five sampling stations were established and their water temperature determined using Mercury-in-glass Celsius Thermometer with the probe inserted into the river; and the value at the pointer of the scale was read off and recorded. Units were in degree Celsius (°C).

Correlation analyses

Correlation between recruitment and catch per unit effort as well as between recruitment and temperature was determined using 2007 micro soft excel package.

RESULTS

Recruitment pattern

There was all-year-round recruitment (Figure 2) of the black tiger shrimp with peak during the rainy season from May to September, though the rate of recruitment over the period of study does not automatically determine the catch per unit effort of the fishers but (recruitment and CPUE) were both higher during the rainy season and lower in dry season. The highest catch per unit effort was recorded during the rainy season from May to October with a value of 78.11 kg/man/h in September while 46.09 kg/man/h was the least recorded and it was in the month of January. The percentage recruitment of *P. monodon* into the fishing ground was lowest (0.61%) in March 2012 and highest (28.41%) in June 2012. The recruitment pattern (Figure 2) can be described to be continuous with a single peak in June. The absence of replicated monthly data of tiger prawn landed limits the calculation of monthly mean and standard error, however, Figure 2 shows the trend of recruitment over a period of twelve months.

Catch per unit effort

There were an average of 350 artisanal shrimp fishers, fishing for an average of 8 hrs on each active boat day (4 active boat days per week) in the Andoni estuaries. The highest catch per unit effort was recorded in September with a value of 78.11 kg/man/h while 46.09 kg/man/h (Table 1) was the least recorded for the month of January.

Temperature

The highest temperature 31± 0.89°C was recorded in
Table 1. Catch data of *P. monodon* of the Andoni River system (March 2012 to February 2013).

<table>
<thead>
<tr>
<th>Month</th>
<th>Catch per Month (kg/month)</th>
<th>MCPUE (kg/man/h)</th>
<th>Catch per day (kg/day)</th>
<th>DCPUE (kg/man/h)</th>
<th>Catch in ton/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012 March</td>
<td>2625.41</td>
<td>60.01</td>
<td>164.09</td>
<td>3.75</td>
<td>2.63</td>
</tr>
<tr>
<td>2012 April</td>
<td>3148.48</td>
<td>71.97</td>
<td>196.78</td>
<td>4.49</td>
<td>3.15</td>
</tr>
<tr>
<td>2012 May</td>
<td>3201.44</td>
<td>73.18</td>
<td>200.09</td>
<td>4.57</td>
<td>3.2</td>
</tr>
<tr>
<td>2012 June</td>
<td>3330.37</td>
<td>76.12</td>
<td>208.15</td>
<td>4.76</td>
<td>3.33</td>
</tr>
<tr>
<td>2012 July</td>
<td>3252.91</td>
<td>74.35</td>
<td>203.31</td>
<td>4.65</td>
<td>3.25</td>
</tr>
<tr>
<td>2012 August</td>
<td>3112.32</td>
<td>71.14</td>
<td>194.52</td>
<td>4.45</td>
<td>3.11</td>
</tr>
<tr>
<td>2012 September</td>
<td>3417.28</td>
<td>78.11</td>
<td>213.58</td>
<td>4.88</td>
<td>3.42</td>
</tr>
<tr>
<td>2012 October</td>
<td>3229.28</td>
<td>73.81</td>
<td>201.83</td>
<td>4.61</td>
<td>3.23</td>
</tr>
<tr>
<td>2012 November</td>
<td>2276.96</td>
<td>52.04</td>
<td>142.31</td>
<td>3.25</td>
<td>2.28</td>
</tr>
<tr>
<td>2012 December</td>
<td>2421.44</td>
<td>55.35</td>
<td>152.34</td>
<td>3.46</td>
<td>2.42</td>
</tr>
<tr>
<td>2013 January</td>
<td>2016.67</td>
<td>46.09</td>
<td>126.04</td>
<td>2.88</td>
<td>2.02</td>
</tr>
<tr>
<td>2013 February</td>
<td>2305.41</td>
<td>52.69</td>
<td>144.09</td>
<td>3.29</td>
<td>2.31</td>
</tr>
<tr>
<td>TOTAL</td>
<td>34337.97</td>
<td></td>
<td></td>
<td></td>
<td>34.35</td>
</tr>
</tbody>
</table>

MCPUE = Monthly catch per unit effort, DCPUE = Daily catch per unit effort. The mean and standard error of data were not calculated since data was collected from one landing site (Kaa water front) and once a month but for temperature, mean and standard error were calculated because water quality was analyzed at five sampling stations.

September and the least 27± 0.32°C in August (Figure 3). Fluctuation was higher in the rainy season and relatively stable during dry season. The temperature range was within acceptable WHO (2006) and FEPA (1991) limits.

**Correlation analyses**

The correlation between percentage recruitment and monthly Catch per unit effort (MCPUE) of *P. monodon* in
Andoni River system (Figure 4) showed that there was a linear relationship between both parameters. The coefficient of correlation (r) being 0.5, indicated a moderate positive correlation but a weak positive correlation (r = 0.2) occurred between temperature and recruitment.

In a similar vein, the correlation between temperature and percentage recruitment (Figure 5) was positive, suggesting that as temperature rose within acceptable range for shrimp growth, percentage recruitment equally rose. The correlation coefficient (r) being 0.2 showed a weak positive correlation between both parameters indicating that temperature was not a major factor that influences recruitment.

**DISCUSSION**

**Recruitment pattern**

The recruitment of *P. monodon* can be described to be continuous with only one peak in June. This corresponded to the findings of Amin et al. (2009) who reported the highest recruitment of *Acetes japonicus* in
the coastal waters of Malacca between April and June. Dinh et al. (2010) recorded recruitment of eight shrimps species, having single peak; in May for *Haliporodes sibogae* and *Parapenaeus gracilimma*; in June for *H. harpax, Metapenaeus affinis* and *M. tenuipes* while *M. breviconis* had its peak in July. *Parapenaeus cultirostris* and *P. maxillipedo* were at their peaks in August; all having their peak during the rainy season which is in consonance with the result of the current study.

The trend of recruitment of *P. monodon* in the Andoni river system also shows seasonality. Recruitment increased to its highest value of 28.41% in the first three months of the rainy season and declined steadily in the dry season to its least value of 0.61%. It is phenomenal that one month out of the twelve months be assumed to be zero (0) recruitment (Gayanilo et al., 1989). Amin et al. (2009) also recorded least recruitment of 0.37% in the dry season. Low recruitment of the invasive black tiger shrimp during the dry season can be attributed to plankton availability (Oketoki, 2015). Shrimp fishers therefore, are likely to have better livelihood due to bumper harvest during the rainy season.

In literature, the recruitment of *A. japonicus* in the coastal waters of Malacca was described to be continuous throughout the year indicating one major peak. The highest recruitment peak occurred between April and June (Amin et al., 2009). The least percentage recruitment was 0.37% in November and highest was 27.47% in May (Amin et al., 2009). The study in the Mekong River Southeast Asia further revealed that during rainy season from May to August, estuarine ecosystem provided a habitat for nursery of shrimps and other aquatic organisms (Dinh et al., 2007). Francis and Sikoki (2005) reported recruitment pattern in Andoni River system to be higher from May to October (which coincided with the rainy season) and low in dry season. This agrees with the findings in the current study. The trajectory of recruitment pattern suggests that more *P. monodon* migrate to fishing grounds during the raining seasons. This suggests that the rains wash off food through water runoff or erosion and increase plankton growth for the shrimps during the rainy seasons.

**Catch per unit effort**

Catch per unit effort was higher during the rainy season (March to October) and declined in dry season (November to February/March). It is however not clear why the month of peak recruitment was different from CPUE peak. This calls for further research. Daily CPUE of *P. monodon* in Andoni estuary ranged from 2.88 to 4.88 kg/man/h. Khan et al. (2003) however, reported CPUE ranging from 0.22 to 16.23 kg/h\(^{-1}\) though only the weight (Kg) and fishing duration (hr) were considered. The relatively higher CPUE of *P. monodon* is indicative of its abundance in the Andoni River system.

Catch per unit effort (CPUE) on the other hand is important in determining maximum sustainable yield, potential yield and abundance of a species (Francis, 2003). Many inshore waters of West African coast are rich in fisheries resources on a commercial scale (Tobor, 1991) including shrimps.

Khan et al. (2003) reported the highest mean catch per unit effort as 16.23 kg\(^{-1}\) and the least 0.22 kg\(^{-1}\) of shrimps between 1985 and 1987. *P. monodon* was 0.40 kg\(^{-1}\); *P. merguiensis* was 0.03 kg\(^{-1}\) while *P. semisulcatus* recorded 0.09 kg\(^{-1}\). Catch per unit effort varied among species from 1.94, 0.01, 0.34, 0.04, 0.13 and 1.64 kg\(^{-1}\) for *Metapenaeus monoceros, M. spinulatus, Parapenaeopsis stylifera, P. indicus, M. brevicornis* and other shrimp respectively.

**Temperature**

Andoni River system maintained a temperature range of 27±0.3 to 31.8±0.95°C, typical of tropical estuarine water. Earlier researchers had reported 26.2 to 32.4°C (Ansa et al., 2007) and 26.05 to 32.1°C on the same Andoni Estuary. Temperature influences migration, spawning, egg incubation, growth and metabolism of aquatic organisms (Kelly and Linda, 1997). The temperature of Andoni River system is favourable to the growth and metabolism of *P. monodon*, hence their adaptation and seeming prolific nature in their new environment. This finding is in consonance with research work in Niger Delta by earlier authors, including, Zabbe, Sikoki and Zabbe (2006), Jamabo (2008), Ansa et al. (2007) reported temperatures of 26.2 to 32.4°C in Andoni flats of Niger Delta. Francis et al. (2007) who also worked on Andoni River system reported a temperature range of 26.05 to 32.1°C.

**Conclusion**

Recruitment being continuous with a single peak is a good index for fisheries management as this will enable law makers to make informed decisions on when to impose a closed season, that is when shrimp fishers will not be allowed to fish. Recruitment had a single peak in June, implying that more matured adults entered fishing grounds in June, though higher throughout the rainy season and low in dry season. Catch per unit effort being higher during the rainy season could be attributed to abundance of food for the shrimp during the season and is reflective of the season for bumper harvest.

The correlation between recruitment and CPUE being moderate and positive suggested that catches of the stock were relatively dependent on the recruitment pattern. If recruitment is interfered by factors such as
pollution, habitat destruction and adverse weather
conditions, catch per unit effort will be affected negatively. The moderate positive correlation implied that as recruitment of *P. monodon* increases, catch per unit effort tends to rise. The correlation coefficient \( r \) of 0.2 between temperature and % recruitment showed weak positive correlation between both parameters indicating that temperature was not a major factor that influenced recruitment. There are therefore, other factors rather than only temperature that affect recruitment of the black tiger shrimp in Andoni River.

Further research is needed to determine those factors that influence recruitment of the stock significantly in Andoni River.

**Conflict of Interests**

The authors have not declared any conflict of interests.

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