PEN CULTURE OF THE BLACK-CHINNED TILAPIA, *SAROTHERODON MELANOTHERON* IN THE AGLOR LAGOON IN GHANA

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ABSTRACT

Pen-fish-culture as a culture-based fisheries approach was investigated in the Aglor Lagoon from December 2003 to June, 2004. The fish used in the study was the Black-chinned tilapia *Sarotherodon melanotheron*. The growth performance of *S. melanotheron* cultured for six months in the Aglor Lagoon under three different treatments were monitored. In the first treatment, the cultured fish was fed with a feed of 29.80% protein at 3% body weight once a day. In the second treatment, bamboo was stacked at a density of 6 per metre square in pens to serve as substrate for periphyton growth and development. In the third treatment, there was no feeding (control). There was significant difference in growth between the fed and the unfed *S. melanotheron* in the pens, with no significant difference in growth between the fish that subsisted on periphyton developed on bamboo and the other treatments. *S. melanotheron* cultured in the bamboo equipped pens had the best condition factor of 3.57 ± 0.23. The experimental values of \( b \) obtained from the length-weight relationship \( W = a L^b \) for the three treatments were 2.07, 2.13 and 2.80 for feeding, unfed and bamboo respectively. From the results, the least yield was obtained from the unfed control pen (0.045 kg/m\(^2\)), whilst the highest was from the bamboo equipped pens (0.183 kg/m\(^2\)).

INTRODUCTION

A fish pen is defined as a fixed enclosure in a water system in which the bottom is the bed of the water body for growing fish (SEAFDEC/IDRC, 1979). A fish pen may be constructed using several local materials including split bamboo or nylon/polyethylene mesh nets for fencing in water (Murugesam et al., 2005). Of the various materials used to enclose fish in water systems, polyethylene mesh is the most common in most parts of the world. Pen fish farming differs from fish culture systems such as ponds and raceways in that there is little or no control over the aquatic environment in which the fish are kept (Alferez, 1977). Fish seed reared in pens erected in suitable areas of existing reservoirs could serve as a cheaper alternative to the expensive land-based nursery ponds (Murugesam et al., 2005). Fish pens do not have solid barriers separating them from the aquatic environment. As such water is exchanged freely between the pens and the surrounding water. These production facilities rely on this exchange, via water currents, to replen-
ish oxygen and remove wastes from the pens. In contrast, closed, land-based aquaculture systems are not in direct contact with natural bodies of water, so the aqueous environment can be environmentally controlled and waste water captured before being filtered or recycled (Caffey and Kazmierczak, 1994).

Escapes of farmed fish from pens can pose serious ecological concerns for both cultured and wild species (Molnar et al., 2008). Escapes occur through chronic leakage, slow, continuous escapement from small holes in the netting or from human error, as well as through large escape events resulting from significant damage often caused by storms or predators (Bridger and Garber, 2002; Goldberg et al., 2001). The large concentration of fish confined in fish pens attracts predators (Sepúlveda and Olivia, 2005). In general, fish pens in marine environments, tend to attract a greater range of predator species than closed, land-based systems or freshwater systems (Beveridge, 1996). Predation in fish pens results in death and injury to fish, and reported economic damage to the industry in many parts of the world can be substantial (Adámek et al., 2003; Nash et al., 2000; Sepúlveda and Olivia, 2005).

In pen construction, nylon or polyethylene mesh nets are attached to posts set at intervals (e.g. between 1 and 2 metres apart) and the bottom of the net is pinned to the substrate with long plastic or metal pegs. Buttressing may be used to strengthen the structures in exposed areas. Fish pens are usually built in shallow waters (<10 m depth), 3-5 m deep and of any size from less than a hectare to about 5 hectares (IDRC/SEAFDEC, 1979) and normally with soft substrates.

There is no record on any form of pen culture practice in Aglor Lagoon where the present study was undertaken. Introduction of fish pen in the lagoon was a pilot project undertaken by a Non-governmental Organization (NGO) known as the Young Farmers Research and Development Society, (YOUFARDES). It was a project of the NGO titled ‘Sustainable Aquaculture for Subsistence Fisheries' or ‘SureFish' as working title. Fishes cultured include Tilapias, Sarotherodon melanotheron, (Rüpell 1852) and Tilapia guineensis, (Bleeker 1862), Mudfish, Clarias spp, (Scopoli 1777) and the Bony Tongue, Heterotis niloticus (Cuvier 1829).

Minimizing production cost is a key issue for most aquaculture operations. Since feed costs generally represent 50-60% of total production cost, finding alternative and less expensive sources of feed for cultured fish will reduce production cost significantly. This study was carried out to compare the growth of S. melanotheron fed with formulated feed and that subsisted on algae developed on bamboo in fish pens.

MATERIALS AND METHODS
Description of the Study Area
Aglor Lagoon lies within latitudes 5° 52' and 5° 54' N and longitudes 0° 42' and 0° 43' E. It is located in the South Tongu District of the Volta Region. Its surface area has been estimated to be about 10 km², but Typha, an aquatic weed, has grown to cover a portion of its periphery. It has a depth ranging from 0.28 to 1.2 m.

The Aglor Lagoon receives water from River Kpem which originates from the Akwapim-Togo ranges and enters the Avu Lagoon (Entsua-Mensah and Dankwa, 1997). The Aglor Lagoon also experiences inflow of sea water at high tide. Totoe Lagoon contributes some water to the Aglor Lagoon when it overflows its banks during the rainy seasons. The closest village to the Aglor Lagoon is Aglorkpovia, located at about 700 m away from the lagoon's shore. The main occupation of the inhabitants is fishing. Farming is not common. However, some farming activities exist at the opposite bank of the lagoon, with cassava, tomatoes and other vegetables as the main crops.

Construction of Pens
A total of six pens were constructed in the Aglor Lagoon to keep fish captive for experimental culture. Each pen measured 3 m x 5 m with an average depth of 1.2 m and was enclosed...
with nylon nets of mesh size 25 mm, 19 m long and 3.4 m wide (Plate A). The pens were situated in shore waters at about 200 m from the shore line. Each pen was separated from others by about 3 m distance to allow easy access around the entire periphery. The bottom of the nets was stitched to 3.3 cm diameter Poly Vinyl Chloride (PVC) pipes. Vertical sides of each pen also had 4.8 cm diameter PVC pipes set at about 1.5 m apart. The pipes were filled with sand and sealed at the ends with mortar to provide support. The bottom of the nets around the pipes was stuck to the substrate with long plastic pegs of 45 cm long.

**Treatment of Pens**

After construction of the pens, spaces enclosed were fished thoroughly using an 8 mm mesh seine net in efforts to get rid of bigger fish that might have been trapped during construction as indicated by Hem (1979). Two pens were staked vertically with dry bamboos. External diameter of bamboos ranged from about 3.7 cm to about 6.8 cm, and about 1.5 m long. The bamboos, staked at a density of 6 per square metre were to serve as substrate for the growth and development of periphyton as natural food for the cultured fish.

**Stocking of Pens with *S*. *melanotheron***

The pens were stocked with wild black-chinned tilapia, *S*. *melanotheron*, of 20-35 g and a mean weight of 27.04 ± 4.53 g fingerlings when algae had developed on the bamboo stakes. This was to ensure ready food for the cultured fish. The stocking density was 2.7 per metre square.

To assess the necessity of providing supplementary feed for growth of fish, three treatments were established for the pens in relation to monitoring fish growth in them. In the first treatment, cultured fish were supplementarily fed on formulated feed of 29.80% protein at 3% body weight of fish once daily. This was to ensure feeding efficiency and to avoid feed waste which could lead to increase turbidity (Compell, 1978; Bruton, 1985) and possible eutrophication of the aquatic environment. No bamboo was inserted in these pens. In the second treatment, pens had bamboo stakes with the periphyton developing on the surfaces as additional feed to what was in water. In the third
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treatment (control), no supplemental feeding and bamboo stakes were used. Fish had only food generated by water to live on.

Monitoring Fish Growth
A sample of 20 fishes was obtained from each of the three treatments monthly during the culture period with a seine net of mesh 10 mm, 1.2 m wide and 3 m long. Standard length (SL), total length (TL) and wet weight of individual fishes were measured (to the nearest 0.1 cm and 0.01 g respectively) using a fish measuring board and a top loading electronic balance.

Before sampling, fish in treatment A were not fed with supplementary feed for 24 hours so as to obtain the true weights during measurement. The feeding rate of fish in Treatment A was adjusted according to new mean weight obtained monthly. Invading juvenile fishes into pens were identified with the aid of taxonomic keys (Lévéque et al, 1992) and the FAO field guide to fishes (Schneider, 1990). They were counted, measured and weighed, but they were not returned to their respective pens. This was to minimize competition between cultured fish and invaders which might affect the growth performance of the former. During each sampling, all the bamboo stakes were withdrawn from the pens that contained them to facilitate the process. Final harvesting of all the pens was done six months after stocking with an 8 mm seine net.

Growth Data Analyses
Test of Significance in Fish Growth
To analyse whether there was a significant difference between the growth rates of the three treatments, Single Factor Analysis of Variance (ANOVA) was used. The mean body weight values obtained for each treatment during the culture period were used in the computation, using MICROSOFT EXCEL software.

Length-weight Relationship
Length-weight relationship in fish is given by the equation W= aL^b Where W and L represent weight in grams and standard length in centimetres, respectively, a and b are constants, with expected values between 2 and 4.

The relation was log-transformed into a straight line of the form: y = mx + c by double logarithmic transformation thus giving the equation as log W = Log a + b log L. By plotting Log W (y) against Log L (x) a straight line was obtained. From this line the value b representing gradient of the straight line and a representing the intercept on the y axis was determined.

The mean and standard deviation values for the weight and the standard length for each treatment were determined monthly during the culture period and the values were pooled and plotted.

Condition Factor
The condition factor or coefficient of condition (K) which is mathematical estimation of physiological well-being of the fish, was calculated by the equation

\[ K = \frac{100W}{L^3} \] (Tesch. 1968).

Where:
W = weight of fish in grams
L = standard length of fish in centimetres

Mean monthly K was calculated for each treatment and the mean values for the various treatments were plotted against their corresponding months during the culture period.

RESULTS
Fish Growth Measurements
Figure 1 shows the growth measurements of penned fish under each study treatment. S. melanotheron grew from a mean total body weight of 26.94 g ± 4.57 g to 51.06 g ± 3.55 g in 6 months when fed with formulated feed. It grew from 27.15 g ± 4.32 g to 42.88 g ± 5.73 g when subsisted on periphyton developed on the bamboo stakes, and from 27.04 g ± 4.71 g to 36.14 g ± 3.36 g when no supplementary feed was added.
For the total culture period, the highest body weight gain of 24.12 g occurred in the fed fish, whilst the least value of 9.10 g was recorded in the unfed fish. In terms of percentages, the weights gain for unfed, bamboo and fed were 34%, 58% and 90%, respectively.

The curves (Fig. 1) for fed, non-fed and bamboo had almost the same mean weight, of about 27.0 g at the beginning of the culture period. From then each curve described a defined pattern of growth during the six months’ culture period. The rate of growth showed that the highest growth rate was recorded in the fed fish during the culture period, whilst the least was recorded in the unfed fish (control).

Growth Data Analyses

Test of Significance
The F-values obtained between fed and unfed, fed and bamboo and unfed and bamboo were 4.99, 1.90 and 0.96, respectively. At significant level of 0.05, the critical value for accepting the null hypothesis is 4.75. Comparing the respective F values to the critical value, it could be said that there was no significant difference in growth between fed and bamboo, and also between bamboo and unfed. However, there was significant difference in growth between fed and unfed.

Length-Weight Relationship
The linear least square regression of log weight (body weight, W) on log standard length (SL) (i.e. \( \log W = \log a + b \log L \)) was computed for the fed, unfed and bamboo treatments using the monthly pooled data for the culture period.

The calculated equations describing the relationships are as follows:
- Feeding: \( W = 0.0026163 L^{2.0692} \) \( (r^2 = 0.9751) \)
- No-feeding: \( W = 0.0019328 L^{2.1311} \) \( (r^2 = 0.9344) \)
- Bamboo: \( W = 0.0000899 L^{2.8000} \) \( (r^2 = 0.9401) \)

Condition Factor
The condition factor, K, of the 3 treatments fluctuated on monthly basis throughout the culture period. The high and low values for each treatment varied from month to month (Fig. 2). The peak values for the fed fish was recorded in January, the unfed and the
bamboo in March. The lowest values for the fed and the unfed were recorded in May, the bamboo in January.

Fish Invading Pens

Table 1 below shows the number of individual fish specimens that invaded each pen treatment. The highest was recorded in the bamboo-equipped pens whilst the least was in the pen in which no supplementary feed was added. Species of recruits recorded in the bamboo-equipped pens included *Tilapia guineensis*, *Hemichromis fasciatus*, swimming crab, *Callinectes amnicola* and *S. melanotheron*, of which the latter dominated. Similar species were recorded in the fed and non-fed pens, but the numbers of the individuals were fewer. The total yield obtained from each treatment at the end of the six-month culture period were 0.183 kg/m², 0.095 kg/m² and 0.045 kg/m² for bamboo, feeding and unfed respectively.

**DISCUSSION**

Stocking of Pens

Since the pens were reasonably fished before stocking, it was assumed that predatory fish and other trash fishes were got rid off from the pens. Hence, there was little, if any, competition between the cultured fish and other fish species for food and space within the pens. This also suggests that the stocked fish was not preyed upon in the pens.

Observations of this study showed that the only predatory fish that invaded the pens during the culture period was *H. fasciatus*, of which the maximum size recorded was 9.8 cm (SL), which was smaller than the stocked fish. *H. fasciatus* is known to be very piscivorous preying on other fishes (Armah et al., 2003; Addo, 2000). In the study of the gut content of *H. fasciatus* in the Keta Lagoon, Addo

### Table 1: Number of various fish specimens counted in pens under different culture treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of fish specimen</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeding</td>
<td>66</td>
<td>30.14</td>
</tr>
<tr>
<td>No Feeding</td>
<td>46</td>
<td>21.00</td>
</tr>
<tr>
<td>Bamboo</td>
<td>107</td>
<td>48.86</td>
</tr>
<tr>
<td>Total</td>
<td>219</td>
<td>100.00</td>
</tr>
</tbody>
</table>
(2000), observed two species of cichlids namely, *S. melanotheron* and *T. guineensis*, one species of gobiid, *Gobiurus sp.* and the clupeid *Ethmalosa fimbriata*.

According to Addo (2000), small sized *H. fasciatus* (3.0-6.9 cm, SL) fed more on clupeids whilst individuals belonging to the medium (7.0-11.9 cm, SL) and the large size classes (> 12.0 cm, SL) fed more on cichlids than on clupeids. This suggests that the *H. fasciatus* caught in the pens preyed on the fry that were spawned in captivity by the stocked *S. melanotheron* as well as migrants from the wild. The highest migrants of *H..fasciatus* recorded in the bamboo pens indicated that more fry and small sized *S. melanotheron* and other migrants were preyed upon in the bamboo pens than the other two treatments. Hence, the effect of predation by *H. fasciatus* affects the overall yield of *S. melanotheron* in fish pens.

**Monitoring Fish Growth**

**Growth Rate**

During the first two months of the culture period, there was a relatively fast growth for the fed fish peaking at 38.53 g whilst for the unfed; there was a relatively slower growth up to 29.45 g (Fig. I). This observation could be due to high protein feed supplied to the former. The growth of fish which subsisted on the algae developed on the bamboo stakes was quite slow, but faster compared to that of the unfed ones; attaining a mean weight of 31.42 g by end of the second month of the culture period. Between the second and the fifth month of the culture period, there was continuous increase in weight gain of the fed fish of which the maximum mean weight was 44.56 g. Within the same time period, the unfed fish recorded an increase in weight peaking at 35.42 g during the fourth month, whilst the growth rate decreased between the fourth and sixth months of the culture period (Fig. 1). The situation that some weight gain was recorded in the unfed fish, suggested that the fish obtained some form of food in the water that flowed into the pens. This might possibly include algae, diatoms and detritus (Armah *et al.*, 2003). Fish in pens with bamboo stakes showed appreciable increase in growth rate from the second month to the fourth month, with the highest growth rate occurring between the fourth and sixth months of the culture period. The better growth recorded in the *S. melanotheron* cultured in the bamboo equipped-pens compared to that of the unfed was attributed to the extra feed that the former derived from the bamboo substrate.

**Length-weight Relationship**

From the length-weight relationship, \( \log W = \log a + b \log L \), the regression equation defined by the method of least squares gave the relationship for each of the treatments as follows:

**Feeding:** \( \log W = -2.5823 + 2.0692 \log L \)

**No Feeding:** \( \log W = -2.7138 + 2.1311 \log L \)

**Bamboo:** \( \log W = -4.0460 + 2.8000 \log L \)

The \( b \) value theoretically is indicative of the type of growth pattern associated with a particular fish. When \( b = 3 \), the fish grows equally in all dimensions and it is termed isometric growth. Significant deviation from this value leads to allometric growth. For instance a value of \( b > 3 \) means that the fish becomes plumper as it grows and for \( b < 3 \), it becomes thinner as it grows. The values of \( b \) obtained from the pooled data for the 6 months' culture period for each treatment were 2.0692, 2.1311 and 2.8000 for feeding, no-feeding and bamboo respectively.

**Condition Factor (K)**

Reproductive activity, food availability and feeding are known to influence the condition of fish (Abban *et al.*, 1996; Birkett, 1972). An accumulation of food reserves increases the condition factor. Hence, the starvation of the fish 24 hours prior to sampling could account for the relatively low condition factor recorded in the fed fish compared to those subsisted on algae which had constant food supply. With the
onset of peak spawning activity, food reserves were used for sexual products and the condition factor declined as reported by Birkett, (1972). This is because K values are known to be lowered during a recovery period after a peak period of spawning (Abban et al., 1996).

According to Schwanck and Rana (1991) in S. melanotheron, the male habitually mouthbroods and during such periods abstain from food which may lead to starvation and consequently loss of weight resulting in decline of condition factor. Hence, the variations in condition factor observed in the different treatments could be attributed to the parental role of the males. The prolific breeding habits of S. melanotheron (Blay, 1981) could also affect the physiological well-being of the females. These changes in fish condition reflect normal seasonal fluctuations in metabolic balance, patterns of maturation, and even state and fullness of the alimentary canal (Bolger and Connolly, 1989).

CONCLUSION
Pen culture of S. melanotheron could be successfully practised in the Aglor Lagoon. Staking of bamboos in fish pens could serve as substrate for the development and growth of algae in the pens which cultured S. melanotheron could feed on to enhance growth. This will overcome the cost of using artificial feed for the development of fish culture in rural areas. Besides serving as a suitable substrate for algal growth, the presence of bamboo stakes in fish pens attract more fishes from the wild as fish aggregating device than those without. This will contribute to increasing fish yield. The use of bamboo stakes in fish pens increased yield of S. melanotheron to about double that of fed ones and it also reduced amount of feed used by about 42%. The use of bamboo in fish pens has the potential for low-input sustainable production system since extra cost is not spent on feed. This study demonstrated that pen culture of S. melanotheron in the Aglor Lagoon is feasible. Hence, the communities could easily adopt the technology.

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