Vol. 8(2)
December 2004

ISSN : 1026-6690

Bangladesh Journal of Fisheries Research

Bangladesh Fisheries Research Institute

Bangladesh Journal of Fisheries Research

Aims and scope: The *Bangladesh Journal of Fisheries Research* is published by Bangladesh Fisheries Research Institute (BFRI). The Journal accepts original research articles, scientific notes and review papers on different aspects of fisheries including, but not limited to, fresh and brackishwater aquaculture, mariculture, reproductive physiology & genetics, nutrition & feed, pollution & disease, post-harvest technology & quality control, and aquatic environment. Priority will be given on the articles covering one of the following fields.

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Publication information: The *Bangladesh Journal of Fisheries Research* is published half-yearly in two issues (July and December). The subscription rate for each annual volume is: (a) individual- BDT 500 (overseas US$ 30), (b) institution- BDT 1000 (US$ 60). The Journal is also available in exchange for publications of learned societies, research institutes and universities. All payments should be made in favour of the *Bangladesh Journal of Fisheries Research*, and all correspondence addressed to the **Director General, Bangladesh Fisheries Research Institute, Mymensingh 2201, Bangladesh. Fax:** (+880-91-55259). **Web:** www.fri.gov.bd **E-mail:** info@fri.gov.bd

Bangladesh J. Fish. Res. 8(2), 2004: 87-93

Laboratory culture of *Moina* with organic and inorganic fertilizers

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Abstract
An experiment was conducted in the laboratory condition to determine the effect of organic (poultry drop, cow dung and mustard oil cake) and inorganic fertilizer (urea) on production, reproduction rate and maturation time of *Moina* species. Production rate was also determined in both aerated and non-aerated system in plastic containers with carrying capacity of 2.5-liter each. Total production was significantly higher in both aerated (2475 individuals/2.5 l water) and non-aerated (3253 individuals/2.5 l water) containers using poultry manure compared to other fertilizers. Moreover, the reproduction rate and maturation time in poultry drops showed distinct efficacy in *Moina* species. Reproduction rate of 11 individuals was the maximal while lowest maturation time was found 78 hours. Reproduction and maturation were induced surprisingly in test tube where the aeration system was absent.

Key words : *Moina* spp., Organic fertilizers, Inorganic fertilizers

Introduction

Moina, a freshwater cladoceran, is a genus of vast array of tiny aquatic crustaceans often called water fleas for their hopping motion of swimming. The length of the female varies from 0.4 mm in newly hatched species to about 1.0-1.65 mm in adult size. The body length of male varies from a newly hatched size of 0.4 mm to an adult size of 0.6-1.13 mm (Rottmann 1992). *Moina* reproduces by both live birth and by eggs (ephippa). They reproduce and develops as all females through parthenogenesis.

It is found mainly in temporary shallow water bodies, which receive limited amount of sewage wastes, poultry cattle or human wastes. This species can tolerate as low as 0°C and high as 35°C but prefer temperature ranging from 20°-30°C. Generally alkaline water is favourable for *Moina* with a p^H between 6.5-9.5 (Rottmann 1992). *Moina* is mixotrophic, i.e. is they are unselective filter feeders (Reddy and Rottmann 1992) and basically feed on wide variety of tiny organisms such as rotifers, paramycium, bacteria, euglena, protozoa, yeast as well as other nutrient or particle of appropriate size that will stay in suspension long enough to be eaten.

Moina serves as an important natural food item of carps in polyculture (Nandy *et al.* 1989), *M. rorenbergii* and Catfishes (Masters 1975, Huisman 1976, Styczynska *et al.* 1979, Billar 1980). Moina may be used successfully as a supplement to Artemia, in over night feeding of M. rosenbergii larvae (Alam *et al.* 1993). Moina could also be used as alternative of *Artemia*. The partial replacement of Artemia by *Moina micrura* was also reporated to have positive effect during the larvae culture of freshwater prawn *Macrobrachium rosenbergii* (Alam 1993). *Moina* can be used solely or mixing with *Artemia* at 50:50 ratio (Alam *et al.* 1993). For the rearing of larvae of *M. rosenbergii*, penacid shrimp and catfishes, the Moina are utilized as ideal food organism (Masterrrs 1975, Huisman 1976, Styczynska *et al.* 1979).

The main advantage of *Moina* is that high production may be possible by paying very simple technique with low cost. Any hatchery can easily be able and adopt this technique and reduce the feeding cost during the larval stage of carp and shrimp species. Moina consist of 95 % water, 4% protein, 0.4% fat 0.67 % carbohydrate and 0.15% ash. It also contains amino acid at living condition (Rottmann 1992).

In Bangladesh *Moina* is locally known as "Makhon Poka" (Butter insect) or "Ghora Poka" (Horse Insect). The distribution of *Moina* in Bangladesh is unknown and there is no systematic investigation carried out. Some private carp hatchery at Jessore region used *Moina* for fingerlings. In shrimp hatchery, few farm owners are supplying artificially bred post larvae. Most of these hatcheries depend upon natural seawater and a particular food organism composing naupli of brine shrimp, *Artemia salina*. The cysts for producing naupli are very expensive and need huge amount of foreign currency. Moreover, the technology of *Artemia* cyst production is complicated compare to *Moina*.

The present study is aimed to find out a suitable medium in which a high and sustained production is possible.

Materials and methods

Sample collection, isolation and inoculation

Samples were collected from a pond near Sonadanga Thana, Khulna District by plankton net. After collection the sample was taken to the laboratory immediately.

From the collected sample *Moina* species were isolated from the many zooplankters. Isolation was done by the micropipette with the help of a microscope slide and removed the water with a pointed brush. Except *Moina*, other zooplankters were removed by the brush.

After complete isolation, the *Moina* species cells were kept into two beakers. Each beaker contained 100 ml of tap water where 125 individuals were kept for two days with complete diet for multiplication.

Phytoplankton culture

Twelve containers were used for *Chlorella* production as the main food source of *Moina* prior to culture. Experiments were carried out in cylindrical plastic pots filled

with 2.5 liter tap water. Four media options were used for *chlorella* production and three replicates were performed for each experiment. The feed ingredients for *Chlorella* culture are named as poultry drops, cow dung, mustard oil cake and urea at the rate of 0.5 g/l. Adequate light was provided to enhance the photosynthesis. The tanks were covered with closed mesh nets to avoid the interference of dragonfly. If the dragonfly are in contact with the tank water, they lay the eggs and the eggs hatch and become nymphs which voraciously feed on the cultured *Moina*.

Culture of Moina

When the water turns to greenish (6 days later), approximately 80-85 *Moina* species were given in each container. The cells were counted on microscope slide. 5 – 7 ml water from the inoculated beaker was taken and the water was poured on slide dropwise. The water was removed from the slide with a pointed brush and counted the cell. In this way 80-85 individuals were given in each container. The growth of each individual was observed for five days. To compensate the loss of water due to evaporation fresh tap water was added as and when required. P^H and water temperature were maintained properly during the study period.

Reproduction rate was calculated in different feeding options (poultry drops, cow dung, mustard oil cake and urea). Three replicates of each treatment were done. A mature *Moina* (1-1.65 mm) was kept in test tube for spawning. Total numbers of individual produced by one individual were counted until the new individuals become mature. The maturation was observed through eye estimation. All the test tubes were kept under light.

Newly hatched larvae were taken into the test tube during the reproduction rate experiment. Three replicates with four feeding option were designed. The maturation time was taken when the individual released first offspring. Adequate light was ensured during the experiment.

After five days the entire sample was homogenized through stirring. Then 10-ml sample was taken with the help of pipette. It was taken on a watch glass dropwise and counted. It was done for six times for a sample. Average number was taken and converted to a total.

Data analysis

Collected data were analyzed using one-way analysis of variance (ANOVA). Mean differences were obtained through DMRT Test (Duncan Multiple Range Test).

Results

The production summary of *Moina* species fed on *Chlorella* is given in Table 1. Significant differences ($P<0.05$) in production of *Moina* species were found among the treatments. Production was highest in poultry drops with mean value of 3253.36±283.23. The lowest production was found in the treatment of urea 1121.11±857.90. The mean

production of all treatments were found to 3253.36±283.23, 1205.56±578.37, 2341.33±580.39 and 1121.11± 857.90 in poultry drops, cow dung, mustard oil cake and urea respectively.

Table 1. Growth rate in different feed treatment

Treatment	Growth without aeration (No. of cell/ 2.5 l)	Growth with aeration (No. of cell / 2.5 l)
Poultry drops	3253.36 ± 283.23	2475.00 ± 484.76
Cow dung	1205.56 ± 578.37	907.54 ± 485.54
Mustard oil cake	2341.33 ± 580.39	847.57 ± 117.56
Urea	1121.11 ± 857.90	673.33 ± 148.90

The Growth rate of *Moina* species was surprisingly dropped in all treatments by aeration. The mean highest production was found in the treatment of poultry drops (2475.00±484.76) while the lowest was found in the treatment of Urea (673.33±148.90). Average growth under the pattern of aeration and without aeration with the different feeding options is shown in Table 1. From the Fig. 1 it is revealed that mustard oil cake and urea treated containers showed almost the double production in non-aerated system compare to aerated one. One of the non-aerated container treated with urea was unable to multiply, even the stock species were died.

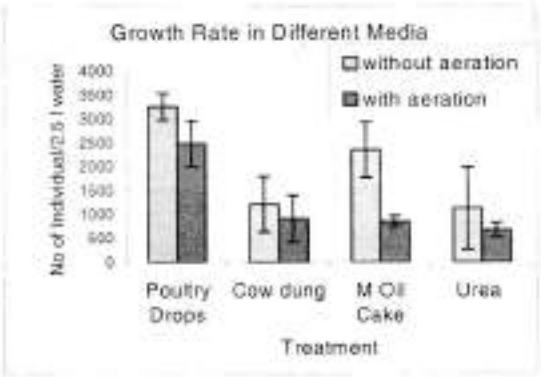

Fig. 1. Growth rate in different feed treatment.

Reproduction rate of *Moina* species in all treatments is presented in Table 2. The mean reproduction rate in poultry, cow dung, mustard oil cake and urea treated container was 11, 8, 10, and 7 respectively. The highest number of individuals was produced in the treatment of poultry drops (11 individuals) and lowest was in the treatment of urea (8 individuals).

Table 2. Reproduction rate in different feed treatment

Treatment	Reproduction rate (no. of cells)
Poultry	11.33 ± 0.94
Cow dung	8.33 ± 0.47
Mustard oil cake	10.00 ± 0.82
Urea	7.66 ± 0.47

The maturation time required for an individuals to become mature for further propagation showed in Table 3. The minimum duration of 78.67±2.87 hrs. was required during treatment with poultry drops to become sexually matured whereas cow dung, mustard oil cake and urea treatment containers required 80.67± 1.25, 79.33±1.70 and 82.33±2.1 hrs. respectively.

Table 3. Maturation Time in different feed treatment

Treatment	Maturation time (hrs.)
Poultry	78.67 ± 2.87
Cow dung	80.67 ± 1.25
Mustard oil cake	79.33 ± 1.70
Urea	82.33 ± 2.1

Discussion

The present study shows the highest production by using poultry drops compared to other feedstuffs. The poultry wastages were collected from the poultry farm where rich feed ingredients are supplied to the chicken to fulfill their nutritional requirements. The wastages contain all the combination of organic substances, like cellulose, nitrogen, ammonia, carbon, minerals and others, which althogether enhance the growth of phytoplankton (David *et al.* 1969) and may cause the maximum production of Moina that may promote fish growth with profit (Rappaport *et al.* 1977). Cow dung, Mustard oil cake and urea contains cellulose, nitrogen and ammonia respectively that are unable to function as that of poultry droppings.

According to Alam *et al.* (1993) *Moina* cultured on poultry manure might have accumulated a high level of n-3 HUFA directly from the manure or indirectly from algae and other microorganisms induced by this fertilizer. Poultry manure may contain higher n-3 HUFA reflecting the diet (e.g. fish meal) of the poultry. A high n-3 content in *Moina* were grown on poultry manure had been demonstrated earlier (Watanble *et al.* 1983 Villegas 1990).

In Singapore, *Moina micrura* grown in ponds fertilized with mostly chicken manure or, less frequently, with pig manure are used as the sole food for fry of many ornamental, tropical fish species and with survival rate of 95 to 99% (Rottmann1992). Unfortunately, there is very little information concerning practical, mass culture methods of *Moina* and

the available information is in mimeograph documents, foreign journals, or other research publications (Rottmann1992).

Organic fertilizers are usually preferred to mineral fertilizers because they provide bacterial and fungal cells and detritus as well as phytoplankton as food for the *Moina*. This variety of food items more completely meets their nutritional, needs, resulting in maximum production (Rottmann 1992).

From the result (Fig. 1) it was observed that the production rate is lower with aerated container than that of without aerated container. The lower production of *Moina* species in aerated container may be the strong small bubbles produced by the aerator. Extremely small bubbles should be avoided; they can get trapped under the carapace. This causes *Moina* to float at the surface, eventually kill them (Rottmann 1992).

One of the urea treated containers (without aeration) showed no individual. to multiply or survive. This may be due to toxic affect of ammonia as because the experiment was brought about without aeration. Another cause may be growth of thread algae. Thread algae reduces or disappear *Moina* (Rottmann 1992). Other noticeable things were that the container was extremely green which indicates the deficient in nitrogen and possibly other nutrients. This might be another cause of motility of *Moina*.

Significant difference ($p<0.05$) were also found in varied among the treatment and the same trends were observed for *Moina* cultivation. All the containers were kept under same environmental condition. The highest and lowest reproduction rate was found in poultry drops (11.33 ± 0.97) and urea (7.66 ± 0.47) respectively. On the other hand, the highest and the lowest maturation time were found in urea (82.33 ± 2.1 hrs.) and poultry (78.67 ± 2.87 hrs.) treated container respectively. Delbare *et al.* (1992) reported their findings that the maturation time of Moina species required 74 to 120 hrs. Present study supported their findings. Rottmann (1992) found the reproduction rate 10-20 individual and A.K. Reddy (1990) found the reproduction rate of *Moina* around 8-10 individuals from a single *Moina* that also agree the present result. Due to the variation of the different feed composition among the treatment the reproduction rate and maturation time varied. Poultry treated container could be possible reason for enhancing the reproduction and thereby reducing maturation time of *Moina*. It is believed that over crowded populations, shortage of food, too low or too high a temperature, too short light period or too dim a light, and excesses of excretory matter or waste metabolites are the main causes of ephippa (resting eggs) production (Rottmann 1992).

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(Manuscript received 29 June 2004)

Bangladesh J. Fish. Res.,**8**(2), 2004: 95-100

Culture potentials of gulsha (*Mystus cavasius*) in monoculture management under different stocking densities

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Abstract
Semi-intensive grow-out trials on monoculture of gulsha (*Mystus cavasius*) were conducted to assess the production potentials for the period of six months from March through August 2002. Three stocking densities such as 40,000 (T-1), 50,000 (T-2) and 60,000/ha (T-3) were tested in three replications. The production of gulsha was 1,474±52, 1,535±71 and 1,370±60 in treatment-1, 2 and 3, respectively and they were significantly different ($p<0.05$) from one to another. A higher net benefit was obtained Tk. 42,291 from treatment-1 (T-1) where the stocking density was 40,000/ha.

Introduction

In recent years, increasing anthropogenic pressure on the inland water resources has led to drastic degradation of the rich ichthyofauna of Bangladesh. Many commercially important indigenous fish are greatly threatened. Gulsha (*Mystus cavasius*) is one of them, which is on the verge of extinction. This fish is great favorite to consumers because of its delicious taste and therefore have a great demand fetching high price in the market.

Mass propagation coupled with judicious culture in controlled environments is often considered as the logistic approach for conservation ventures. With this in mind and also to increase its production through aquaculture, the Bangladesh Fisheries Research Institute under its Freshwater Station, Mymensingh has developed seed production technology through artificial propagation (Akhteruzzaman *et al.* 1991). Though this species have been reported quite favorable under standard conditions of carp farming (Hossain *et al.* 1998), their monoculture culture has not yet been developed and established. The present study has, therefore, been proposed to evaluate their production potentials of gulsha in monoculture management

Materials and methods

Experimental design and pond preparation

This trial was under taken in three earthen ponds each with three chambered (90m^3 each) over a period of six months during March to August'02 at Freshwater Station,

Bangladesh Fisheries Research Institute, Mymensingh. The experiment had three treatments and three replicates of each. Three stocking density of gulsha fingerling (*M. cavasius*) such as 40,000, 50,000 and 60,000/ha were tested, which considered as treatment-1 (T-1), treatment-2 (T-2) and treatment-3 (T-3), respectively. Before starting the experiment, ponds were drained to eradicate all fishes, embankments were repaired. Pond bottoms were treated with lime (CaO) at the rate of 250 kg ha^{-1} and left for 3 days. Then ponds were filled with groundwater and fertilized with cow manure 2,000 kg ha^{-1} and left for three days.

Stocking of fingerling

Fingerlings of gulsha were stocked at the rate of 40,000 (T-1), 50,000 (T-2) and 60,000/ha (T-3) in three ponds with 9 chambers. Gulsha fingerlings were stocked in 1st March in all the treatments. The initial weight range of fingerling was 3.94 to 4.06g.

Feeding and fertilization

After stocking, fingerlings were fed with supplementary feed (25% crude protein) at the rate of 4-6% of estimated biomass. Organic fertilizer (Cattle manure) was also applied at the rate of 1,000 kg/ha in fortnightly interval.

Fish sampling

The ponds were sampled fortnightly by using a seine net (mesh size 5 mm) to determine growth rate as well as feed adjustment.

Analysis of water quality parameters

Water quality parameters such as water temperature (°C), DO (mg/L), p^H, alkalinity (mg/L), were monitored at weekly interval (APHA 1992).

Statistical analysis

Analysis of variance accompanied by DMRT was employed to see if treatment had any significant effect or not. The statistical analyses were carried out using statistical software, Statgraphics 7.0.

Results and discussion

The overall mean values of water quality parameter of ponds in different months are presented in Table 1. The mean values of water quality parameters in different months were: temperature 25.62±0.28 to 31.31±1.57°C, dissolved oxygen 4.57±0.91 to 8.25±1.83 mg/l and alkalinity 161.25±38.38 to 211±5.48 mg/l.

Water temperature is one of the most important factors, which influence the physico-chemical and biological events of a water body. The ranges of mean value of water temperature in different months in the present study were 25.62-31.31°C. The

values of water temperature are more or less similar to that reported by Paul (1998) and M.M. Rahman (1999) and Kohinoor (2000). The pH in all pond water was alkaline throughout the experimental period. Different authors have reported a wide variation in pH from 6.7 to 7.2 (Ahmed, 1993); 6.7 to 8.3 (Hossain *et al.* 1997), 7.18 to 7.24 (Kohinoor *et al.* 1998) and 6.5 to 8.8 (Rahman 2000) in fertilized fish ponds and found the ranges productive. The ranges and mean values of pH recorded in present study are alkaline, which indicating the productive nature of the fertilized ponds.

Table 1. Mean value (±SD) of water quality parameters in different months

Month	Water temperature (°C)	pH	Dissolved oxygen (mg/l)	Total Alkalinity (mg/l)
March	25.62±0.28	7.82-8.62	8.10±2.55	211±5.48
April	28.88±0.96	7.94-8.37	8.25±1.83	161.25±8.38
May	30.38±2.60	7.67-8.65	5.93±3.2	166±10.75
June	27.55±0.13	7.37-7.69	4.57±0.91	174±9.52
July	31.31±1.57	7.37-7.69	4.86±0.42	198±16.25
August	30.46±1.06	7.5-8.11	5.47±1.73	176.25±12.92

Dissolve oxygen is the most important factor for all aquatic organisms except anaerobic bacteria. The value of dissolve oxygen concentrations was found to vary from 4.57±0.91 to 8.25±1.83 mg/L. Dissolve oxygen concentrations more than 3.5 mg/L in pond waters reported by several researchers (Ali *et al.* 198, Martyshew 1983, Rahman 2000 and Kohinoor 2000) which was similar to the present study.

Total alkalinity more than 100 mg/L should be present in high productive water bodies (Alikunhi 1957). Paul (1998), Kohinoor (2000) and Grag and Bhatnagar (2000) found the average total alkalinity values above 100 mg/L in their experiments. The total alkalinity values found in the present study were within the suitable range. The water quality parameters of the experimental ponds were found to be within the acceptable ranges for aquaculture and there was no abrupt change in any parameter of the experimental pond water.

Growth and production

Details of stocking, harvesting, growth and production of gulsha (*Mystus cavasius*) in different treatments during the study period are presented in Table 2. On the basis of final growth attained under treatments-1, 2 and 3 were 41.42±6.20, 36.11±3.85 and 28.99±4.52g, respectively. The highest growth was obtained in treattment-1 and lowest in treatment-3. The harvesting weight showed significant difference ($p<0.05$) in T-1 followed by T-2 and T-3 when ANOVA was performed. The monthly sampling weight of gulsha under different stocking densities are shown in figure 1. Fig. 1 indicates that the growth rate was always higher in treatment-1 then followed by treatment-2 and 3. The results showed that higher growth rate was observed at lower stocking densities. The percentage increase in weight (g) was found to be 920.19%, 807.28% and 635.71% in

treatment-1, 2 and 3, respectively. The SGR (%) values were more or less same in all the treatments and which showed in significant difference among the treatments.

Table 2. Growth, survival and production of gulsha (*Mystus cavasius*) under different stocking densities

Treatments	Initial weight (g)	Harvesting weight (g)	Increase of growth (%)	Survival (%)	Production (kg/ha)	SGR (%)
Treatment-1	4.06±1.11	41.42±6.20	920.19	89	1,474±52[a]	1.23[a]
Treatment-2	3.98±0.96	36.11±3.85	807.28	85	1,535±71[a]	1.16[a]
Treatment-3	3.94±1.0	28.99±4.52	635.79	79	1,370±60[b]	1.03[b]

* Figures in the same column with different superscripts are significantly different (P>0.05)

Fig. 1. Growth rate of gulsha (*M.cavasius*) under different stocking densities during the experimental period

The survival rate of gulsha was found to vary with the stocking densities. The highest survival (89%) was obtained in treatment-1, where the stocking density was 40,000/ha. and the lowest (79%) was obtained in treatment-3, where the density was 60,000/ha (Table 1). The survival rate did not show any significant difference ($p>0.05$) among the treatments. The results reveal that higher survival rate was found at lower stocking density.

Production data of fish per hectare was extrapolated from the data of $90m^3$ water area over a 180-day culture period. The productions of gulsha were 1,474±52, 1,535±71 and 1,370±60 kg/ha, respectively in treatments-1, 2 and 3. These data showed significant differences among treatments when compared using ANOVA.

Culture of small indigenous fish such as gulsha, pabda, sharpunti, koi, mola, chela punti has not yet been attempted on large scale in this country. Consequently, published informations on production of small indigenous fish species in freshwater ponds are rather little. Akhteruzzaman (1988) reported that the production of koi (*Anabas*

testudineus) was 450 kg/ha/5 months where the stocking density was 16,000/ha by applying supplementary feed, (rice bran, mustard oil cake and fish meal). In another study, Akhteruzzaman *et al.* (1990) observed that in monoculture condition the production of (*P. sarana*) was 1,200 kg/ha/6 months. Kamal (1996) obtained a net production of 461 kg/ha/5 months from *P. sophore* in monoculture condition by applying fertilization. Rahmatullah *et al.* (1998) reported to obtain a net yield of chapila (*Gudusia chapra*) to be 92.13 kg/ha in 3 months culture period.

Cost and benefit

A simple cost-benefit analysis was performed to estimate the amount of profit that has been generated from these types culture. The results of the analysis are shown in Table 3. The cost of production were Tk. 77,469, Tk. 84,515 and Tk. 92,841 in treatments-1, 2 and 3, respectively. The cost of production was higher in treatment-3 and lower in treatment-1. The higher net profit of Tk. 42,291 was obtained from T-1 where gulsha was stocked in 40,000/ha. Hussain *et al.* (1989) analyzed the cost and benefit of Nile tilapia (*Oreochromis niloticus*) in monoculture condition and got the net benefit of Tk. 72,827/ha/6 months where fish were fed with rice bran and mustard oil cake. The net benefit of rajpunti (*Puntius gonionutus*), Kohinoor *et al.* (1993) found that Tk. 68,135 to 75,028/ha/6 months could be achieved by applying supplementary feed and fertilization. Whereas, Kohinoor (2000) got the net profit of Tk. 32,910/ha/6 months in monoculture of small indigenous fish punti (*Puntius sophore*).

In view of above, it may be concluded that the production and economic return of gulsha in monoculture condition was not very encouraging but culture of endangered species could ensure the availability as well as conservation of this species in inland waters.

Table 3. Cost and return analyses of fish production in different densities in one hectare area

Inputs	T-1		T-2		T-3	
	Quantity (Kg)	Cost (Tk.)	Quantity (Kg)	Cost (Tk.)	Quantity (Kg)	Cost (Tk.)
Lease value	-	25,000	-	25,000	-	25,000
Pond preparation		4,875		4,875		4,875
Feed	2,533	45,594	2,980	53,640	33,87	60,966
Cowdung	2,000	500	2,000	500	2,000	500
Harvesting cost		1,500		1,500		1,500
Total cost		77,469		84,515		92,841
Benefits						
Sell price of pabda (Tk.120/kg)	998	1,19,760	1,022	1,22,640	1,048	1,25,760
Net benefit/ha	42,291		38,125		32,919	

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(Manuscript received 23 August 2003)

Bangladesh J. Fish. Res.,8(2), 2004: 101-111

Ecology of Shakla *beel* (Brahmanbaria), Bangladesh

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Abstract
The beel Shakla, comprising an average area of 75.0 ha is located in the northeastern region (Brahmanbaria district) of Bangladesh. The study was carried out to assess the ecological aspects of beel ecosystem. Surface run-off and increase inflow of rain water from the upper stretch during monsoon cause inundation and resumption of connection between beel and parent rivers. The range of dissolved oxygen (DO) content (4.5-8.9 mg/L) was found congenial for aquatic life. pH was in the alkaline range (7.3-8.5) and free CO_2 was reletavely high. Lower values of total hardness and total alkalinity indicated less nutrients in the beel water. A wide variation (1.4–27.2 x 10^3 cells/L) in the standing crop of total plankton was recorded during study period of which phytoplankton alone contributed about 90%. Phytoplankton diversity in the beel represented by three groups *viz.* Chlorophyceae, Myxophyceae and Bacillariophyceae in order of abundance. A total of 52 fish species belonging to 36 genera, 20 families and 1 species of prawn were identified so far from the beel. About 13 types of fishing method were found in operation. Seine nets (*moshari berjal, ghono berjal*) and gill net (*current jal*) were identified as detrimental gear killing juveniles of different species during post spawning period. Kua fishing was also found harmful due to dewatering nature. A total of 11 species belonging to 11 genera and 10 families of aquatic weeds were identified from the beel. The eggs of *Macrobrachium lamarrei* were identified into the *Najas najas* vegetation during April-September.

Key words : Ecology, *Beel*

Introduction

The inland freshwater fisheries resources of Bangladesh have been among the most productive fisheries in the world, with only China and India reporting more inland fish production than Bangladesh. The flood dependent fishery has been notable for the diversity of its fish and prawn species and the primary source of fish for all Bengalis (Rahman 1989). Inland open water capture fishery as a whole is in decline over the decades due to multiple causes. This capture fishery is made up of three inter-related general areas (riverine, beel/baor and floodplains), the declines in one area are an indicator of problems in all areas (DoF 2002). To mitigate the prevailing situation there is a search of new interventions, policies, and management options and future programs

should be designed to prevent the further decline and possible collapse of the existing fishery.

Beel is a saucer-shaped depression, which may hold water permanently or dry up during the dry period. A total area of beels in Bangladesh was estimated to be 114,161 ha, occupying 27.0% of the inland freshwater area. The number of beels in the Northeast region has been reported to be between 3,440 (covering 58,500 ha with a mean size of 7 ha) and 6,149 (covering 63,500 ha with a mean size of 10 ha) (Bernacsek et al. 1992). About 58% of the beels in the Northeast region are permanent and the reminder is seasonal.

The WorldFish Center of Bangladesh has been implementing a project (CBFM-2) in 115 open water bodies of Bangladesh in collaboration with the Department of Fisheries (DoF) and a number of Non-Government Organizations (NGOs) to promote sustainable use of open water fisheries resources by community management. Among 115 beels, the beel Shakla (N 23°56.508' and E 091°08.448') located in northeast region (Brahmanbaria district) was selected to carry out the present study. This beel is leased out to Beel Management Committee (BMC- a community based local forum headed by a Chairman) for consecutive five years. The beel is managed by BMC with the cooperation of WorldFish Center (WFC), DoF and PROSHIKA.

Materials and methods

The study was carried out in the beel Shakla during July'03 to June'04. The research was based on both primary and secondary data, comprehensive literature review and extracts of local knowledge and information. Data collection was limited with the visiting schedule. Collection of primary data was made by field observation and different experimentations *viz.* experimental fishing in the beel, survey of different fishing methods, survey of fish markets adjacent to beel, monitoring of hydrological, meteorological, physico-chemical and biological characteristics of beel and fishers' perception as well. Secondary data were collected from the fishers, lease holders, Beel Management Committee (BMC), local administration, Water Development Board (WDB), Department of Fisheries (DoF), Bangladesh Fisheries Research Institute (BFRI), Meteorological Department and related NGOs.

A bamboo made meter scale measured water depth. A Secchidisc measured water transparency. Temperature of air and water was measured with a centigrade thermometer. Free CO_2 content was determined by phenolphthalein indicator method (Welch 1948). Total alkalinity was estimated by using phenolphthalein and methyl orange indicator method (Welch 1948). Total hardness was determined by EDTA titrimetric method (APHA 1995). HACH test kit (Model-FF-2, USA) was used to measure water pH, dissolved oxygen (DO), ammonia and nitrite only.

For planktonic study 50 L water were collected from the euphotic zone of the *beel* and passed through bolting silk plankton net of 55μ. The filtrates were immediately preserved in Lugol's solution. Qualitative and quantitative analysis of both phyto-and zooplankton were done following drop count method (APHA 1995). Microscopic identification was performed up to genera. Each sample was stirred smoothly just before

microscopic analysis. One ml of agitated sample was poured in a Sedgwick-Rafter (S-R) counting cell. A binocular microscope did identification and enumeration of each sample. Qualitative studies were done according to Presscott (1964) and Needham and Needham (1972).

Identification of fishes was done through collection of different species directly from fishers' catch, experimental fishing, fishing through enclosure with *bana* (locally called *pati*), *katha* fishing, *kua* fishing and surveying local fish markets. Catch-effort survey was done through *in situ* observation.of fishers' nets. Resident fish species was recorded through experimental fishing in the deep pool areas in the *beel* and man-made *kuas* where water remains during dry season (early January-mid April). Local knowledge as well as fishers' perception has been considered also. Aquatic weeds were collected from the beel and identification was made into the laboratory.

Results and discussion

Morphometry and hydrodynamics

The main morphometric features that influence the productivity of beel ecosystem are shoreline, area, depth and slope. These, in turn, are closely linked with the hydrodynamics of wetlands. Generally there are three main sources of water input into the beel ecosystem *viz.* overspill from the river channel, surface flow and regeneration. River flows are determined both by rainfall and snowmelt from the mountain range. The beel Shakla lies in Machihata union of Brahmanbaria sadar upazila, about 13 km southeast of the district town. The Titas river passes through the eastern side of the beel. This river is used to inundate as well as drain the beel. This beel is connected with the Titas river by three canals locally called khals *viz.* Audaubbah, Katakhal and Kuralia. In dry season, almost all the areas of beel become dried up except the aforesaid canals where water remains during mid-January to mid-April. Flooding originates from the Meghna river, the west of the beel. The average area of Shakla beel is about 75.0 ha. The bottom of the beel is uneven. Surface run-off and increase in river height due to inflow of rain water from the upper stretch, cause inundation of floodplains, often causing resumption of connection between beels and parent rivers. The more water gain or exchange of water in the beel takes place during southwest monsoon when the floodplains are flooded. After recession of flood, water level in the river decreases snapping the beel's connection with the river. The beel gets dried up through evapo-transpiration and seepage. Except deeper portion of beel, the people use most of the area for crop practice by extracting water from the beel. The water loss by various means causes shrinkage of the effective water area and lowering of depth in the beel.

Water quality

The water quality profile of the beel Shakla is given in Table 1. The color of beel water was found to be changed periodically. The nature of the beel bed was observed almost hard. The water level fluctuated between 0.8 and 3.0 m. The highest depth was

recorded in June and the lowest in January. The mean water level obtained 1.93±0.7 m. The Secchidisc visibility fluctuated much; it ranged from 0.33 m to 1.25 m. The transparency of water was lower in January and highest in November. Almost muddy water prevails during rainy season. The mean value of water transparency was 0.75±0.4 m. Air temperature was fluctuated remarkably during the study period. It ranged from 22.0°C to 34.0°C. The air temperature was found always higher than surface water temperature. The mean air temperature was 29.8±4.6°C. Surface water temperature ranged between 21.0 and 32.0°C. The mean water temperature was recorded 28.5±3.9°C. Water temperature showed an increasing trend in monsoon and post-monsoon season and decreasing in winter is supported by Mathew (1975). Water temperature is influenced by the air temperature, and it found highly synergistic with the air temperature. Rahman (1992) stated that the transparency of productive water bodies should be 40 cm or less, and water temperature ranging from 26.0 to 31.0°C was found suitable for aquatic life. The range of water temperature of the studied beel indicating almost suitable for fish habitat and breeding as well.

Table 1. Meteorological and physico-chemical parameters of Shakla *beel*

Parameters	Values					
	Jul	Sep	Nov	Jan	Jun	Mean±SD
Color of water	Clear	Clear	Turbid	Turbid	Brownish green	-
Average depth of beel (m)	1.78	2.20	1.89	0.80	3.0	1.93±0.7
Nature of beel bed	Hard	Hard	Hard	Hard-soft	Hard	-
SD transparency (m)	0.93	0.90	1.25	0.33	0.34	0.75±0.4
Air temperature (°C)	34.0	33.0	31.2	22.0	30.0	29.8±4.6
Water temperature (°C)	32.0	31.5	29.1	21.0	29.0	28.5±3.9
Dissolved oxygen (mg/L)	8.2	8.9	8.2	6.9	4.5	7.3±1.6
Free CO_2 (mg/L)	0.8	2.3	15.8	12.8	16.3	9.6±6.7
pH	8.0	8.0	8.5	7.3	8.5	8.1±0.4
Total hardness (mg/L)	21.6	20.0	33.6	29.0	9.0	22.6±8.4
Total alkalinity (mg/L)	31.5	26.0	29.7	35.0	12.0	26.8±8.0
Ammonia (mg/L)	0	0	0.2	0.01	0.17	0.08±0.09
Nitrite (mg/L)	0	0	0	0	0.3	0.06±0.12

Dissolved oxygen concentration (DO) varied between 4.5 and 8.9 mg/L, the higher concentration was found in post-monsoon period. The average oxygen concentration was recorded 7.3±1.6 mg/L. Banerjea (1967) reported that water bodies having a range of 5 to 7 mg/L DO is productive, while those having below this range are unproductive ones.

The values of free CO_2 were observed high at the advent of beel inundation; it showed wide fluctuation (0.8-16.3 mg/L) during the study period. The average value was recorded 9.6±6.7 mg/L. The high values (5-65 mg/L) of free CO_2 were also reported from the Surma-Kushiyara project area (FAP 1992). Free CO_2 content more than 20 mg/L may be harmful to fish and even lower concentration may be equally harmful when dissolved oxygen contents are less than 3 mg/L (Lagler 1972). Ruttner (1953) reported

that very low values even 0 mg/L of free CO_2 the photosynthetic activities of phytoplankton occurs normally.

The values of pH were found alkaline range (7.3-8.5). Ruttner (1953) quoted that a eutrophic lake normally maintains alkaline pH. The highest and the lowest values were found in November and June, and January respectively. The mean value of pH was 8.1±0.4. It exhibited a narrow range of fluctuation throughout the investigation period. According to Swingle (1967) pH value of 6.5 to 9.0 is suitable for fish culture and more than 9.0 is unsuitable because free CO_2 is not available in this situation.

Total hardness varied between 9.0 and 33.6 mg/L. The highest and the lowest values were observed in November and June respectively. The mean value was 22.6±8.4 mg/L. Total alkalinity varied between 12.0 and 35.0 mg/L. The highest and the lowest values were recorded in January and June respectively. The mean value was recorded 26.8±8.0 mg/L. The lower concentration of hardness and alkalinity indicated the beel water to be less nutrient enriched. Almost similar values of total hardness and total alkalinity were reported by FAP-16 (1992) from the northeastern areas of Bangladesh. Banerjea (1967) reported that 60 to 70% of average to highly productive ponds have total alkalinity ranging from 20-200 mg/L. Lake water registering hardness as calcium carbonate below 24 mg/L is generally regarded as soft (Clegg 1974). From the above discussion it may be concluded that the *beel* waters were found as soft-medium hard type and moderately productive.

Ammonia varied between 0.01 and 0.17 mg/L, it was recorded zero in the month of July and September. The mean value was 0.08±0.09 mg/L. Nitrite concentration ranged from traces to 0.3 mg/L. Low values of nitrite contents takes place due to rapid absorption of such nutrients by the infestation of macrophyte communities in the beel ecosystem.

Planktonic organisms

Abundance of total plankton in Shakla *beel* is presented in Table 2. It is evident from the table that a wide variation (1.4–27.2 x 10^3 cells/L) existed in the standing crop of total plankton in different months. The highest concentration of total plankton count was recorded in July and the lowest count was obtained in January with a mean of 15.4 x 10^3 cells/L. The contribution of phytoplankton ranged between 64.3 and 92.4% with a mean of 90.3%, while the contribution of zooplankton ranged from 7.5 to 35.7% with a mean of 9.7% to the total planktonic organisms. Low production of zooplankton in a lotic ecosystem is not uncommon. The highest concentration of phytoplankton and zooplankton were recorded in November and January respectively. Ehshan *et al.* (1996) recorded high phytoplankton (30-66x10^3 cells/L) and low zooplankton count (0.5-0.7x10^3 cells/L) from Chanda beel.

During the present investigation 23 genera of phytoplankton belonging to 15 families and 10 genera of zooplankton belonging to 7 families were recorded from Shakla *beel* (Table 3). The phytoplankton population was composed of algal flora belonging to the groups Chlorophyceae, Myxophyceae and Bacillariophyceae. Among the planktonic

algae Chlorophyceae contributed the bulk and the predominant genera were *Protococcus, Mougeotia, Microspora, Mesotenium, Closterium, Eremesphaera, Chlorococcum, Ophiocytium, Penium, Spirogyra, Zygnema, Trochiscia, Kirchneriella.* Myxophyceae included various species belonging to genera *Mycrocystis, Anabaena, Merismopedia, Polycystis, Anacystis* and *Nostoc.* Bascillariophyceae was represented by various species belonging to genera *Melosira, Navicula, Diatoma, Synedra.* Several authors (Ehshan *et al.* 1996; Hossain *et al.* 1998; Ehsha1 *et al.*1997) reported the dominance of Myxophyceae and Chlorophyceae groups from different beel ecosystems of Bangladesh. Phytoplankton diversity in the beels of upper Assam zone represented by four groups in the order of Chlorophyceae > Bacillariophyceae > Myxophyceae > Dinophyceae (Sugunan and Bhattacharjya 2000).

Table 2. Month wise planktonic abundance of the Shakla *beel*

Month	Phytoplankton ($x10^3$ cells/L)	Zooplankton ($x10^3$ cells/L)	Total Plankton ($x10^3$ cells/L)	Phytoplankton (%)	Zooplankton (%)
July	25.0	2.2	27.2	91.92	8.08
September	20.0	2.5	22.5	88.89	11.11
November	9.8	0.8	10.6	92.45	7.55
January	0.9	0.5	1.4	64.29	35.71
Mean	13.9	1.5	15.4	90.30	9.70

Table 3. Diversity of plankton in the Shakla *beel*

Plankton	Group	Genera
Phytoplankton	Chlorophyceae	*Protococcus, Mougeotia, Microspora, Mesotenium, Closterium, Eremesphaera, Chlorococcum, Ophiocytium, Penium, Spirogyra, Zygnema, Trochiscia, Kirchneriella*
	Myxophyceae	*Mycrocystis, Anabaena, Merismopedia, Polycystis, Anacystis, Nostoc*
	Bacillariophycese	*Melosira, Navicula, Diatoma, Synedra*
Zooplankton	Rotifers	*Polyarthra, Keratella, Filinia, Trichocerca*
	Cladocera	*Daphnia, Bosmina*
	Copepoda	*Cyclops, Nauplius, Diaptomus*
	Ostracoda	*Oicomonas*

Among zooplankton the represented genera were *Polyarthra, Keratella, Filinia, Trichocerca, Daphnia, Bosmina, Cyclops, Nauplius, Diaptomus* and *Oicomonas* belonging to four groups, Rotifera, Cladocera, Copepoda and Ostracoda. Rotifera was the most dominant group followed by Copepoda, Cladocera and Ostracoda. Almost similar observations were also made by Ehshan *et al.* (1996), Ahmed *et al.* (1997) and Patra and Azadi (1987). Similar observation was also made by Sugunan and Bhattacharjya (2000) from the beels in Assam.

Ichthyo-diversity and fishing methods

Fish genetic resources in northeastern regions are unique being a mixture of migratory, resident and exotic fish species. A total of 52 fish species belonging to 36 genera, 20 families and 1 species of prawn were accounted and identified so far from the Shaka *beel*. Out of them 38 resident fish species belonging to 27 genera, 17 families and 1 species of prawn were identified. Of the 52 fish species recorded, 16 species were belonging to the family Cyprinidae followed by Siluridae, Anabantidae and Channidae of which each family belongs to four species. The identified fish species were categorized into 25 groups. A list of those fishes with their harvesting methods is presented in Table 4. This beel is inhabited by the carps, barbs, catfishes, snakeheads, eels, minnows, loaches, featherbacks, gouramies, perches, gobies, puffer fishes, needle fishes, sardines, half-beaks and small prawns. The common and more abundant fish species in the beel are- glass perch (*Chanda nama, C. ranga*), barbs (*P. ticto*), gouramies (*Colisa sota, C. lalius*), loaches (*Lepidocephalus guntea*), freshwater spiny eels (*Mastacembelus pancalus*), gobies/mud skipper (*Glossogobius giuris*), catfish (*M. tengra*), needlefish (*Xenentodon cancila*), pufferfish (*Tetraodon cutcutia*) small prawn (*Macrobrachium lamarrei*). Haroon *et al.* (2002) identified a total of 92 species of fish and prawn from Sylhet-Mymensingh basin. He found the dominance of barbs, catfishes and major carps in the Sylhet sub-basin and catfishes, major carps and prawns in the Mymensingh sub-basin. In India, Sugunan and Bhattacharjya (2000) recorded 54 fish species belonging to 18 families from Dighali beel (Kamrup district), the common species contributing to commercial landings belong to eight groups (carps, catfishes, murrels, featherbacks, air-breathing fishes, hilsa, prawns and miscellaneous fishes).

Table 4. Fish species observed in the Shakla *beel*

Groups	Family	Scientific names	Fishing methods
Carps	Cyprinidae	*Labeo rohita, Cirrhinus mrigala, C. reba, L. boga, L. calbasu, L. gonius*	Enclosure with *pati*[$], FAD, Gill net, Seine net
Minnows	Cyprinidae	*Rohtee cotio, Esomus danricus, Salmostoma phulo, S. bacaila, S. cachius, Amblypharyngodon mola*	Drag net, Seine net, cast net, FAD
Barbs	Cyprinidae	*Puntius sarana, P. ticto, P. sophore*	Gill net, Push net, Cast net, FAD
Chinese carp	Cyprinidae	*Cyprinus carpio*	FAD, Seine net
Air-breathing catfish	Clariidae	*Clarias batrachus*	FAD*
Fresh water shark	Siluridae	*Wallago attu*	FAD, Seine net, Long line
Butter catfish	Siluridae	*Ompok pabda*	Seine net
Stinging catfish	Heteropeeustidae	*Heteropneustes fossilis*	FAD
Catfish	Schilbeidae	*Ailia coila, Acrichthys aor, M. vittatus, M. tengra*	Seine net, Push net, FAD
Feather back	Notopteridae	*Notopterus notopterus*	Seine net

Sardines	Clupeidae	*Gudusia chapra, Corica soborna*	Gill net, SM** seine net
Freshwater spiny eels	Mastacembelidae	*Macrognathus aculeatus, Mastacembelus armatus*	Gill net, Seine net, Drag net, Cast net, FAD
Spiny eel	Mastacembelidae	*M. pancalus*	Gill net, Seine net, Drag net, Cast net, FAD
Climbing perch/ Gouramies	Anabantidae	*Colisa sota, C. fasciatus, C. lalius, Anabas testudineus*	Gill net, Push net, FAD
Gobies/Mud skipper	Gobiidae	*Glossogobius giuris*	Push net, Seine net, Gill net, FAD
Mud perch	Nandidae	*Nandus nandus*	Gill net, Push net, FAD
Perch	Pristolepidae	*Badis badis*	Seine net, Push net
Glass perch	Centropomidae	*Chanda nama, C. ranga*	Push net, SM Seine net, FAD
Loaches	Cobitidae	*Botia dario, Lepidocephalus guntea*	Seine net
Snake-heads	Channidae	*Channa striatus, C. marulius, C. orientalis, C. punctatus*	Cast net, FAD, Hand line
Needlefish	Belonidae	*Xenentodon cancila*	Seine net, FAD
Half-beak	Hemirhamphidae	*Hyporhamphus gimardi*	Seine net
Puffer fish	Tetradontidae	*Tetraodon cutcutia, Chelonodon fluviatilis*	Seine net, FAD
Mud eel	Synbranchidae	*Monopterus cuchia*	Gill net, Seine net, Drag net, Cast net
Small prawn	Palaemonidae	*Macrobrachium lamarrei*	Push net, SM Seine net, FAD

[1]Fence made by bamboo splits and rope

* Fish aggregating device (FAD)-Fishing using Brush Park and from Kua (dewatering)

** SM- Small meshed

Local fishers, BMC members, Kua owners, retailers of local fish markets, NGO workers, Fisheries officials, and peoples residing along the immediate vicinity of the *beel* informed that species diversity and fish production of the *beel* ecosystem have declined, many species have been lost over time due to loss of fish habitat, over fishing, siltation, use of fertilizer and insecticide in the rice field and use of destructive fishing gears during the post-spawning season.

In Shakla beel, 13 types of fishing methods were generally found in operation. Those included enclosure for fish trapping, fish aggregating device (FAD) like katha (brush park) and kua fishing, and other traditional fishing gears *viz.* seine nets (purse seine net, moshari berjal, ghono berjal), gill nets (chapila jal, current jal, koi jal), cast net (jhaki jal), push net (felun jal), drag net (moi jal) and long line (chara borshi). Fishing gears of different meshes (2.5-40 mm) were found to operate into the beel ecosystem. Catch per unit effort (CPUE) of different gears varied between 1.5 and 14.0 kg/day. Sugunan and Bhattacharjya (2000) found a wide variety of fishing methods (passive gear, active gear, FAD, falling gear, dewatering) employed in the beels of Assam, which are very similar to the present findings. Haroon *et al.* (2002) reported eighteen types of fishing gears from the Sylhet sub-basin and thirteen types from Mymensingh sub-basin. They also recorded many kinds and sizes of bamboo made traps.

Inundation of the nutrient-rich and food-rich beel provides fishery habitat in the form of spawning grounds, nursery areas and a major feeding opportunities for a wide

range of fin-fish and a prawn species. A few types of fishing gears *viz.* seine nets (*moshari berjal, ghono berjal*) and gill net (*current jal*) were so far identified for indiscriminate killing of juvenile fishes of different species in the beel during post spawning period.

Macrophytes

A total of 11 species belonging to 11 genera and 10 families of aquatic weeds were identified from Shakla beel (Table 5). The identified macrophytes are five types *viz.* floating, emergent, spreading, submerged and rooted plants with floating leaves. The weeds usually grow along the beel margins and absent in the deeper regions. The weeds are used as human consumption, cattle food and main food item of Buffalo. Among the identified weeds *Najas najas* species was accounted dominant. The eggs of *Macrobrachium lamarrei* were identified into the *Najas najas* vegetation during April-September. Water hyacinth (*Eichhornia crassipes*) is usually used for covering a layer on the surface of brush park (FAD) installation, which provides shelter and additional nutrients for fish species. FAP-16 (1992) reported less abundant macrophytes from Surma-Kushiyara floodplain project. Sugunan and Bhattacharjya (2000) found a rich growth of marginal and submerged vegetation in the floodplain wetlands of Brahmaputra basin. Rahman *et al.* (1997) could not find any floating aquatic vegetation from the spawning locations of Halda, the Jumuna and the Brahmaputra river and there were no significant relationship existed between the aquatic vegetation and spawning of major carps. A unique feature of the floodplain wetlands is the rich growth of marginal and submerged macrophytes due to allochthonous and autochthonous nutrient loading, which often tend to replace the plankton community and hastens the pace of eutrophication. This is almost happened for closed beels, which are choked with floating and marginal vegetation. Open beels, however, generally harboured less macrophytes, which are favorably disposed for energy transformation through phytoplankton.

Table 5. Aquatic weeds in Shakla *beel*

Family	Local name	Scientific name	Type
Pontederiaceae	Kachuripana	*Eichhornia crassipes*	Floating
Lemnaceae	Edurkanipana	*Wolffia arrhiza*	Floating
Gramineae	Arail	*Leersia hexandra*	Spreading
Gramineae	Dal	*Hydrorzya aristata*	Emergent
Nymphaeae	Shapla	*Nymphaea nouchali*	Rooted plants with floating leaves
Najadaceae	Najas	*Najas najas*	Submerged
Compositaceae	Helencha	*Enhydra fluckruans*	Spreading
Marsiliaceae	Shusnishak	*Marsilea quadrifolia*	Emergent
Convolvulaceae	Kalmilata	*Ipomoea aquatica*	Spreading
Commelinaceae	Kanaibashi	*Commelina bengalensis*	Spreading
Nymphaeae	Padma	*Nelumbo nucifera*	Rooted plants with floating leaves

The abundance and succession of biotic communities occupying in the beels are influenced mainly by the unique water renewal pattern of the ecosystem. The high

fluctuations in water level and the alternating seasonal riverine connections are the inherent characters of the beel ecosystem. Fluctuation of water level in the *beel* ecosystem is an important parameter for fish spawning. The shallower areas of the *beels* were found suitable for the spawning of some resident fishes (*viz., Glossogobius giuris, Heteropneustes fossilis, Channa* spp, *Xenentodon cancila, Puntius* spp, *Mystus* spp, *Mastacembelus* spp., *Macrobrachium lamarrei* etc.). Ali (1997) reported that most of the smaller sized fishes breed into the shallower water areas, mainly in beel/floodplain.

In floodplain wetlands, water quality is influenced to a great extent by inflow of water from the connecting rivers, local catchment areas and by the metabolic processes of plants and animals living within the water body and the aquatic vegetation in particular. The turbidity in beel water was mainly due to silt and organic debris carried by the run-off waters. The weed-choked beels have the lowest turbidity. The basin and aquatic soil can influence the value of pH. The variations in the concentrations of DO and free CO_2 were mainly due to the rate of photosynthetic activity by aquatic vegetation and variation in the organic matter contents in the basin soil. The DO levels of beel water were fairly high and within the optimal range for the growth of fishes. An evaluation of hydrology and physico-chemical properties of water indicates that in spite of low values of hardness and alkalinity Shakla beel is found to be conducive to enhanced fisheries, capture fisheries and biological production as well.

The kua owners excavate ditches along the canals of the beel that connect the beel to the main river stream and, have a tendency to encroach *khas lands.* As such, most of the connecting canals of the beel become blocked off by the raised dyke of kuas and siltation as well. So, it is an essential task to excavate the connecting canals from the mouth of the river to the tail end of the beel for easy access of incoming water. For the sake of sustainability of species diversity every one should avoid complete harvesting of fish (mother as well their progeny) from the kua by dewatering. Initiative should be taken to well circulate the harmful effect of dewatering through mass media.

The dry season represents the most critical season for all species of fish and the greatest impact occurs at this period, mortality rate is high, populations are at their lowest levels, fishery habitat is limited, predation is at peak and growth is slowed. In this period, a certain amount of fish can be conserved in the deeper pools of beel ecosystem with the installation of brush park for next years successful breeding and recruitment to the population. In addition, to protect growth overfishing (indiscriminate killing of juveniles of different fishes) during post-spawning season fishing regulation should be imposed properly on such destructive fishing gears. In addition, conducting awareness program for the fishers can reduce indiscriminate killing of juveniles.

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(Manuscript received 2 August 2004)

Bangladesh J. Fish. Res.,8(2), 2004: 113-116

Selection of freshwater pearl mussel species for mantle transplantation in Bangladesh

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Abstract
Allograft mantle transplantations were studied in six species of freshwater mussels, *Lamellidens marginalis, L. corrianus, L. jenkinsianus, L. phenchooganjensis, Parreysia corrugata and P. favidens* by transplanting foreign mantle tissue into the mantle tissue of a host mussel. After three months of rearing, maximum survivability and pearl formation were observed in *L. marginalis* and *L. jenkinsianus* followed by *L. corrianus* and *L. phenchooganjensis*. Very poor results were observed in case of *Parreysia corrugata* and *P. favidens*. In addition to the natural pearl producing capacity of individual species, survivability and pearl production were related to the size of the mussel species. *L. marginalis* has been identified as the best species for mantle transplantation in Bangladesh.

Key words : Pearl, Mussel, Mantle transplantation

Introduction

Pearl culture is a type of aquaculture with high economic value. The prospect of pearl culture is bright and promising in Bangladesh due to the warm weather with twelve months growth period both for pearly mussel and pearl. Freshwater mussels, which are used for pearl culture, can be cultured in the fish pond and other suitable water bodies. Mussels filters the water as water cleaner, therefore, the pearl culture is environment-friendly. Pearl culture can be conducted in any kind of water bodies like ponds, lakes, rivers, reservoirs, etc. So, it is easy to extend in rural area with low input and high output. Pearl culture operation can be done by women. Therefore, it will provide more employment opportunities to the rural women who will play an important role in social and economic development of Bangladesh.

Although there is a great potential, pearl culture has not yet been flourished commercially in the country due to lake of technical know-how and financial constraints (Sarker 1994). A recent survey report also described the past history and present status of natural pearl culture and suggested the bright prospect of pearl culture in Bangladesh (Mazid 2001). Freshwater pearl culture started in China 2,000 years ago. Today, Chinese cultured pearls have demand throughout the world, 95% of freshwater pearl production

in the world market comes from China. Freshwater pearl culture is growing as a source of employment and income in many South-East Asian countries (Ram 1997).

Pearl production and quality mainly depends on the mussel species and operation techniques. The mantle tissue of different part has the different nacre secretion capability to produce the various qualities of pearl. Different place of tissue transplantation also affect the pearl quality. Pearl quality also depends on the age of mussels, juvenile secrets pearl layer and forms pearls much faster than adult. The environment such as water depth, water quality, natural food, etc. is also important to the pearl culture. Among all those factors related to pearl culture, mussel species is the key factor to the pearl culture. Because, nacre secretion of various mussel species may be different. In the present study, pearl formation through tissue transplantation in some mussel species have been investigated.

Materials and methods

Species selection

Six species of freshwater mussels have been selected. The species were, *Lamellidens marginalis, L. corrianus, L. jenkinsianus, L. phenchooganjensis, Parreysia corrugata* and *P. favidens.* Only strong and healthy mussels were selected for mantle tissue transplantation.

Methods for mantle tissue operation

Operation includes two steps, mantle tissue slice making and transplantation. For slice making, mussels of healthy and strong condition were selected. Mussel was opened and mantle tissue was then separated along pallial line from the mussel. Separated tissue strip was then transferred into a glass board and cut into small spices of 2 mm x 2 mm size.

For the mantle tissue transplantation, mussels of 1 year age, healthy and strong, with broad and distinct growth line and without disease or injury were selected. A piece of mantle tissue was taken with needle in one hand and a wound was created in the mantle tissue of mussels along the horizontal direction with a hook in another hand. At this point tissue slice was transplanted into the bottom of the wound. Similarly, the next one was transplanted following the direction from posterior side to center. In this process 8-10 slices were inserted in a single mussel.

Management practice

Operated mussels were transferred to a rearing pond of 65 decimal within 3-4 hours of operation. Water depth of the pond was 1.5-2.0 meters. In a net bag 3 mussels were stocked and hanged from a rope stretched across the pond in the surface of water. The hanging depth was 30-35 cm. Mussels are primarily plankton feeder, therefore yellow green water colour and about 30 cm transparency were maintained through proper fertilization to maintain the optimum plankton density in the pond.

Sampling

Mussels were checked for survival and health condition fortnightly. Water quality parameters were recorded fortnightly. After 3 months of rearing, mussels were counted for survival. Each mussel was opened and number of pearl in each mussel was counted.

Results and discussion

Table 1 showed the water quality parameters of rearing water. Temperature of water was suitable and in optimum range for pearl formation. Oxygen, pH and alkalinity also affect the pearl growth, which were in suitable range. Calcium is the most essential element to pearl culture, as calcium carbonate is the major component of both the mussel's shell and pearl. Mussel and pearl production depend on assimilation of calcium. It is recommended that calcium content of rearing water should be over 10 mg/l for better mussel growth and pearl production (Dan *et al.* 2001). In the present study, calcium in rearing water was more than 10 mg/l throughout the rearing period.

Table 1. Water quality parameters in the ponds during the rearing period

Parameters	Rearing period (weeks)						
	0	2	4	6	8	10	12
Temperature (°C)	28.5	28.0	29.2	30.0	31.1	29.8	31.5
Oxygen (mg/l)	5.2	5.4	5.8	6.0	5.5	5.4	5.8
pH	7.8	7.2	7.5	7.6	7.3	7.5	7.6
Alkalinity (mg/l)	170	170	180	165	185	190	175
Calcium (mg/l)	50	30	35	38	42	46	52

Survivability of mussels after tissue transplantation was the highest (100%) in *L. marginalis* (Table 2). Similar results also obtained in case of *L. Phenchooganjensis, L. jenkinsianus and L. corrianus.* Survivability was low in *Parreysia corrugata* and *P. favidens.* Low survivability in this two species was related to the smaller sizes of the mussels.

Table 2. Growth of pearl and survival of mantle tissue transplanted mussels after 3 months rearing in pond

Name of species	Average length (cm)	No. of mussel operated	survivability	% of pearl bearing mussels	maximum no. of pearl/ mussels	Average no. of pearl /mussels
L. marginalis	9.5	50	100	93	10	6.4
L. phenchooganjensis	10.5	50	87	75	8	5.0
L. jenkinsianus	9.4	50	97	89	8	6.0
L. corrianus	9.4	50	84	68	7	5.3
P. corrugata	6.1	50	56	45	5	2
P. favidens	5.1	50	59	53	6	3

Among the survived mussels, 93% of *L. marginalis* found pearl bearing, which was 89% in *L. jenkinsianus*. In case of *L. phenchooganjensis* and *L. corrianus* pearl bearing mussels were 75% and 68%, respectively. Only 45% and 53% of survived mussels was pearl bearing in case of *P. corrugata and P. favidens*, respectively.

In the present study, allotransplantation of mantle tissue has been followed. Pahna and Kasavititkul (1997) studied the mantle transplantation in freshwater pearl mussels in Thailand and observed that allotransplantation yielded the highest success rate of forming pearl sacs. Maximum numbers of pearl were produced in *L. marginalis* and *L. jenkinsianus*, highest average number of pearl also was belong to this two species. Begum *et al.* (1987) studied the pearl formation in *L. marginalis*. They used ceramic bead of 1-2 mm diameters and mantle pieces of 2 mm size. They observed that 15.1% of the transplanted mussels produced matured pearl. Mian *et al.* (2000) studied pearl production in freshwater mussel *L. marginalis*. They used nuclei pearl production process and selected sand, stone, fish eye ball and artificial pearl bead as nuclei. They recorded highest pearl production in stone and lowest in the sand. It is not clear from that study, whether a pieces of mantle was simultaneously inserted with nucleus, which is essential for pearl formation. From the results of the present study, it is clear that maximum pearl formation was found in *L. marginalis*. This is related to the size of this species, which is wider than other species. Long species *L. corrianus* and *L. phenchooganjensis* also showed encouraging results of pearl. formation. *P. corrugata* and *P. favidens* are not suitable for pearl culture operation due to its small size and high mortality after tissue transplantation. Among these species *L. marginalis* can be selected for freshwater pearl culture in Bangladesh. Because, this species is abundant in almost all freshwater bodies of Bangladesh (Sarker 1994). The present study was for a short period to investigate the pearl formation in different mussels species. Further, long-term study is necessary to compare the size and quality of pearl produced in different species.

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(Manuscript received 19 September 2004)

*Bangladesh J. Fish. Res.*8(2), 2004: 117-126

Effect of salinity on food consumption and growth of juvenile Nile tilapia (*Oreochromis niloticus* L.)

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Abstract
The effect of salinity (0, 10 and 20‰, water temperature 28 ± 1°C) on food consumption and growth of juvenile Nile tilapia, *Oreochromis niloticus* L.. (9.94 ± 0.15 g) were investigated by feeding group of 20 fish at 2% body weight day^{-1}. Individual food consumption was measured using X-radiography. There were no significant differences in growth or white muscle protein concentrations among groups. During feed deprivation, weight loss was similar for fish held at 0‰ and 10 ‰ salinity, but after 7 days over 50% of the fish maintained at 20‰ salinity developed lesions covering 5-25% of the body. No significant relationships were observed between individual specific growth rates and food consumption rates within the groups. The fish in all salinity groups showed a negative correlation between specific growth rate and food conversion ratio. The coefficient of variation for wet weight specific food consumption and the mean share of meal for each fish were used as a measure of social hierarchy strength. A negative correlation was observed between coefficient of variation in food consumption and mean share of meal. The social hierarchy structure was similar in all salinities; 25% of the fish were dominant (18.29% above an equal share of meal) and 30% were subordinate (16.19% below an equal share of meal) and the remainder 45% fish fed theoretical share of meal (MSM, 5.26%).

Key words : Nile tilapia, salinity, food consumption, growth.

Introduction

Some tilapias are eurythermal and euryhaline (Stauffer *et al.* 1984, Suresh and Lin 1992, Likongwe *et al.* 1996, Stickney, 1986). Increased growth with increasing salinity up to the maximum level that can be tolerated by a particular species has been observed amongst many species of fish (De Silva and Perera 1976). The effect of salinity on growth is influenced by temperature and is species specific (Stauffer *et al.* 1984). Likongwe *et al.* (1996) found that *O. niloticus* grew better at 28-32°C than 24°C when reared at 12‰ salinity. Increased growth with increasing salinity has been attributed to an increase in food consumption and lowered food conversion ratios in the mullet (De Silva and Perera 1976) and European bass (Dendrinos and Thorpe 1985). Jurss *et al.* (1984) attributed the better growth of *O. mossambicus* at 10 and 33 ‰ than at 0 ‰ lower

food conversion ratios. The effect of salinity on food consumption and growth of tilapias has been studied in relatively few species and in those studies conducted food consumption was not measured accurately and/or for individual fish. Hence, the relationship between food consumption and growth is poorly understood. For most species, optimal ranges of salinities for growth have been inferred from data on natural distribution or fragmentary experimental evidence.

The main aim of the present study is to investigate the effect of salinity on growth and food consumption relationships of individual *O. niloticus* held in groups. When individual food consumption rates are known it is possible to examine the feeding behaviour of fish and to compare the nutritional status of an individual fish with its physiological performance (McCarthy *et al.* 1993, Cater *et al.* 1995). Also, studying white muscle protein concentrations give more detail on protein growth, which provides a better understanding of the relationships between this parameter with growth performance and food conversion efficiency compared to using live wet weights only.

X-radiography is a valuable technique that provides direct quantitative measurements of food consumption for individual fish (Talbot and Higgins 1983). In recent years, X-radiography has been used to measure food consumption rates of individual fish under a variety of experimental conditions (Carter *et al.* 1992, Stead *et al.* 1999, Jobling *et al.* 1989). This technique is a relatively simple, which may be applied to studies in which knowledge of individual feed intake is required. Hence, the aims of this study were: (i) to identify the optimum salinity for better growth performance of O. *niloticus* and (ii) to compare the interrelationships between individual estimates for food consumption, growth rate and white muscle protein concentration of O. *niloticus* under different salinities.

Materials and methods

Fish husbandry

Juvenile Nile tilapia *Oreochromis niloticus* (≈ 450 fish, 7-8 g) were held in fresh water in a 150L stock tank at 28±1°C prior to the start of the experiment. The fish were hand-fed a commercial pellet (45% protein, oil 18%, ash 8.5%, fibre 2%; "Ewos" fish food company, UK) offered once (9.00 - 9.30h) at 2 % body weight (bw)/day.

After 15 days acclimation, fish (9.94 ± 0.15g) were anaesthetised (4% Benzocaine in ethanol, 0.15 g/l), blotted dry freeze branded with a unique set of marks using liquid nitrogen. They were then distributed among six glass tanks (size 60×37×29.5cm, 65.5L) with a water volume of 60L. Water temperature 28.3 ± 0.5°C, oxygen was maintained at 5.3±0.7 mg/ and photoperiod was 18L: 6D. Three salinity treatments with two replicates for each salinity T_1 (freshwater 0‰), T_2 (10‰) and T_3 (20‰) were maintained by adding Artificial Sea water mixture to recirculated, filtered aerated fresh water. Salinity was measured daily using a Refractometer (HANNA). Salinities were in T_1 (0‰), T_2 (10.2±0.5‰) and T_3 (20.3±0.6‰).

After stocking the experimental tanks, fish were acclimated for 7 days and fed at 2% body weight ration once a day. The salinity in T_2 (10‰) and T_3 (20‰) were adjusted by

gradually increasing (2‰ day^{-1}) the amount of crude salt added to achieve the required rate of increase in salinity. After the required salinities, 10‰ and 20‰ were reached within 5 (for 10‰) and 10 (20‰) days, then the fish were allowed to acclimatize to their new salinities for up to 10 days before measurements of individual food consumption and growth were made. All the fish were fed the previously described feed (normal pellets reconstituted in the same manner and part of feed used to make ballotini labelled feed) at the rate of 2% body weight ration once a day. Faeces and un-eaten feed were removed daily from the tanks and 30% of water was exchanged and water lost in this process was replaced by freshwater from a holding tank (0, 10 and 20‰) sterilised with an UV-light.

Preparation of repelleted diets

For the measurement of individual food consumption, the normal feed was replaced by feed containing radio-opaque ballotini (size 30, 0.40 - 0.60 mm, British Optical Ltd., Walsall). The marked feed was prepared by grinding the normal feed, and ballotini (2.5% of the food wet weight) and water (15% of the food wet weight) were added. The feed was then mixed for three hours and repelleted using a California Pellet Mill (pellet size was 2 mm) and dried overnight 70°C and stored at 0°C until required. Dry weight of the experimental feed was measured following the usual procedures described by AOAC (1983).

To calculate the relationship between the amount of food consumed by each fish and the number of ballotini present in the digestive tract of each fish, a calibration line was calculated for the marked feed before the experiment commenced. This was carried out by X-raying known weights of food (0.025 - 2.701 g) and counting the number of ballotini (X-ray negative) contained. A regression line was then constructed relating the number of ballotini to a weight of food ($Y = 0.0138X - 0.039$, $n = 38$, $R^2 = 0.99$; $P < 0.05$). The diet calibration curve was constructed and the high correlation of the regression line suggested the uniformity of the labelling of the feed with ballotini.

Measurements of individual food consumption

Individual food consumption was measured using a modified version of the X-radiography technique described by Talbot & Higgins, (1983). Food consumption was measured on 31 July, 14 August and 28 August 2001. Fish were fed the marked feed, and one hour after feeding the fish were anaesthetised and X-rayed, in groups of 10 using a portable X-ray machine (Todd Research 80/20 Portable X-Ray Unit, 20 mA, 80 Kv, 1.5 sec. exposure; Kodak Industrex CX film). Total length and weight of each fish were recorded and, if necessary, fish were remarked and returned to their respective tanks. Individual food consumption was measured by using formula used by Stead *et al.* (1999) and also described in next data treatment section of this paper.

Starvation experiment

A starvation experiment was conducted over 7 days using three groups of fish (8.36 ± 0.10 cm and 9.80 ± 0.24 g, n = 20) maintained at 0‰, 10‰ and 20‰ salinity) in tanks as previously described. After 7 days fish were anaesthetised, length and weight were recorded and fish were killed.

Measurement of protein content

At the end of the feeding experiment, protein concentration of white muscle in each fish was measured. After 15 days from the last X-ray, all the fish from each tank were anaesthetised using benzocaine and weight and length recorded. A sample of white muscle (≈ 120-150 mg) was taken from 10 fish (5 dominant and 5 subordinate, according to their ranking position measured by mean share of meal) from each tank and immediately frozen in liquid nitrogen and then stored at -20°C until analysed for protein concentration. Protein concentration in white muscle was determined according to the method of Lowry *et al.* 1951.

Treatment of data and statistical analysis

The wet weight specific growth rates, SGR (% body weight day^{-1}) for individual fish were calculated followed the equation of Ricker (1979). Food consumption, FC (mg dry weight food) for individual fish was determined using the following equation: FC (mg dry weight of food) = GB * X; where, GB is the number of glass beads observed in each fish based on one X-ray measurement and X is the milligrams of dry food corresponding to one glass bead from the calibration curve. The variability in daily feeding of each fish was determined using the coefficient of variation, CV_i (McCarthy *et al.* 1992).

The share of meal, SM (%) was defined as the proportion of the total food consumed by all fish in a tank that was eaten by an individual fish and calculated as SM (%) = AC/ $\sum AC \times 100$; where, AC is the absolute daily food consumption rate (wet weight mg day^{-1}) of an individual fish and $\sum AC$ is the sum of the absolute daily food consumption rates for all fish in a group. As repeat measurements of consumption were made in this study, the mean share of the group meal (MSM, %) for each fish over the experiment was calculated. The mean share of the meal shows the inter-individual variation in consumption and was used as a measure of dominance and assign social rank to individual fish. The mean share of the meal, MSM (%) was then calculated for each individual fish as MSM (%) = $\sum SM / n$; where, is the sum of all the shares of the meal for an individual fish and n is the number of estimates (based on 3 X-ray measurements) for the SM for each individual fish. MSM was used as an indicator of the feeding rank of each individual fish. The food conversion ratio, FCR (mg dry weight of food .g^{-1} wet weight of fish) was calculated as described by Stead *et al.*, (1999).

Statistical analysis

ANOVA was used to examine differences within and between treatments (salinity). Where ANOVA indicated significant differences among groups, Scheffe's multiple range test was used to locate the means that were significantly different from each other (Zar 1984). Pearson's product moment correlation was used to investigate the relationships between individual specific growth rates, food consumption rates, food conversion ratios, coefficient of variation and mean share of the meal. All statistical analysis was carried out using SPSS 9.0 statistical package.

Results

No significant differences were found in group consumption rates when the fish were fed the daily diets (extruded form) and the re-pelleted diets that were fed to the fish on each X ray occasion (data not shown). From the three X-ray occasions an average of 91.94 ± 1.34% of group meals was accounted for from the X ray data. The X-radiography technique has previously been shown to give accurate measurements of individual food consumption in rainbow trout, accounting for over 93% of the food hand-fed to the fish (Carter *et al.* 1992).

The average initial body weight of fish in each of the experimental groups are shown in Fig. 1a. ANOVA indicated that there were no significant differences ($p<0.05$) in the average initial body weight of the replicate groups of individual fish at each salinity and between the 3 treatments (0, 10 and 20‰). Mean final weight (g) and protein concentrations in white muscle in fish at different salinities were not significantly different (Figs. 1b & 1c). Mean specific growth rate, weight loss, food consumption rates and food conversion ratio were also not significantly different (Figs. 1d, 1e & 1f, respectively).

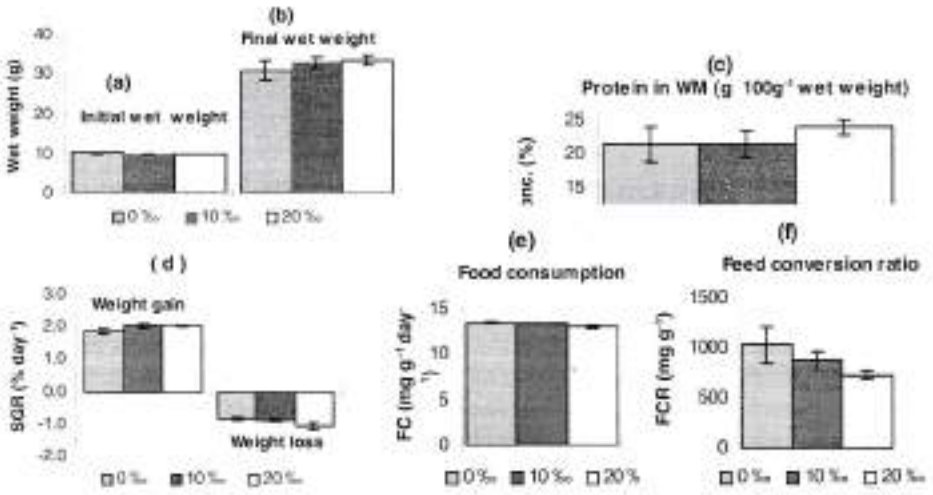

Fig. 1. Mean initial wet weight (g) in 1a, mean final wet weight (g) in 1b, protein concentration in white muscle in 1c, mean specific growth rate and mean weight loss in 1d, mean food consumption in 1e and food conversion ratios in 1f of fish under different salinity treatments (0, 10 and 20 ‰) during the experimental period.

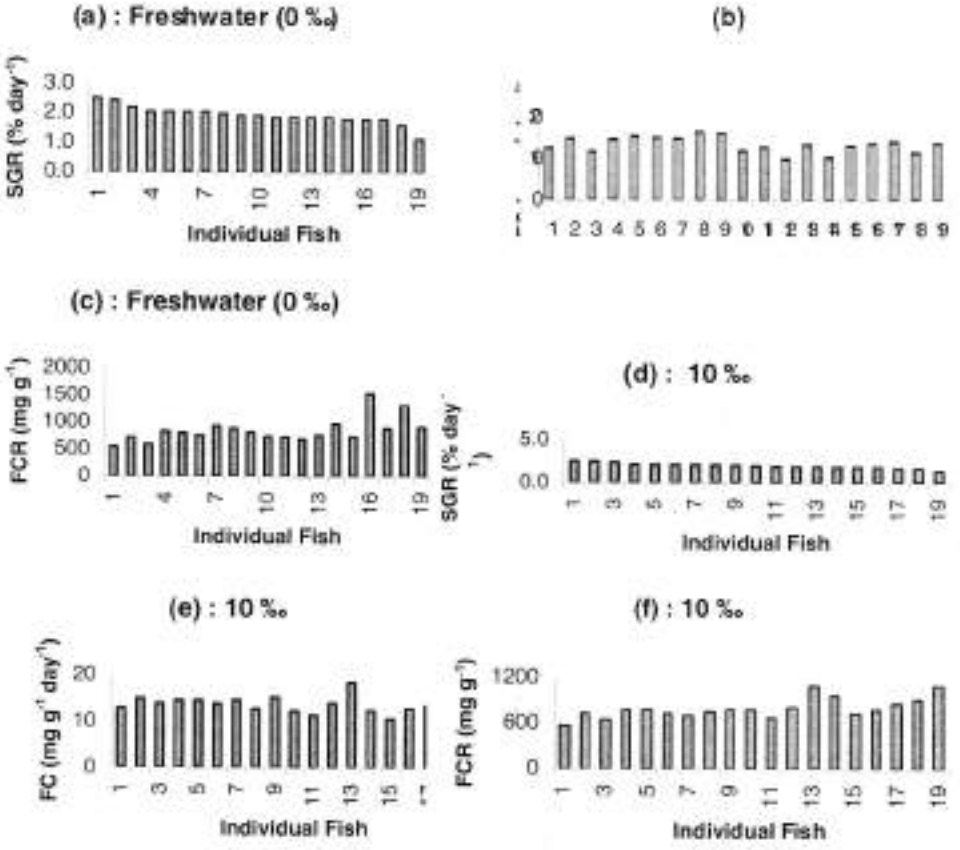

Fig. 2. Individual specific growth rates for fish in freshwater (0‰) are ranked in descending order 2a and the respective rates of food consumption are plotted directly below for each corresponding fish in 2b and similarly for food conversion ratios in 2c, respectively. Similarly, SGR for fish in 10‰ are shown in 2d and the respective FC in 2e and FCR in 2f.

When specific growth rates for individual fish in each of the three salinity groups were ranked in descending order and then compared to their corresponding rate of food consumption and food conversion ratios for the same fish, no significant correlation ($p > 0.05$) were observed (Figs. 2a, 2b & 2c) for the fish in freshwater (0‰). In addition, there were no significant ($p > 0.05$) correlation (Pearson product moment correlation) between food consumption and food conversion ratios (Figs. 2b & 2c) for the fish in freshwater (0‰ salinity). Significant (Pearson product moment, $p < 0.05$) negative correlation (Figs. 2a & 2c) were observed between individual specific growth rates and food conversion ratios for fish in freshwater (0 ‰ salinity). Similar results and trends were observed for

fish reared in 10‰ (Figs. 2d, 2e & 2f) and 20‰ (Figs. 3a, 3b & 3c) salinities, respectively.

During the starvation (feed deprivation) experiment the weight loss (SGR %. day^{-1}) was not significantly different for all treatments (Figs. 3a, b, c). Here to note that during feed deprivation after 7 days over 50% of the fish maintained at 20‰ salinity developed lesions covering 5-25% of the body.

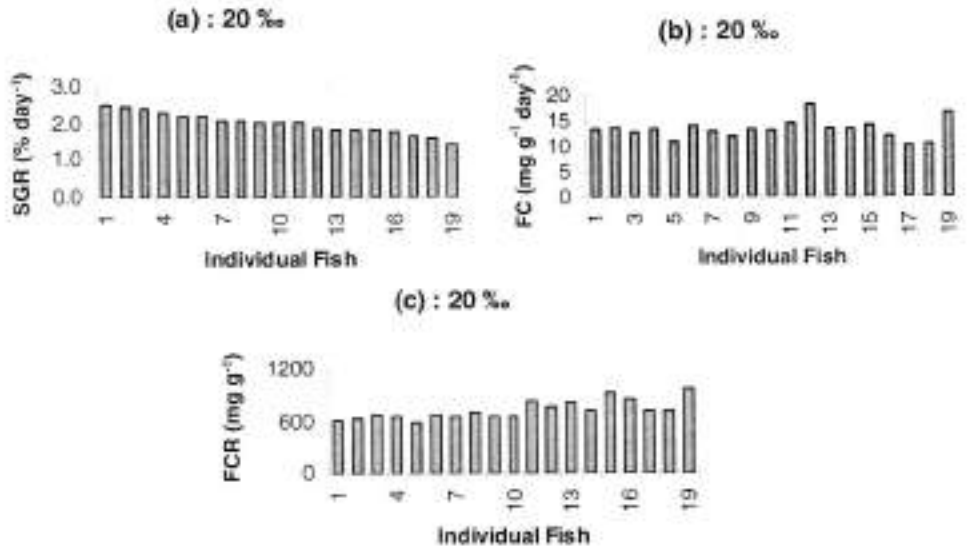

Fig. 3. Individual SGR for fish in 20‰ fish (n = 19) are ranked in descending order in 3a and the respective rates of FC are plotted directly below for each corresponding fish in 3b and similarly for FCR in 3c, respectively.

The MSM (%) of all individuals in each group of fish reared under different salinities were ranked in descending order and are illustrated in Figs. 4a, 4b & 4c. There were no differences observed in feeding hierarchies between the groups of fish reared at different salinities; 25% of the fish were dominant (18.29% above an equal share of meal) and 30% were subordinate (16.19% below an equal share of meal) and the remainder 45 % fish fed theoretical share of meal (MSM, 5.26%). The coefficient of variation for wet specific food consumption CV_c (%) and the share of the meal MSM (%) for each fish were used to determine social hierarchy strength. The relationship between mean share of meal and coefficient of variations for wet specific food consumption for all replicate groups are shown in Figs. 4d, 4e & 4f. In all the treatment groups there is a negative correlation between MSM and CV_c and both the range of meal sizes and the range of individual values for CV_c were significantly ($p<0.05$) different within the group indicating the strength of the social hierarchy within the groups. A lower CV_c value indicates that the meal size of the individual fish was similar from day-to-day whilst a higher CV_c value indicates a more varied feed intake. Dominant fish have been shown to

have less variation in day-to-day food consumption compared to subordinate fish. Dominant fish can obtain food on all feeding occasions; however, subordinate fish are often unable to feed due to their low ranking position and only fed when possible, hence subordinate fish have tended to show higher CV_c values.

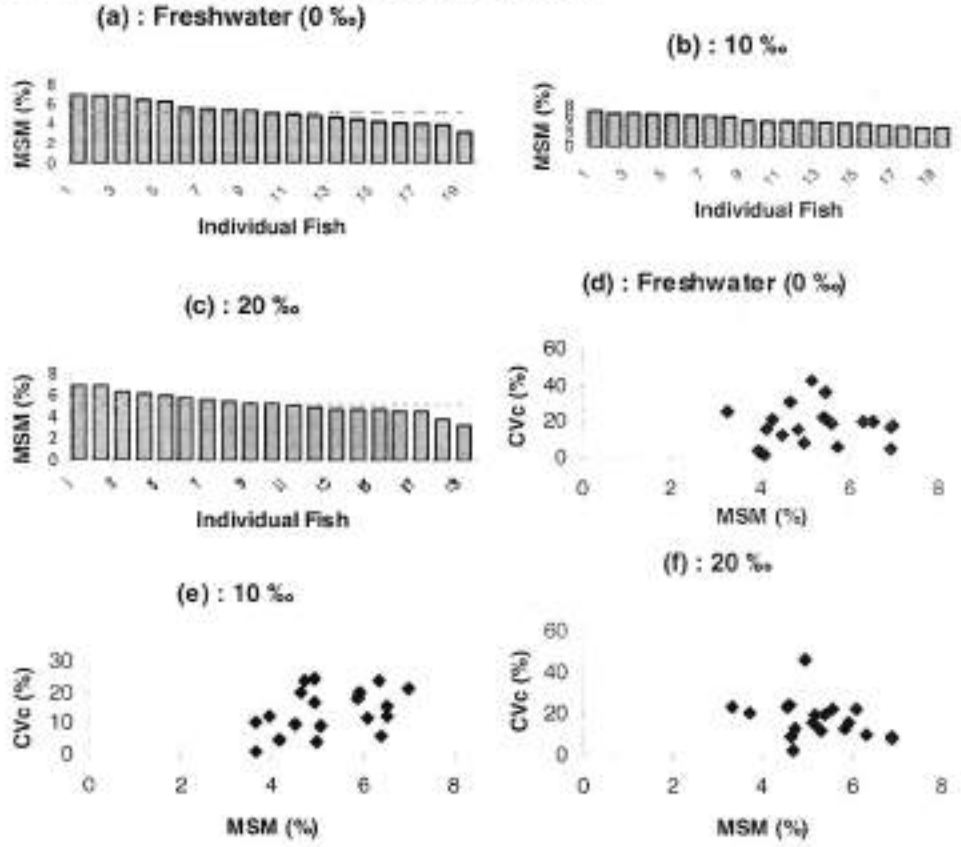

Fig. 4. Mean share of meal (MSM, %) for individual fish (n = 19) in different salinities; 0‰ in 4a, 10‰ shown in 4b and 20‰ in 4c. The horizontal dashed (------) line on each graph represents the theoretical mean share of the meal, if all fish were feeding at an equal rate. The relationship between the mean share of meal (MSM, %) and the coefficient of variation for wet weight specific food consumption (CV, %) for individual fish (n = 19) in different salinities: 0‰ are shown in 4d, 10‰ in 4e and 20‰ in 4f.

Discussion

Weights and specific growth rates of *O. niloticus* reared at 0, 10 and 20 ‰ increased from about = 10g to ≈ 35g over 75 days and there were no significant differences among salinity treatments. Similarly, protein concentration in the white muscle was not significantly different between salinity groups. Likongwe *et al.* (1996) reported that a

temperature of 28-32°C and salinity 0-12‰ could promote rapid growth of juvenile Nile tilapia , but a salinity of 16‰ combined with water temperature of 32°C may be deleterious because the fish developed body lesions under these conditions (when fish were fed at 3% bw/day ration). The results of the present study did not agree with the findings of Likongwe *et al.*, (1996) because during the growth experiment no visible sign of stress on the fish body when the fish were fed at 2% bw/day ration and reared at 20 ‰. In the present study, only body lesions were observed in fish grown at the highest salinity (20‰) after 7 days feed deprivation (starvation experiment) and this was the disagreement with Likongwe *et al.* (1996) as their study reported body lesions were observed during the growth experiment. In all salinities (0, 10 and 20 ‰), fish in the current study were observed to exhibit aggressive behaviour when feeding and it is possible that the 2% bw day^{-1} ration level was low for the experimental juvenile fish (*O. niloticus*). The ration level (2% bw/day) was chosen after consultation of the available literature and it was assumed that 2% bw/day ration for one meal (one meal was chosen because X-radiography was involved to measure food consumption) would be suitable for growth of juvenile Nile tilapia. However, Jauncey (1998) suggested this level may be low for optimum growth.

An increase in food consumption and growth with increasing salinity has been reported for several species of fish (De Silva and Perera 1976). Watanabe *et al.* (1985) suggested that feed conversion efficiency increased with increasing temperature and higher salinity levels. However, in general increasing temperature and salinity adversely affected feed conversion efficiency (Likongwe *et al.* 1996). In the present study, no correlation was observed between individual specific growth rates and rates of food consumption with increasing salinity but the fish with higher specific growth rates showed lower food conversion ratios i.e. SGRs were negatively correlated with FCRs. Similar relationships were reported by Watanabe *et al.* (1993) for juvenile Florida red tilapia and their study also suggested that specific growth rate is positively correlated with food consumption.

Average meal size was used as a measure of dominance to assign social rank to individual fish. All fish in each tank were either assigned as being dominant or subordinate on the basis of their share of meal. Dominants were all those fish who consumed more than the theoretical equal share of meal, and the subordinates were all those below the theoretical mean line. From the results it appears that the social hierarchy structure is similar in all treatments. Also, approximately 25% of the fish were dominant (18.29% above an equal share of meal) and 30% were subordinate (16.19% below an equal share of meal) and the remaining (45%) fish were within the theoretical mean share of meal (MSM, 5.25%). Similar trends were observed in all treatment groups. The fish were hand-fed and the entire ration consumed 2 in minutes or less and it was observed that maximum fish showed aggressive behaviour. This may reflect that tilapia is aggressive when feeding at low stocking densities (33.3 g/fish/l). Competition amongst fish is often found to increase under conditions of resource restriction (space and feed). Tilapiine fishes like other animals, form dominance hierarchies in accord with this theory and subordinate fish may suffer at the expense of a few dominant individuals. In

the present study both the range of meal sizes (MSM) and the range of individual values for CV_c were negatively correlated. Similar negative correlation between MSM and CV_c were observed for fish in the different salinities.

Although changes in salinity (0, 10 and 20‰) did not appear to have a significant effect on growth performance of *O. niloticus*, the results reported the complexity of the interrelationships of food consumption and growth rate with salinity. Furthermore, the study has raised some interesting questions with regard to the effect of ration level and stocking density on growth performance of *O. niloticus* under different salinities.

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(Manuscript received 4 May 2005)

Bangladesh J. Fish. Res., 8(2), 2004: 127-133

Growth and reproductive performance of locally isolated brackishwater rotifer (*Brachionus plicatilis*) feeding on different microalgae

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Abstract
Population growth and reproductive capacity of brackishwater rotifer, *Brachionus plicatilis*, were evaluated, for a period of 8 days in a temperature controlled (~25°C) microalgal laboratory, under three different algal feeding regimens. The algal species that were tested are: (i) *Chlorella* sp. (T_1), *Tetraselmis chui* (T_2), *Nannochloropsis oculata* (T_3). The feeding density of each algal species was maintained similar as of $4.5x10^6$ cells ml. The rotifer fed on *T. chui* showed the highest ($p<0.05$) population growth (131.5 ind./ml), compared to that fed on *Chlorella* sp (45.67 ind./ml) and *N. oculata* (43.44 ind./ml). The abundance of egg bearing rotifers was also higher (35.77%) with *T. chui* than with *Chlorella* sp (27.76%) and *N. oculata* (24.60%). The results of the present study indicate that *T. chui* could be the most suitable algal food for the stock culture of locally isolated rotifer *B. plicatilis*.

Key words : Microalgae, Rotifer, Growth, Reproductive performance

Introduction

The rotifer, *Brachionus plicatilis* is an important and essential food item in the early larval stages of many marine and brackishwater fish species. It is an excellent first food for larvae because of its (i) relatively smaller size, (ii) slow swimming speed, (iii) habit of staying suspended in the water column, and (iv) ability propagation in captivity at high density and reproductive rate. Microalgae comprise the principal food component for most cultured rotifer. Many species of algae may be used and the choice may depend on the availability, ease of culture under local conditions and the exact nutritional requirements of the rotifers and target aquaculture species. Microalgae high in □-3 HUFAs such as *Nannochloropsis* sp. have been regarded as very good food for culturing rotifers (Hirata 1989, Fulks and Main 1991). The most commonly used algal species that are being used to culture rotifer are *N. oculata, Tetraselmis tatrathele, T. suecica* and *Isochrysis galbana* (Person-Le Ruyet 1975), *Chlorella* sp. (Theilacker and McMaster 1971) Highly concentrated *Chlorella vulgaris* and freeze-dried algae have also been used successfully to feed rotifers in Japan (Hirayama *et al.* 1989). *Tetraselmis subcordiformis, Chlorella* sp., *Chlamydomonas* sp. and *Nitzschia closterium* have been found excellent

foods for growth and hatching of *B. plicatilis*, although the green algae *Tetraselmis* was better than the others in mass culture (Wang and Liang 1980).

Though the seed production of marine shrimp, *Penaeus monodon*, has already reached to a level of self sufficiency in Bangladesh, that of many important marine and brackishwater finfishes has yet to support the commercial production. Besides the lack of technical know-how of breeding and larval rearing, knowledge on culture and supply of appropriate live food for the first feeding fish larvae is scanty. In a series of studies on live food culture for marine and brackishwater fin and shellfish, the present experiment was conducted to determine the feeding effect of three different locally available microalgal species on the growth and reproductive performance of locally isolated brackishwater rotifer, *Brachionus plicatilis*, under stock culture condition.

Materials and methods

The stock culture of the rotifer was done in a temperature controlled (about 25°C) microalgal laboratory at the Brackishwater Station of Bangladesh Fisheries Research Institute (BFRI), Paikgacha, Khulna. Three different microalgae, *viz.*, *Chlorella* sp. (T_1), *Tetraselmis chui* (T_2), and *Nannochloropsis oculata* (T_3) were used as food to evaluate their effects on growth and reproductive performance. Nine 500 ml Erlenmeyer flasks were divided into three treatment groups. The flasks were placed at a distance of approximately 30 cm from a fluorescent tube light, having an intensity of about 2500 lux/m^2/sec. Photoperiod was maintained as 16:8 hrs L:D. *Chlorella* sp., *Tetraselmis chui*, and *Nannochloropsis oculata* were collected, isolated and cultured separately in laboratory conditions using the BFRI microalgae culture medium (Shah *et al.* 2004). When the concentration of each algae reached to 4.5×10^6 cells/ml, three rotifer culture flasks were filled in up to 300 ml with each algal culture following completely randomized design.

Rotifers were collected and isolated from the local brackishwater rivers and shrimp ponds using a zooplankton net of 250 to 90μ mesh. Each of the test flasks was inoculated with rotifer at a density of 5 ind./ml. The salinity of microalgae and rotifer culture water was 20‰. The initial abundance of initial egg bearing rotifers was estimated to about 12.53%. The duration of algal feeding trial on growth and reproductive capacity on rotifer was 8 days.

The concentration of rotifers was estimated every two days. Depending upon rotifer density, an unspecified amount of rotifer culture was poured through a 45μ sieve to catch a large number of rotifers on the screen. These were then rinsed with a small amount of filtered seawater using a squirt (wash) bottle and placed in to petri dish. These concentrated rotifers were then sampled with a bulbed pasteur pipette and placed on the Sedgewick-Rafter counting cell and counted under the dissecting microscope (Braley 1994). The mean count was obtained from 6 counts. Instantaneous growth rate (K) was calculated from the expression of -

$$K = \frac{\text{Log}_e N_t - \text{Log}_e N_0}{t}$$ (James *et al.* 1983)

Where, K = instantaneous growth rate;
N_0 = initial number of rotifers; and
N_t = final number of rotifers after t days.
t = culture days

While the growth of rotifer was estimated under microscope, the number of egg bearing rotifers was also recorded. The percent abundance of egg bearing rotifers (EBR) was estimated, to understand the reproductive capacity (RC) of rotifers, following the formula given below:

$$\text{Reproductive capacity (RC)} = \frac{\text{Number of egg bearing rotifers}}{\text{Total number of rotifers}} \times 100 \text{ (Braley 1994)}$$

Data were analyzed following one way ANOVA and Duncan's Multiple Range Test (DMRT), using a PC equipped with STATAGRAPHICS *Ver. 7.*

Results and discussion

Population growth of rotifer, *Brachionus plicatilis*, fed on different microalgal diets is given in Table 1. Among the three microalgae, *Tetraselmis chui* (T_2) resulted in the significantly highest mean population growth of 131.5 ind./ml ($p < 0.05$) at the end of the eight days culture. The population growth of rotifers fed on *Chlorella* sp (T_1) and *Nannochloropsis oculata* (T_3) was not only similar ($p > 0.05$) with the growth values of 45.67 ind./ml and 43.44 ind./ml, respectively, but also nearly three times lower than that fed on *T. chui*. In 2 - 6 days of culture, the rotifers fed on *Chlorella* sp. and *N. oculata* showed apparently higher percent abundance of carrying eggs compared to those fed on *T. chui* (Table 1). However, at the 8th day of culture, the egg bearing rotifers (EBR) was significantly higher ($p < 0.05$) in those fed on *T. chui* (35.77%) than in those fed on *Chlorella* sp. (27.76%) and *N. oculata* (24.60%).

Table 1. Growth and reproductive capacity of rotifer, *Bracchionus plicatilis*, fed on different microalgal diets for an eight-day culture

Microalgal diets (Treatments)	Time in days	Population growth		Reproductive capacity	
		Initial no. (ind./ml)	Final no. (ind./ml)[1]	Initial EBR (%)	Final EBR (%)[1]
Chlorella sp (T_1)	2	5	17.26 ± 5.05	12.53	16.18 ± 4.15
	4		28.33 ± 4.50		18.26 ± 5.50
	6		34.20 ± 6.23		21.85 ± 5.75
	8		45.67 ± 7.65[b]		27.76 ± 5.85[b]
Tetraselmis chui (T2)	2	5	29.82 ± 5.84	12.53	13.58 ± 6.46
	4		58.91 ± 4.78		14.56 ± 6.78
	6		88.76 ± 5.45		15.39 ± 4.45

	8		131.5 ± 7.32[a]		55.77 ± 5.30[a]
Nannochloropsis oculata (T3)	2	5	16.63 ± 7.25	12.53	15.19 ± 5.85
	4		26.63 ± 5.50		19.89 ± 6.55
	6		29.82 ± 6.60		20.50 ± 5.75
	8		43.44 ± 5.15[b]		24.60 ± 6.14[b]

[1]Dissimilar superscripts in column denote differences at 5% level of significance (P<0.05).

The results clearly indicate that, among the three microalgae, *T. chui* possesses the dietary superiority over *Chlorella* sp. and *N. oculata* in culturing *B. plicalities*. The highest population growth and reproductive capacity in rotifers feeding on *T. chui* might be due to its comparatively larger cell size and better nutritional quality than the other two microalagal species (Hoff and Snell 1989). The incremental growth rate in rotifer population feeding on *T. chui* was progressively higher and steady (Fig. 1), indicating significant dietary role in propagation of rotifer in controlled conditions. Rotifers fed with *T. chui* had higher instantaneous growth rates compared to rotifers fed on *Chlorella* and *N. oculata* (Fig. 2). The trend in instantaneous growth rates in rotifers indicates that *T. chui* also might have beneficial effects in early growth phase in brackishwater rotifer population. However, the instantaneous growth rates of rotifers fed on different microalgae under the present culture conditions was higher than that of 0.133, which has been observed in rotifers fed on Chlorella sp. and baker's yeast (James *et al.* 1983).

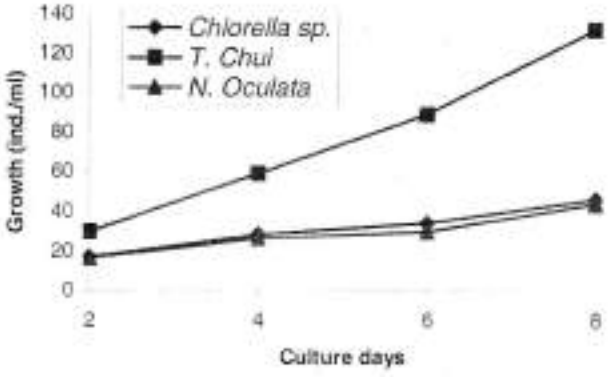

Fig. 1. Increment in growth of *B. plicatilis* fed on different microalge.

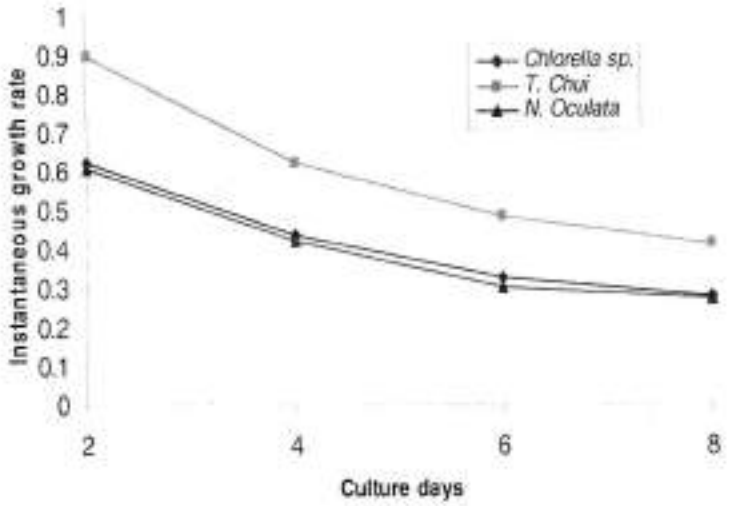

Fig. 2. Instantaneous growth rate in *B. plicatilis* fed on different microalgal diets.

The results of the present experiment is consistent with Braley (1994), who conducted experiments on stock culture of rotifer *B. plicatilis* in 600 ml flasks and reported a final density of 103 ind./ml at four days of culture, while feeding with *T. chui* at density of 4-5 x 10^{6} cells /ml. The author also estimated about 38% of *T. chui* fed rotifers carrying eggs. Okauchi and Fukusho (1984) also reported *Tetraselmis* as a better marine rotifer food than *Chlorella* sp., due to not only its ease in mass culture, but also its capacity of transfer of favorable nutritional characteristics to marine rotifers making them excellent food for rearing many marine fish larvae.

Though bakers's yeast and some prepared feeds are used in feeding rotifer culture, microalgae have been found to produce the best growth. The common microalge that are being used widely are *Chlorella* sp., *Tetraselmis chui*, *N. oculata* and *I. galbana* (Hirayama *et al.*1979, Liao *et al.* 1991). However, different authors have reported the suitability of one species over the others at different culture conditions. Kongkeo (1991) observed rotifer density of 100 - 200 ind./ml after seven days of initial stocking (10-30 ind./ml) by feeding *N. oculata* (1-2 x 10^{6} cells/ ml) and *T. chui* (2-4 x 10^{4} cells/ ml) respectively under pure laboratory culture. Pi (1991) observed rotifer density of 200 ind./ml on the fifth day in mass culture by feeding *N. oculata* at the density of 2 x 10^{7} cells/ ml. A rotifer density of 100-200 ind./ml, after four to five days of inoculation with initial density 30-50 ind./ml under mass culture condition, feeding *Chlorella* sp. at 8-10 x 10^{6} cells/ ml has been reported by Park (1991). James *et al.* (1983) reported rotifer population density of 203 ind./ml, within seven days of mass culture from initial density of 80 ind./ml, by feeding *Chlorella* and Baker's yeast.

Villegas (1990) evaluated the effects of three selected algal species, *T. tetrathele, I. galbana and Chlorella* sp. on the population growth of *B. plicatilis* after 3, 5, and 7 days of culture. The rotifers fed on *T. tetrathele* showed superior growth with mean peak density of 92.5 ind./ml to those fed on *I. galbana* (48.2 ind./ml) and *Chlorella* sp. (47.2 ind./ml) in 5 days of culture. In consistent with this finding, it could be concluded from the results of the present study that *T. chui* might be an effective food species for stock culture of locally isolated rotifer *B.plicatilis* as well as for upscaling to mass culture of this zooplankton for larval rearing of crustaceans and finfish.

The available information of elsewhere and of the present study on effects of different microalgal diets on *B. plicatilis* culture indicate that the suitability of a particular microalgae species in rotifer culture largely depends on location of origin and nutritional quality. While marine *Chlorella* sp. has been considered better in the nutritional value than other species in Japan (Hirata *et al.* 1979), it has found nutritionally inferior to *N. oculata* in Taiwan aquaculture system (Liao *et al.* 1991). In spite of lower EPA content (4 – 8%), the nutritive value of *T. chui* for rotifers has been found higher than that of *N. oculata* (Liao *et al.* 1991). However, best growth in rotifer culture may be obtained by secondary enrichment of *T. chui* fed rotifer population with *Nannochloropsis* sp. Besides the choice of suitable microalgae species, factors like temperature, salinity and feed concentration must be taken into well consideration, as all these affect the growth of both L- and S-type strains of rotifer. It has already been reported (Liao *et al.* 1991) that while *Tetraselmis* sp. are less sensitive to environmental stress, *Nannochloropsis* sp. must be cultured in greenhouse where temperature is kept below 30°C.

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(Manuscript received 23 October 2004)

Bangladesh J. Fish. Res., 8(2), 2004: 135-142

Comparative study on the toxin production and profiles of Raphidophytes at different salinities

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Abstract
Toxin production and toxin profiles of four Raphidophytes grown under different salinities were compared to investigate the influence of salinity on cellular content of neurotoxin. In *Chatonella antiqua* CaTx-I, CaTx-II, and CaTx-III peaked at 25 ppt with yields of 0.99, 0.42, and 2.90 pg/cell, but the highest yields (2.35 pg/cell) of CaTx-IV was attained at 30 ppt. On the other hand, *Chatonella marina* yielded higher proportions of CmTx-I (0.55 pg/cell) and CmTx-III (2.50 pg/cell) at 25 ppt. However, CmTx-IV was present in its highest amount (1.65 pg/cell) at 30 ppt, as seen in *C. antiqua*. A small amount of CmTx-II was also detected at 20-35 ppt. The toxin compositions indicate that *H. akashiwo* is more sensitive to higher salinities than the other three raphidophytes. Substantial compositional change was observed in case of *H. akashiwo*. HaTx-II (corresponding to PbTx-9) was detected only as a trace at 20 and 25 ppt. Toxin HaTx-IV (corresponding to oxidized PbTx-2) was most dominant and peaked at 20 ppt with a yield of 0.3 pg/cell. Considerable amounts of HaTx-I and III (corresponding to PbTx-2 and 3) were also detected. At higher salinities of above 25 ppt HaTx-II was not detected. *F. japonica* gave highest yields of FjTx-II (PbTx-2) and FjTx-IV (Oxidized PbTx-2) at 20 ppt with yields of 0.95, 1.54 pg/cell while the production of toxic profiles FjTx-I (PbTx-1) and FjTx-III (PbTx-3) peaked at 25 ppt with yields of 0.99, 2.54 pg/cell. A sharp decrease in all toxins profiles (CaTx, CmTx, HaTX and FjTx) was found at salinities of above 30 ppt.

Key words : Raphidophytes, Toxin profiles, Salinity

Introduction

Algal blooms are a serious coastal problem with consequences for seafood consumption, human health, ecosystem, and tourism and recreation. Although they can occur naturally and provide food for other organisms, they can also have harmful effects on the aquatic ecosystem. Global increases in the frequency and severity of harmful algal blooms (HABs) have posed a significant threat to the world's coastal environment (Anderson 1989, Hallegraeff 1993, Landsberg 2002). Most marine Raphidophyceae are bloom and ichthyotoxin producers. Raphidophycean flagellates produce neurotoxic, hemolytic, haemo-agglutinating compounds and oxygen radicals and have caused severe

fish mortalities with significant damage to the aquaculture economy in several countries. Massive fish kills due to raphidophycean bloom have been noticed worldwide, including in Hong Kong, Japan, Canada and Australia (Hallegraeff *et al.* 1998, Landsberg 2002).The raphidophytes *Chattonella antiqua* (Hada) Ono *C. marina* (Subrahmanyan) Hara et Chihara have been found to produce brevetoxin and posing a great threat to the aquaculture industry along the coast of Japan (Onoue and Nozawa 1989, Onoue *et al.* 1990, Ahmed *et al.* 1995a, 1995b). *Heterosigma akashiwo* (Hada) Hada is a bi-flagellated, single celled, golden brown Raphidophycean. This ichthyotoxic red tide organism has been associated with fish kill events within the aquaculture industry for many years. Net-penned fish deaths related to *Heterosigma* blooms have been particularly prominent in the northeast Pacific, notably around Japan. In the United States it has been found on both coasts (Hargraves and Maranda 2002) and is considered the causative organism involved in fish farm kills in Washington State on the West coast.

Fibrocapsa japonica (Toriumi and Takano) is a yellow-brown bloom producing raphidophyte associated with devastating effects on mariculture and causing Neurotoxic Shellfish Poisoning (NSP). Bloom of *F. japonica* have been reported in different coastal areas of Japan. In 1991, *F. japonica* was also detected in European coastal waters for the first time : on the channel coasts of Normandy, France and in Dutch coastal waters. Red tides, arising in bays and enclosed marine waters, have been observed along the north-eastern coastline of New Zealand (1992), in the southern central North Sea (1993) and at the Seal station at Friedrichskoog. During a bloom, the tissue from dead seals contained considerable amounts of fibrocapsin, a toxin specifically associated with *F. japonica*.

The potential toxicity, the world-wide distribution of these raphidophytes algae represents a growing threat to human health and is a global socio-economic problem. Therefore, there is a need to understand the ecophysiological factors that control growth bloom dynamics as well as toxin production and toxicity. Information on the ecophysiology of these blooms, based on associations with environmental variables is needed. Some investigations associated with the toxin production of these raphidophytes have been reported (Khan *et al.* 1995 1997, Haque and Onoue 2002a, b). But toxin production of these four raphidophycean at different salinities was not compared. In this study, we investigated and evaluated the potentiality of raphidophytes and compared the toxin profiles of the four cultured raphidophytes, *H. akashiwo, C. marina, C. antiqua, F. japonica and H. akashiwo.*

Materials and methods

Culture conditions

The raphidophyte *C. antiqua* used in this study was isolated from Yatsushiro Sea, Japan during massive red tide out break in 1984. *C. marina* and *H. akashiwo* were isolated from Kagoshima Bay in Japan, during the red-tide outbreak in 1978 and 1995, respectively. The strain of *F. japonica* was obtained from Dr. Engel G. Vrieling (University of Groningen, the Netherlands), which was isolated from the Dutch part of the North Sea in 1993. All the strains were maintained in the laboratory. The stock

culture of each species was maintained in the test tubes containing 10 ml of Provasoli's ES media (Provasoli 1968) at 25°C (±1°C), irradiance 60 μE $m^{-2}s^{-1}$ and photoperiod 12L: 12D. For analysis of toxin compositions the cultures (*C. antiqua, C. marina, H. akashiwo* and *F. japonica*) were grown in 15L media in 20L Pyrex carboys receiving very gentle aeration. The salinity of the culture media was increased from 20 ppt to 40 ppt. The experiments were done in triplicate. Culture media were made using sea water from Kagoshima Bay, autoclaved for 15 minutes at 121°C, and aged for several days.

Separation of neurotoxins

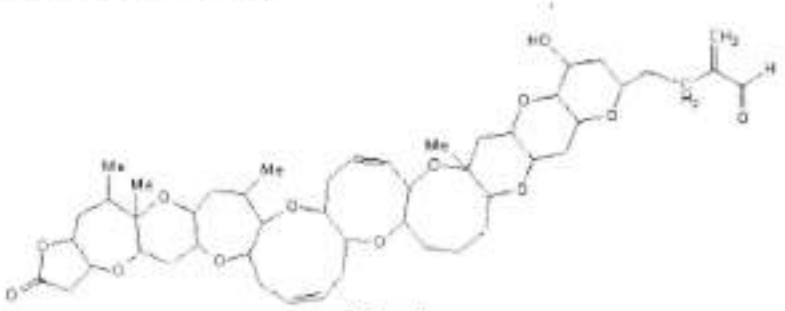
The mid logarithmic cultures of all the species were used for the extraction of toxin. Neurotoxins were extracted from the 16L cultures of all the raphidophytes at 20-40 ppt by a modification of Method of Baden and Mende (1982). The cultures were fractionated with dichloromethane using a ratio of 2:1 (culture media: dichloromethane). The dichloromethane layer was concentrated at 37°C in *vacuo* to dryness, dissolved in 90% methanol, and shaken with petroleum ether. The methanol layer was then concentrated to dryness and dissolved in ethanol. The ethanol extract containing crude neurotoxins were partially purified on fluorescent TLC plates (20x20 cm) of silica gel (Merck, Germany) with a solvent system of acetone: petroleum ether (30:70). Fractions of *C. antiqua* (designated CaTx-I, CaTx-II, CaTx-III and CaTx-IV) and of *C. marina* designated CmTx-I, CmTx-II, CmTx-III and CmTx-IV) were collected from the plates and extracted with ethanol. Four neurotoxic components HaTx-I, HaTx-II, HaTx-III and HaTx-IV were separated from *H. akashiwo* cultures on HPLC analysis which were compatible with PbTx-2, PbTx-9, PbTx-3 and oxidized PbTx-2. Four toxic fractions of *F. japonica* (designated FjTx-I, FjTx-II, FjTx-III and FjTx-IV) with Rf values of 0.32, 0.29, 0.17 and 0.06 were collected. Toxin fractions collected from the four raphidophytes and their and Rf (ratio of the distance traveled by a fraction to the distance traveled by the developing solvent) values in a solvent system of acetone: petroleum ether (30:70) are given in Table 1.

Table 1. Rf values of four raphidophytes in a solvent system of acetone: petroleum ether (30:70)

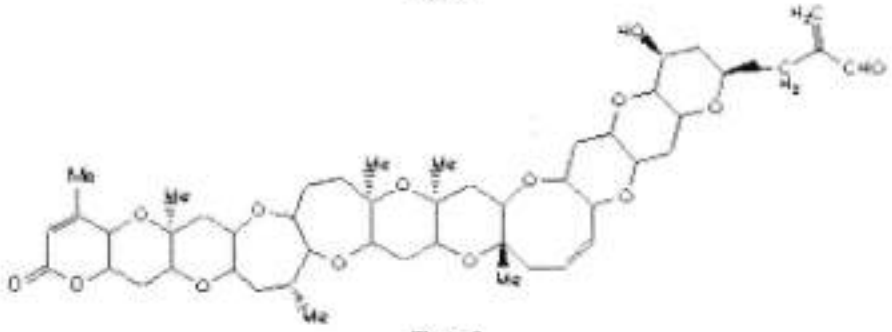
Species	Toxin component	Standard toxin	Rf values
Chattonella antiqua	CaTx-I	PbTx-1	0.32
	CaTx-II	PbTx-2	0.29
	CaTx-III	PbTx-3	0.17
	CaTx-IV	Oxidized PbTx-2	0.06
Heterosigma akashiwo	HaTx-I	PbTx-2	0.29
	HaTx-II	PbTx-9	0.24
	HaTx-III	PbTx-3	0.17
	HaTx-IV	Oxidized PbTx-2	0.06
Fibrocapsa japonica	FjTx-I	PbTx-1	0.32
	FjTx-II	PbTx-2	0.29
	FjTx-III	PbTx-3	0.17
	FjTx-IV	Oxidized PbTx-2	0.06

Chattonella marina	CmTx-I	PbTx-2	0.29
	CmTx-II	PbTx-9	0.24
	CmTx-III	PbTx-3	0.17
	CmTx-IV	Oxidized PbTx-2	0.06

The collected fractions from each species were then applied to a C-18 reverse phase HPLC (Hitachi type 65, Tokyo) system with isocratic 85% aqueous methanol as the mobile phase. Toxins were detected on a UV monitor at 215 nm. Retention times of the components were compared with those of standard brevetoxin, (PbTx-1, PbTx-2, PbTx-3, PbTx-9 and Oxidized PbTx-2 (Fig. 1). The peaks corresponding to PbTx-1, PbTx-2, PbTx-3, PbTx-9 and oxidized PbTx-2 were collected and their Rf values were compared with standards on the same fluorescent TLC plate (20 x 20 cm) of silica gel (Wako). They matched exactly each other.



Type-1



Type-2

Fig 1. Structures of Brevetoxins (Roszell *et al.* 1990)

Results

C. antiqua (Hada) Ono contained toxin components CaTx-I, CaTx-II, CaTx-III, and CaTx-IV, which corresponded to brevetoxin components PbTx-1, PbTx-2, PbTx-3, and oxidized PbTx-2. The major components of the toxins were CaTx-III (PbTx-3) and CaTx-IV (Oxidized PbTx-2), and the minor components were CaTx-I (PbTx-I) and

CaTx-II (PbTx-II). Similarly, *C. marina* included CmTx-I, CmTx-II, CmTx-III, and CmTx-IV corresponding to PbTx-2, PbTx-9, PbTx-3, and oxidized PbTx-2. Toxin yields in both species varied markedly with a change in salinity concentration. In *C. antiqua* CaTx-I, CaTx-II, and CaTx-III peaked at 25 ppt with yields of 0.99, 0.42, and 2.90 pg/cell, but the highest yields (2.35 pg/cell) of CaTx-IV was attained at 30 ppt. The yields of all CaTx components decreased sharply at salinities exceeding 30 ppt. On the other hand, *C. marina* yielded higher proportions of CmTx-I (0.65 pg/cell) and CmTx-III (2.50 pg/cell) at 25 ppt. However, CmTx-IV was present in its highest amount (1.65 pg/cell) at 30 ppt, as seen in *C. antiqua*. A small amount of CmTx-II was also detected at 20 ppt-35 ppt. *H. akashiwo* showed variations in toxin production at different salinity levels also. Lower salinity greatly influenced the toxin production of this species. The highest amount of toxin was produced at 20 ppt. Toxin HaTx-II (PbTx-9) was not produced at 30-40 ppt salinities. A negative correlation between salinity increase and toxin production was found on HPLC analysis of *H. akashiwo* toxins (HaTx-I, II, III and IV). Toxin HaTx-IV (corresponding to oxidized PbTx-2) was most dominant and peaked at 20 ppt with a yield of 0.3 pg/cell. Considerable amounts of HaTx-I and III (corresponding to PbTx-2 and 3) were also detected (Table 2). However, HaTx-II (corresponding to PbTx-9) was detected only as a trace at 20 and 25 ppt. The yields of all the toxic components were relatively high at 20 ppt salinity. A sharp decrease in all toxins was found at salinities above 30 ppt (Table 2). In case of *F. japonica* toxin composition FjTx-III (PbTx-3) and FjTx IV (Oxidized PbTx-2) was the major component and FjTx-I (PbTx-1) and FjTx-II (PbTx-2) was the minor component. Highest amount of FjTx-II (PbTx-2) and FjTx-IV (Oxidized PbTx-2) was produced at 20 ppt with yields of 0.95, 1.54 pg/cell while the production of FjTx-I (PbTx-1) and FjTx-III (PbTx-3) peaked at 25 ppt with yields of 0.99, 2.54 pg/cell.

Table 2. Yields of toxin composition (pg/cell) of four raphidophytes at different salinities

Toxin composition	Salinity ppt				
Chattonella antiqua	20	25	30	35	40
CaTx-I (PbTx-1)	0.69	0.99	0.63	0.45	0.25
CaTx-II (PbTx-2)	0.40	0.42	0.35	0.23	0.09
CaTx-III (Pb-3)	1.84	2.90	1.50	1.00	0.70
CaTx-IV (Oxidized P bTx-2)	1.95	2.00	2.95	2.00	1.85
Chattonella marina					
CmTx-I (PbTx-2)	0.50	0.65	0.35	0.25	0.18
CmTx-II (PbTx-9)	0.45	0.55	0.20	0.18	--
CmTx-III (PbTx-3)	1.85	2.50	1.65	1.00	0.65
CmTx-IV (Oxidized PbTx-2)	1.40	1.47	1.53	1.20	1.00
Heterosigma akashiwo					
HaTx-I (PbTx-2)	0.10	0.09	0.07	0.05	0.02
HaTx-II (PbTx-9)	0.05	0.04	-	-	-
HaTx-III (PbTx-3)	0.20	0.10	0.08	0.067	0.04
HaTx-IV (Oxidized PbTx-2)	0.30	0.20	0.095	0.065	0.05

Fibrocapsa Japonica					
FjTx-I (PbTx-1)	0.78	0.99	0.65	0.56	0.48
FjTx-II (PbTx-2)	0.95	0.85	0.78	0.70	0.63
FjTx-III (PbTx-3)	1.98	2.54	1.65	1.58	1.46
FjTx-IV (Oxidized PbTx-2)	1.54	1.42	1.35	1.28	1.15

Discussion

Temperature, light intensity and salinity are important environmental factors which greatly affect the algal physiology. Graneli *et al.* (1998) reported that toxin contents in phytoplankton cells could vary widely in relation to the growth phase and external biotic environmental factors such as temperature, salinity, light intensity and nutrients. Variations in salinity control the biological process of algae and thus the toxin production. In our investigation toxin production of four raphidophytes were found to be influenced by the salinity change. Several researchers have emphasized the importance of salinity on toxin production and bloom occurrence. A marked variation in toxin production was observed due to salinity change in *Gonyaulax excavata* (Braaud) Balech (White 1978) and *Pyrodinium bahamense* var. compressum (Usup *et al.* 1995). Blooms have been most related to temperature and moderate salinity in the coastal zone (Li and Smayda 2000, Connell and Jacobs 1997).

From our experiment it was observed that each of the species responded differently to the salinity change. Lower salinity greatly influenced the toxin production of the species *H. akashiwo*. The highest amount of toxin was produced at 20 ppt. Similar trend of toxin production was documented for *Pyrodinium bahamense*, where four fold increases in toxin production at low salinities was observed compared to high salinities (35 ppt) (Usup *et al.* 1995). In this study *H. akashiwo* was more sensitive to higher salinities than other three raphidophytes. Nielsen and Tonseth (1991) suggested that each strain and species of phytoplagellates has a specific preference and requirement for ecological parameter and they response to each of the factor differently.

Raphidophytes *C. antiqua*, *C. marina*, *H. akashiwo* and *F. japonica* have all been implicated in numerous fish kills globally. Due to the potential environmental and commercial impacts inherent with a bloom of these species, it becomes imperative to understand the parameters that govern their toxin production. The effect of salinity in toxin production was investigated to evaluate the importance of this factor in natural population. The data generated by this investigation can be used to evaluate the importance of this factor in natural population and will help to detect the locations and seasonality of these harmful algal blooms.

The information on the physiological responses of cells to salinity observed in the present study could provide a better understanding of the bloom dynamics and toxicity of raphidophytes. Understanding the dynamics of bloom can assist in the predicting of raphidophycean blooms and is essential for the mitigation of harmful dinoflagellates in coastal and estuarine ecosystems.

Acknowledgement

We gratefully acknowledge Dr. Baden. (University of North Carolina at Wilmington, USA, Center for Marine Science Research Wilmington, USA) for the generous provision of brevetoxin standards. And to Dr. Engel G. Vrieling (University of Gromugen, the Netherlands) for the strain of *Fibrocapsa japonica*.

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(Manuscript received 17 September 2003)

Bangladesh J. Fish. Res., 8(2), 2004: 143-150

Fishery, population characteristics and stock assessment of cuttlefishes, *Sepia aculeata* and *Sepia pharaonis* at Kakinada along the east coast of India

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Abstract
Cuttlefishes were exploited exclusively by trawls along the coast. Growth, recruitment, mortality and exploitation rates of *Sepia aculeata* and *Sepia pharaonis* were studied. Fishery of the former was supported mainly by zero year and the latter by zero and one + age groups. Both attain sexual maturity during the first year itself and spawn during August-March with peak during November-December. Natural mortality of *S.aculeata* was 2.22, fishing mortality 2.34 and total mortality 4.56. It was 1.69, 1.97 and 3.66 respectively for *S.pharaonis*. Exploitation rate was 0.52 and E_{max} 0.72 for *S.aculeata* and it was 0.54 and 0.76 respectively for *S.pharaonis*. Their mortality and exploitation rates indicated that stock remains under-exploited and have considerable scope for improving the production. However, both stock and catch exhibited wide annual fluctuation with declining trend during the period. These necessitated immediate attention including measures to minimise juvenile exploitation for improving stock and fishery.

Key words : Cuttlefishes, Population characteristics, Stock assessment

Introduction

Cuttlefish is one of the commercially important marine fishery resources of Indian waters by virtue of its export demand. In the recent past, several studies were conducted aimed at understanding the stock and biology of commercially important species and their response to exploitation (Silas *et al.* 1985, Nair *et al.* 1993 and Rao *et. al.* 1993). These reports and review by Meiyappan *et al.* (2000) indicated that resource is optimally exploited from east coast and under-exploited from west coast. Successful exploitation and management of the resource requires sound knowledge on distribution pattern and factors controlling their abundance. However, knowledge on several crucial aspects on the biology of many species remains limited. Present study was to update such information on the commercial species of cuttlefishes along the east coast.

Species composition and seasonal abundance : Fishery was supported by four species. *Sepia pharaonis* is the most dominant (41.6%) in the catch. Other species in the fishery are *Sepiella inermis* (31.4%), *Sepia aculeata* (22.6%) and *Sepia brevimana* (4.4%). They were available round the year in the catch with peak abundance of *S.aculeata* and *S.pharaonis* during August-October (Table 2).

Table 2. Seasonal fluctuation in the abundance of species as indicated by catch rate (kg/hour of fishing) in trawls

Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
S. pharaonis	0.19	0.28	0.05	0.12	1.76	2.52	1.27	1.08	0.84	0.40	0.15	0.11
S. aculeata	0.31	0.24	0.10	0.22	0.85	1.19	0.54	0.54	0.36	0.24	0.18	0.20
S. brevimana	0.06	0.06	0.04	0.05	0.10	0.15	0.09	0.06	0.11	0.07	0.10	0.06
S .inermis	0.68	0.04	1.32	0.84	0.52	0.91	1.03	0.67	0.72	0.63	0.36	0.30

Population characteristics of S. pharaonis

Growth : Growth parameters, $L\infty$ and K were estimated as 319.9 mm and 0.92/year respectively and 't_0' as 0.0314 years. Their growth against time can be described by von-Bertalanffy growth equation as,

$$Lt = 319.9\,[1- e^{-0.92\,(t-0.0314)}]$$

Length at age data obtained from the above relation shows that they grow to 58.3, 112.1, 154.7 and 188.7 mm respectively by 3, 6, 9 and 12 months. They attain 267.6, 299.1 and 311.6 mm by the end of 2nd, 3rd and 4th years respectively.

Size composition : 40-290 mm animals with 144.4 mm as mean size supported fishery in trawls (Table 3). Mainly zero and one+ year groups supported their fishery. Juveniles of 40-60 mm size entered fishery in large numbers during February-March. Their age at this stage was between 1.93 and 2.9 months. Size and age of the species at first capture was estimated as 158.5 mm and 9.1 months respectively.

Table 3. Annual size range, modes, mean size and commercial size of *S. pharaonis* in the catch

Period	Size range (cm)	Modes	Mean Size (cm)	Commercial size (cm)
1995-'96	50-290	50-60, 160-170, 180-190	133.3	160-240
1996-'97	60-260	130-140,150-160,170-180	157.7	120-210
1997-'98	40-290	70-80, 200-210	128.8	180-230
1998-'99	60-270	100-110, 160-170	142.9	120-230
1995-'99	40-290	50-60,130-140,170-180	144.4	120-240

Spawning and recruitment pattern : Recruitment pattern showing the time of origin of the stock (Fig 2), presence of animals with matured and spent gonads and small juveniles in the catch indicated that species spawn during August-March with peak, accounting 67% of the activity during November-December.

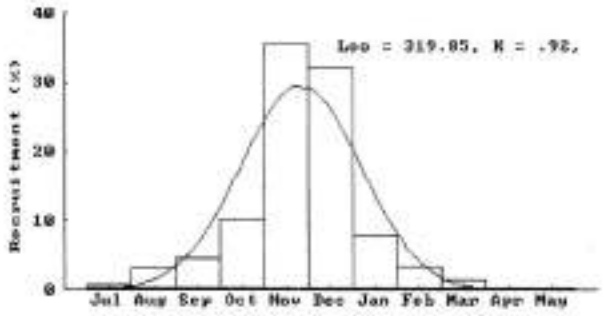

Fig 2. Recruitment pattern of *S. pharaonis* along Kakinada coast.

Mortality rates : Estimates of total mortality rate (Z) ranged between 2.19 and 4.92 during 1995-'99 with 3.66 as mean (Table 4). Natural mortality (M) was 1.69. Average fishing mortality (F) was 1.97 and it varied between 0.5 and 3.23 during the period.

Exploitation rate : Exploitation rate (E) fluctuated between 0.228 and 0.657, with 0.54 as mean for 1995-'99 (Table 4). E_{max} is large, 0.759, indicating some scope for increasing future production (Fig 3).

Table 4. Mortalities, exploitation rates, exploitation ratios, catch, biomass and stock of exploited *S. pharaonis* population during 1995-'99 (Natural mortality (M) is 1.69)

Period	Total mortality (Z)	Fishing mortality (F)	Exploitation rate (E)	Exploitation ratio (U)	Catch (t)	Stock (t)	Biomass (t)
1995-'96	2.97	1.28	0.431	0.409	279	682	218
1996-'97	4.08	2.39	0.586	0.576	391	679	164
1997-'98	2.19	0.50	0.228	0.203	86	424	172
1998-'99	4.92	3.23	0.657	0.652	148	227	46
Average	3.66	1.97	0.538	0.524	226	431	115

Yield and stock : Their stock and biomass in the present fishing grounds continued to decline during 1995-'99 (Table 4). Stock was 682 ton during 1995-'96 and it declined to 227 ton by 1998-'99. Average stock for the period was 431 ton. Biomass during the same period declined from 218 to 46 ton with 115 ton as mean. Yield however fluctuated widely over the period between 86 and 391 ton. Maximum sustainable yield of the species from the present fishing grounds is 249 tons/year (Fig 3).

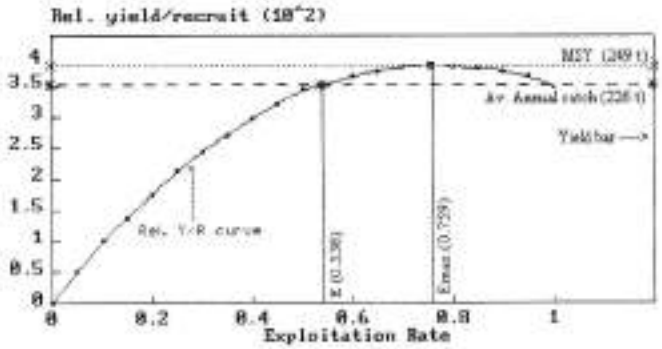

Fig 3. Relative yield/recruit of *S. pharaonis* at different levels of exploitation, super imposed with yield bar showing MSY.

Population characteristics of S. aculeata

Growth : Growth parameters, $L\infty$ and K were estimated as 225 mm and 1.2/year respectively and 't_0' as 0.059 years. Their growth against time can be described by von-Bertalanffy growth equation as;

$$Lt = 225\,[1 - e^{-1.2(t-0.059)}]$$

Length at age data obtained from the above relation indicated that species grow to 46.1, 92.5, 126.8 and 152.3 mm respectively by 3, 6, 9 and 12 months. They attain 203.1, 218.4 and 223.0 mm by the end of 2nd, 3rd and 4th year respectively.

Size composition : 20-210 mm animals, with 109.7 mm as mean size supported the fishery (Table 5). Mainly zero-year groups supported their fishery. Juveniles of 20-40 mm size entered the fishery during February-March. Their age at this stage was between 1 and 2.1 months. Size and age of the species at first capture was estimated respectively as 105.7 mm and 6.5 months.

Table 5. Annual size range, modes, mean size and commercial size of *S.aculeata* in the catch

Period	Size range (cm)	Modes	Mean size (cm)	Commercial size (cm)
1995-'96	20-200	50-60, 110-120	81.5	110-170
1996-'97	30-170	110-120, 130-140	124.2	110-160
1997-'98	40-210	60-70, 120-130, 140-150	100.7	120-170
1998-'99	50-200	110-120, 130-140	118.5	110-160
1995-'99	20-210	50-60, 110-120, 130-140	109.7	110-160

Spawning and recruitment pattern : Recruitment pattern showing the time of origin of the stock (Fig 4) and presence of animals with matured and spent gonads and young juveniles in the catch indicated that species spawn during August-March, with peak accounting 72% of the activity during November-January.

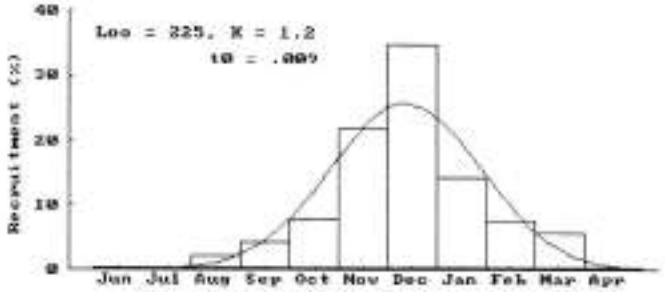

Fig 4. Recruitment pattern of *S. aculeata* along Kakinada coast.

Mortality rates : Estimates of total mortality (Z) ranged between 3.2 and 6.94 with 4.5 as mean (Table 6). Natural mortality (M) was 2.22. Average fishing mortality (F) was 2.34 and it varied between 0.67 and 4.72 during the period.

Table 6. Mortalities, exploitation rates, exploitation ratios, catch, biomass and stock of exploited *S. aculeata* population during 1995-'99 (Natural mortality (M) is 2.22)

Period	Total mortality (Z)	Fishing mortality (F)	Exploitation rate (E)	Exploitation ratio (U)	Catch (t)	Stock (t)	Biomass (t)
1995-'96	3.43	1.21	0.353	0.341	150	440	124
1996-'97	6.94	4.72	0.680	0.679	195	287	41
1997-'98	3.51	1.29	0.368	0.356	82	230	64
1998-'99	3.20	0.98	0.306	0.301	64	213	65
Average	4.56	2.34	0.520	0.514	123	239	53

Exploitation rate : Exploitation rate (E) fluctuated between 0.209 and 0.68, with 0.52 as mean during 1995-'99 (Table 6). E_{max} is large 0.723, when compared to present levels of exploitation indicating scope for increasing future production (Fig 5).

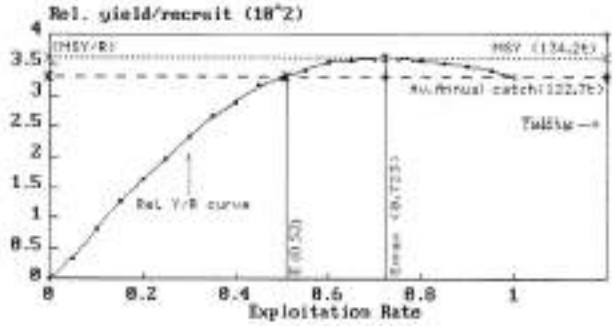

Fig 5. Relative yield/recruit of *S. aculeata* at different levels of exploitation, super imposed with yield bar showing MSY.

Yield and stock :Their stock and biomass in the present fishing grounds showed a declining trend during 1995-'99 (Table 6). Stock was 440 ton during 1995-96 and it declined to 213 ton by 1998-'99. Average stock for the period was 239 ton. Biomass during the same period fluctuated between 41 and 124 ton with 53 ton as mean. Yield fluctuated between 64 and 195 ton with a clear declining trend. Maximum sustainable yield from the present fishing grounds of the coast is 134 ton/year (Fig 5).

Discussion

Catch and catch rate of cuttlefishes shown declining trend with wide annual fluctuation during 1995-'99. Stock of major species also shown such fluctuation with declining trend. However, present level of exploitation of the species is low compared to Emax. This suggested operation of some fishery independent factors in the fishing ground unfavourable for the stock. These have to be traced out through constant and close monitoring of the fishery, fishery environment, behaviour of the stock and their response to fishing.

Fishery of *S.pharaonis* was supported mainly by zero and 1+ year groups and *S.aculeata* by zero year groups with large proportions of juveniles. Silas *et al.* (1985) reported that along the east coast former attain sexual maturity at 121-138 mm size and latter at 100-118 mm size. Present growth estimate shows that their ages at these sizes will be respectively 7-8 and 6-7 months. Though they attain sexual maturity at an early age and have prolonged spawning season, vulnerability of young ones to fishing and precedence of peak fishing season to spawning season, may limit chances of large proportion of the population for spawning before being caught. So the present level of exploitation though low may have some adverse effect on the recruitment and stock as evident from continuous and sharp decline in the catch and stock of *S.pharaonis*.

These species spawns in shallow inshore waters and young ones feed on small shrimps and fishes in the shelf area, they are vulnerable to trawls from their early juvenile stage onwards. Trawls being aimed primarily for resources like shrimps, mesh size of the gear is expected to be very small. So mesh size regulation to conserve this resource alone is not a practically viable proposal. The only alternative is regulating effort to reduce fishing pressure in coastal waters especially during peak period of juvenile abundance. Fishing pressure on the stock can also be reduced by diverting large trawlers to deeper waters, for exploitation of other under-exploited resources. Such measures will improve catch and also the stock by way of enhanced survival and recruitment.

Acknowledgement

We sincerely acknowledge the encouragement shown by Dr. K.A. Narasimham, former Head, Molluscan Fisheries Division, Dr. N. Gopalakrishna Pillai, Head, Pelagic Fisheries Division and Dr. K.K. Appukkuttan, Head, Molluscan Fisheries Division during the course of this study. This work has been carried out under the project MF/RE/1 of CMFRI.

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(Manuscript received 13 May 2004)

Bangladesh J. Fish. Res.,8(2), 2004: 151-156

Comparative economic analysis of pond fish production in Mymensingh and Jessore Districts, Bangladesh

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Abstract
The study was conducted to determine the cost, return and relative profitability of pond fish production of Mymensingh and Jessore districts. A total of 75 ponds were selected on the basis of purposive random sampling technique from 7 villages under 2 Upazila (Trishal and Gouripur) of Mymensingh districts and 8 villages under 4 Upazila (Monirumpur, Jhikorgacha, Chowgacha and Sadar) of Jessore district. It was found that per hectare per year gross cost of pond fish production in Mymensingh and Jessore were Tk 333457.75 and Tk 54327.74, while gross return were Tk 434131.16 and Tk. 96640.00 and net return were Tk 100673.41 and Tk. 42312.26, respectively. The findings of this study revealed that the pond fish production in Jessore district was more profitable than that of Mymensingh district. Cobb-Douglas production function was applied to realize the specific effect of the factors on pond fish production. Out of six variables included in the function three variables had positive impact on return from pond fish production, in Mymensingh district but five variables had positive impact on return from pond fish production in Jessore district.

Key words : Fish culture, Cost and return, Cob-Duglas production function

Introduction

Bangladesh is a developing country with a vast water resource. Fishery has been making special contribution to the economy of Bangladesh. It plays a vital role in the alleviation of poverty in Bangladesh. It meets up the nutritional requirement of the people, creates employment opportunity and earns foreign exchange for the country. Most of the people in this country depend on fish as main source of animal protein. It has been estimated that about 1.3 million people are directly employed in this sector. Another 1.2 million people indirectly earn their livelihood from fisheries related activities. Frozen shrimp, fish and fishery products occupy the third position in the country's exports (4.76% of total foreign exchange earning). In 2001-2002, fisheries sector contributed 5.24 percent to the total GDP of the country (DoF 2003). The country's total production of fish was 1890459 tones in 2001-2002 of which 1475039 tones were from inland sources and

415420 tones from the marine sources. The growth rate of the production during the last decade, on average, was 7.20 percent per year.

In Bangladesh, increased aquaculture production, mainly pond fish production can help to meet the increased domestic demand for fish (2.075 million tones; (FFYP 1997-2002). In order to meet the shortage of fish, the Department of Fisheries (DoF) and some Non-Government Organizations (NGOs) are encouraging people to increase fish production in their surrounding water areas (*pond, haor, baor, beel etc.*). In response to government's initiative for augmenting fish production in the country, people have started to be occupied in different types of fish production activities. The two important activities are rising for fingerlings and production of table fish using different types of technologies popularized by various government and non-government agencies.

The main purpose of the present study was to generate information regarding the comparative profitability of pond fish production in different areas. It was also interesting to look at the efficiency of input use in the production process.

Materials and methods

The study was carried out from July'03 to June'04 in seven villages at Mymensingh district and eight villages at Jessore district. A set of interview schedules were pre-tested and developed. Data were collected from 7 villages under two Upazila (Trishal and Gouripur) of Mymensingh district and 8 villages under four Upazila (Monirumpur, Jhikorgacha, Chowgacha and Sadar) of Jessore district. A total of 150 producers were selected from the study areas on the basis of purposive random sampling technique. A simple tabular method was followed to illustrate the whole picture of analysis. The sum, mean, percentage, ratio, etc. were the simple statistical measures employed to show the comparative performance of pond fish. Relative profitability of pond fish and production was determined on the basis of net return analysis.

Functional analysis

To find the effects of variable inputs both linear and Cobb-Douglas production function models were estimated initially. Data were converted to per farm basis to facilitate the analysis. The results of the Cobb-Douglas models appeared to be superior on theoretical and econometric grounds. So, the Cobb-Douglas model was accepted for interpretation. Six independent variables were employed to explain the gross returns from pond fish production in Mymensingh and Jessore districts. Regression analysis (ordinary least squares) method was used to determine the effect of these inputs. A series of regression procedures were carried out to be sure that serious multicollinearity problem did not exist. The function was specified as:

$$Y = aX_1^{b1}X_2^{b2}X_3^{b3}X_4^{b4}X_5^{b5}X_6^{b6}e^{Ui}$$

The function was linearised by transforming it into the following double log or log linear form:

$$InY = Ina + b_1 InX_1 + b_2 lnX_2 + b_3 lnX_3 + b_4 lnX_4 + b_5 lnX_5 + b_6 lnX_6 + Ui$$

Where,
Y = Gross return from fish/fingerlings production (Tk), X_1 = fingerlings cost (Tk), X_2 = Fertilizer cost (Tk), X_3 = Lime cost, X4 = Feed cost per farm, X_5 = Poison cost per farm, X_6 = Labour cost (Tk), In = Natural logarithm, a = Intercept, bi = Production coefficients, and U = Error term.

Few important variables like pond keeping, pond area, number of ponds, duration of water etc., which might affect pond fish production could not be included in the model due to non-availability of appropriate data for the model.

Results and discussion

Costs and returns

Among the different cost items, cost of feed appeared to be the highest and represented 68.70 percent of total cost of pond fish production in Mymensingh district. In Jessore district the cost of fingerlings was highest and represented 22.72 percent of the total cost of production. The average per hectare gross cost per year amounted to Tk. 333457.75 and Tk. 54327.74 for pond fish production in Mymensingh and Jessore districts, respectively (Table 1). Gross returns from pond fish production of Mymensingh and Jessore districts amounted to Tk. 434131.16 and Tk. 96640.00, respectively. The net returns from pond fish production in Mymensingh and Jessore were computed at Tk. 100673.30 and Tk. 42312.26 per hectare, respectively. The benefit cost ratio (BCR undiscounted) of pond fish production in Mymensingh and Jessore were 1.30 and 1.78, respectively. It indicates that the production of fish in pond was more profitable in Jessore than in Mymensingh. Ahmed (2003) studied yield the gap, production loss and profitability of pond fish culture in Netrokona district. He observed that the gross cost was Tk. 77496.00, gross return was Tk. 233250.00 and net return was Tk. 155754.00 per hactare of pond fish production. Haque (2000) conducted a comparative economic analysis of pond fish production in Pabna district. He found the gross cost of Tk. 65917.52, gross return of Tk. 91706.61 and net return of Tk. 25789.09 from the same study. Islam (2000) studied fish farmers and fishermen and gender role in fisheries development in Mymensingh, Tangail, Chandpur, Cox's Bazar and Khulna districts. He found that BFRI contract farmers gross cost was Tk. 9758.00 and gross return was Tk. 20247.00 and net return was Tk. 10489.00 per hectare from fish production. Sultana (2001) studied the adoption of BFRI evolved polyculture and carp nursery technologies in Mymensingh district. She found that the gross cost was Tk. 70953.00, gross return was Tk. 120974.00 and net return was Tk. 50021.00 from per hectare of pond fish production. Results of the present study were comparable to those studies.

Table 1. Per hectare annual cost and return from pond fish production

Items	Mymensingh	Percent	Jessore	Percent
Cost of Fingerlings (Tk)	49,111.41	14.73	12,342.22	22.72
Fertilizer Cost (Tk)	1,827.19	0.55	3,091.73	5.69
Lime cost (Tk)	1,386.64	0.42	1,401.78	2.58
Feed cost (Tk)	229,098.60	68.70	10,638.22	19.58
Poision cost (Tk)	455.29	0.14	624.00	1.15
Labour cost (Tk)	1,5874.73	4.76	7,457.33	13.73
Total variable cost (Tk)	297,753.86	89.29	35,555.28	65.45
Interest on Operating capital (Tk)	20,842.77	6.25	2,488.87	4.58
Land Use cost	14,861.12	4.46	16,283.58	29.97
Total Fixed cost (Tk)	35,703.89	10.71	18,772.45	34.55
Gross cost (Tk)	333,457.75	100.00	54,327.74	100.00
Gross Return (Tk)		434,131.16		96,640.00
Net Return (Tk.)		100,673.41		42,312.26
Gross Margin (Tk.)		136,377.30		61,084.71
BCR		1.30		1.78

Source: Field Survey 2003-04

Factors affecting pond fish production

The effect of the various inputs used in the process of fish production was analyzed. Inputs used in production was classified broadly into material inputs (fingerlings, feed, lime and fertilizer, etc.) and labour. Furthermore, there were some inherent characteristics of pond environment and factors that could affect its production such as pond area, be employed to explain the variation in output of ponds. Accordingly, some crucial inputs were identified and included in the model to explain the variation of productivity of fish in ponds.

Interpretation of results

Estimated values of coefficients and related statistics of the Cobb-Douglas production function for pond fish production are given in Table 2. The function fitted well for pond fish production of Mymensingh and Jessore districts as indicated by F-values and R^2. The coefficients of multiple determination, R^2 were 0.885 for Mymensingh and 0.912 for Jessore district. It indicated that the variables included in the model succeeded in explaining about 88.50 % and 91.20% of the total variations in the value of pond fish production of Mymensingh and Jessore districts, respectively. The F-values were highly significant at 1% levels implying that all the included explanatory variables was important for explaining the variations in pond fish production. The sum of all the production coefficients (production elasticity) of the equations for pond fish production were 0.57 and 0.965 indicating that the production function exhibited

increasing returns to scale for pond fish production of Mymensingh and Jessore districts, respectively.

Interpretation of Coefficients for Individual Variables

The regression coefficients of feed cost was positive and significant at 1% level of significance, which indicated that 1 percent increase in feed cost, keeping other factors constant, would increase gross return 0.466 percent in the Mymensingh districts but in Jessore district fingerlings and feed cost were positive and significant at 1% level of significance, which indicated that 1 percent increase in cost of fingerlings and feed cost, keeping other factors at their same level, would increase the gross return 0.719 and 0.104 percent, respectively. The coefficients of fertilizer cost, lime cost and poison cost were negative and insignificant at Mymensingh district and lime cost at Jessore district was negative and insignificant, which indicated the over use of these inputs. Cost of fingerlings and labour cost were positive and had no significant impact on pond fish production of Mymensingh and cost of fertilizer, poison and labour cost were positive and had no significant impact on pond fish production of Jessore district.

Table 2. Estimated values of coefficient and related statistics of Cobb-Douglas production function model

Explanatory variables	Mymensingh	Jessore
Intercept	5.56	2.45
Cost of fingerlings (X_1)	0.154 (0.121)	0.719* (0.15)
Fertilizer cost(X_2)	- 0.016 (0.028)	0.047 (0.099)
Lime cost(X3)	- 0.0354 (0.065)	- 0.034 (0.051)
Feed cost (X4)	0.466* (0.069)	0.104* (0.026)
Poison cost (X_5)	- 0.0009 (0.025)	0.021 (0.016)
Labour cost (X_6)	0.0115 (0.082)	0.108 (0.174)
R^2	0.885	0.912
F value	87.103*	117.328*
Returns to scale ($\sum b_i$)	0.58	0.965

Note: Figures in the parentheses indicate standard error
*Significant at 1% level

Conclusions

The production of fish in ponds was higher in Mymensingh than in Jessore. The cost was significantly lower (Table 1) in Jessore district than Mymensingh district. The cost of fish production was minimum but the net return was maximum in Jessore than

Mymensingh. The study reveals that the Benefit-cost ratio was higher in Jessore than in Mymensingh. In the functional analysis, it was found that the some of factors of fish production (fingerlings, fertilizer, feed, poison and labour) were positive in Jessore district, where as three factors (fingerlings, feed and labour) were positive in Mymensingh district. The results of the study indicate that the pond fish production can be increased and made more profitable by efficient reallocation resources in the production process.

Acknowledgement

The present study was carried out under financial support by the Ministry of Science and Information & Communication Technology, GOB.

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(Manuscript received 5 September 2004)

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