

Competitive Research Grant

Sub-Project Completion Report

on

Production of Asian Seabass (*Latescalcarifer*) in Brackish and Freshwater Earthen Pond under Natural and Artificial Feeding Regime in South- West Coastal Zone of Bangladesh

Project Duration

July 2017 to September 2018

Department of Aquaculture, Faculty of Fisheries, Patuakhali Science and
Technology University



Submitted to
Project Implementation Unit-BARC, NATP 2
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215



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Project Implementation Unit

National Agricultural Technology Program-Phase II Project (NATP-2)

Bangladesh Agricultural Research Council (BARC)

New Airport Road, Farmgate, Dhaka – 1215

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Acronyms

°C	: Degree Centigrade
ANOVA	: Analysis of Variance
AOAC	: Association of Official Analytical Chemists
DMRT	: Duncan's Multiple Range Test
DO	: Dissolved Oxygen
g	: Gram
kg/ha	: Kilogram Per Hectare
mg/l	: Milligram Per Litre
MS	: Master of Science
NaCl	: Sodium Chloride
NH₃-N	: Ammonia Nitrogen
NH₄⁺	: Ammonium Ion
NO₃-N	: Nitrate Nitrogen
PO₄-P	: Phosphate Phosphorus
ppt	: Parts Per Thousand
RTC	: Research and Training Centre
SGR	: Specific Growth Rate
FCR	: Feed Conversion Ratio
BCR	: Benefit Cost Ratio

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Executive Summary

Asian Seabass (*Latescalcarifer*), locally known as *Koralmach* a popular edible marine fin fish, commands consistent demand in domestic and international markets. Most of the previous experiments focused on culture of Seabass with Tilapia where Tilapia fries were used as Seabass food. But for commercial and semi-intensive/intensive aquaculture, it is important to develop artificial feed for Seabass culture. Considering the facts, present investigations were carried out to develop a sustainable culture system of Seabass by feeding natural and artificial feed during September 2017 to July 2018. In this context, three experiments were carried out at Kalapara, Dumki and Bauphalupazila under Patuakhali district: to compare and standardize production and stocking density of Seabass and Tilapia in brackish- and freshwater earthen ponds using monoculture and mixed culture techniques; and to develop suitable artificial feed for Seabass aquaculture in captive culture system. Seabass fingerlings were collected from the river Andharmanik, Kalapara and stocked in nursery ponds. Both natural and artificial feed (commercial nursery feed) were used for feeding the fries. At the end of Seabass nursing, fingerlings were stocked carefully in the experimental ponds. In monoculture system, water quality parameters were not significantly different among the treatments except pH in brackish water. In mixed culture system, $\text{NO}_3\text{-N}$ in freshwater was significantly different but remaining water quality parameters were not significantly different among the treatments. In monoculture of Seabass, the highest net yields in T2 (25 Seabass/decimal) were 1255.55 ± 58.63 kg/ha and 1186.79 ± 113.46 kg/ha in brackish water and freshwater environment respectively with significant difference among the treatments which might be associated with higher specific growth rates (SGR) of fish under trial. Under mixed culture, higher net yields of Seabass and Tilapia were found 1508.38 ± 47.45 kg/ha and 6629.60 ± 395.97 kg/ha in T3 (20 Seabass + 80 Tilapia/decimal) with significant difference among treatments in brackish water ponds, might be associated with specific growth rates (SGR) of the experimental fish. Under polyculture in freshwater ponds, higher net yields of Seabass and Tilapia were found 1420.10 ± 101.73 kg/ha and 6896.26 ± 265.16 kg/ha in T3 (20 Seabass + 80 Tilapia/decimal), which might be due to higher SGR of the experimental fish. In feed enrichment trial, water quality parameters were not significantly different among the treatments except water temperature and DO in freshwater. Higher net yields were observed 1407.07 ± 116.44 kg/ha and 1221.77 ± 63.67 kg/ha at T4 (2% NaCl) both in brackish water and freshwater culture systems, respectively, with significant differences among the treatments which could be the effect of adding salt to the diet of Asian Seabass reared in brackish and freshwater environment. Benefit cost ratios (BCR) ranged 1.02 to 1.19 in monoculture of Seabass but higher ranges 1.30 to 1.41 were obtained in case of mixed culture of Seabass with Tilapia. BCR ranged 1.16 to 1.40 in feed enrichment trial (with 2% NaCl) of Seabass. The highest BCR 1.41 was obtained from mixed culture (20 Seabass + 40 Tilapia/decimal) both in brackish and freshwater environment with the net benefits of BDT 349394/ha and BDT 360476. Although, the highest net benefit was estimated from mixed culture (20 Seabass + 80 Tilapia/decimal) under brackish water environment was BDT 465,756/ha but BCR was found lower compared to the former polyculture combination. As per proximate analysis, the Seabass feed was prepared with 40% crude protein, 8% crude lipid and Tilapia feed prepared with 28.10% crude protein, 6.65% crude lipid applied as supplementary feed during the experiment. According to the findings of the present studies, it may be concluded that the introduction of mature Tilapia with Seabass provided with supplementary feed in earthen ponds of brackish and freshwater environments has profound impacts on SGR which ultimately enhances the yield of Seabass and Tilapia as well as higher economic growth.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. **Title of the CRG sub-project:** Production of Asian Seabass (*Lates calcarifer*) in Brackish and Freshwater Earthen Pond under Natural and Artificial Feeding Regime in South-West Coastal Zone of Bangladesh
2. **Implementing organization:** Department of Aquaculture, Faculty of Fisheries, Patuakhali Science and Technology University

3. Name and full address with phone, cell and E-mail of PI/Co-PI (s):

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4. Sub-project budget (Tk):

Total:Taka 3,723,400 (In word: Thirty seven lac twenty three thousand and four hundred) only

Revised (if any): Not applicable

5. Duration of the sub-project:

Start date (based on LoA signed): 13 July 2017

End date: 30 September 2018

6. Justification of undertaking the sub-project:

Asian Seabass (*Lates calcarifer*), locally known as Koralmach a popular edible marine fin fish, commands consistent demand in domestic and international markets. It is a carnivorous, euryhaline species and has widely been distributed in the Bay of Bengal, Indo-Pacific region and extending up to Taiwan, the southeast Australian coast, the Arabian Sea and the Persian Gulf. Having the characteristics of catadromous pattern of life cycle, it's population occupies a wide range of habitats starting from freshwater rivers, estuaries and inshore coastal waters. Therefore, it can be cultured in a variety of culture systems using marine water, brackish water and freshwater (Harpazaet *al.*, 2005; FAO, 2006). It is unfortunate that the Seabass resource has become vulnerable in marine environment due to over exploitation (Cheung *et al.* 2005). To overcome this existing problem, many south-east Asian countries gave concerted efforts over the last couple of decades and

developed seed production and commercial aquaculture techniques of Seabass (Almendras *et al.*, 1988; Rimmer *et al.*, 1994; Thirunavukkarasu *et al.*, 2001).

Although sea bass is a popular and high valued fish in Bangladesh and an ideal candidate for marine and coastal aquaculture, the breeding and culture techniques yet to be developed. A few researches have been done so far on Seabass culture in Bangladesh. Most of the experiments were focused on culture of Seabass with Tilapia where Tilapia fries were used as Seabass food. But for commercial and semi-intensive/intensive aquaculture, it is important to develop artificial feed for Seabass culture. Another important issue is to culture the Seabass in the freshwater ponds and develop feed for Seabass that would be helpful for ensuring higher growth of marine Seabass in freshwater environment.

7. Sub-project goal:

The goals of this research project are

- To develop aquaculture model of Asian Seabass in brackish and freshwater earthen ponds.
- To develop suitable artificial feed for Seabass aquaculture system.

8. Sub-project objective (s):

- To compare growth and survival of Asian Seabass in brackish and freshwater pond;
- To determine optimum stocking density of Seabass in captive aquaculture system; and
- To develop suitable feeding regime for Seabass aquaculture

9. Implementing location (s):The experiments were conducted in farmer's ponds. The sites were the Kalapara, Dumki, Bauphalupazila of Patuakhali District.

a) Brackishwater Zone: In Kalaparaupazila, coastal river side ponds were selected where water salinity is higher (about 5-10 ppt).

b) Freshwater Zone: In Bauphal and Dumkiupazlia, the freshwater (0 ppt) ponds were selected for the experiment.

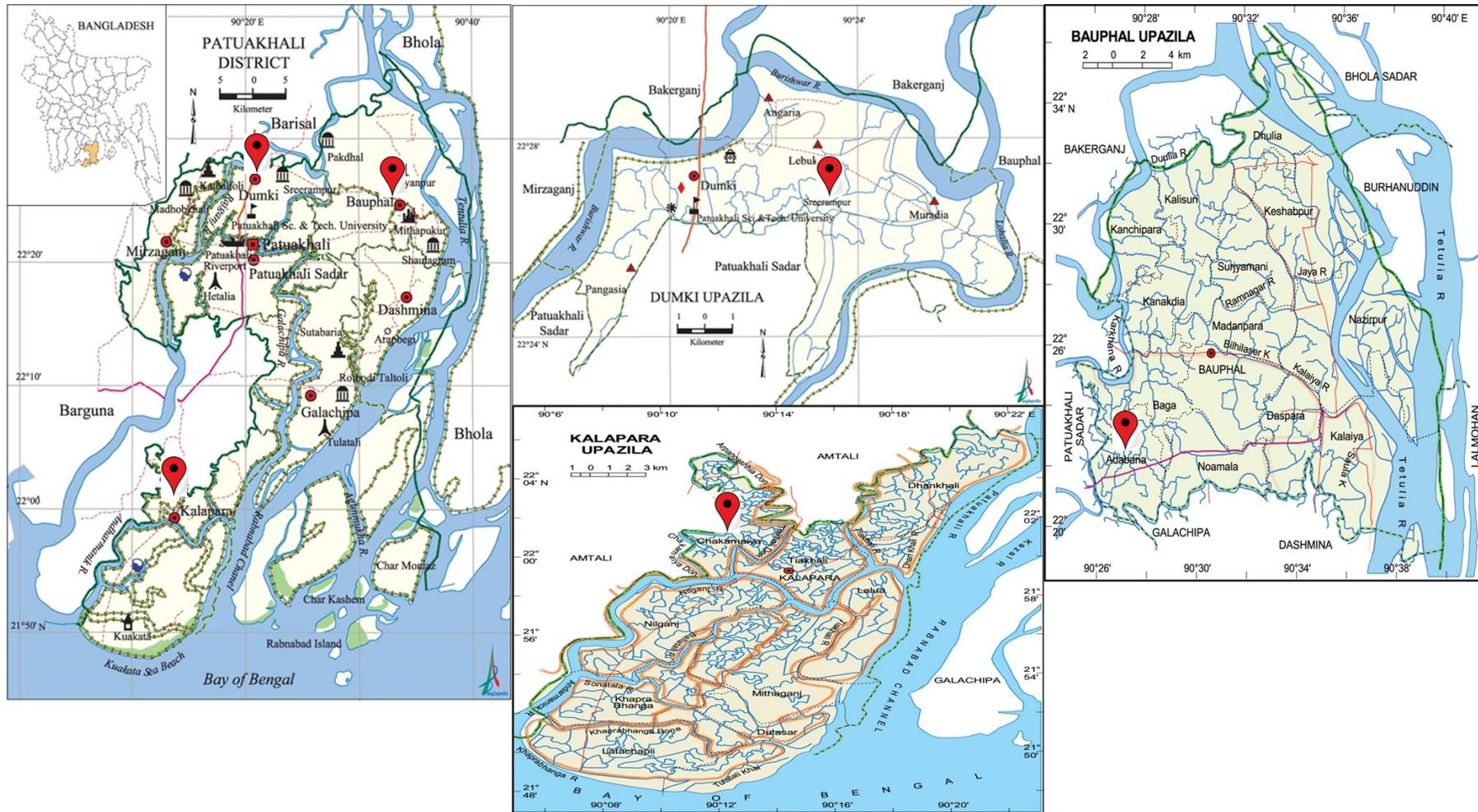


Fig. 1 Map showing the location of the study areas of Dumki, Bauphal and Kalapara upazila under Patuakhali district.

10. Methodology in brief:

10.1 **Pond renovation:** The experiments were conducted in farmer's ponds. As most of the farmer's Ponds in the coastal area were irregular shaped with low water depth, the ponds were renovated as standard aquaculture pond.

10.2 **Pond preparation:** Twenty seven (27) freshwater ponds and 27 brackish water ponds were prepared as per standard pond preparation protocol as grow-out ponds with average area and depth of 15 decimal and 1.50 meter respectively. Two (2) nursery ponds were also prepared as per standard pond preparation protocol for nursing the fish fries. The average area of nursery ponds was also 15 decimal.

10.3 **Sources of Seabass seed:** Seabass seeds were collected from natural sources of Andharmanik River, Kalapara and stocked in nursery ponds.

10.4 **Nursing of Seabass:** River originated Seabass seeds were collected and reared in brackish and freshwater ponds. Both natural and artificial feed (commercial nursery feed) were used for feeding the fries. Natural feed were enhanced by applying manure and fertilizers at standard dose.

10.5 **Stocking of Seabass fingerlings and mature Tilapia**

Stocking of Seabass: After nursing period, the Seabass were transported directly from the nursery pond to the experimental ponds. The fingerlings were weighed and kept in a bucket containing water from experimental ponds for about 15 minutes to adjust with the new environment. Then, the healthy and strong fingerlings were gradually released in the experimental ponds. The mean initial weight of Seabass ranged 59.00 to 71.00 g at the time of stocking.

Stocking of Tilapia: Mature GIFT Tilapia (*Oreochromis niloticus*) were collected from Chanchol Matshya Hatchery, Bauphal, Patuakhali. Tilapia fingerlings were weighed and kept in a bucket containing water from experimental ponds for about 15 minutes to adjust with the new environment. Then, the healthy and strong fingerlings were gradually released in the experimental ponds. The mean initial weight of Tilapia ranged 160.67 to 166.00 g at the time of stocking. Both Seabass and Tilapia were stocked into the experimental ponds in September 2017.



Plate 1. Seabass fingerlings



Plate 2. Stocking of Seabass

10.6 Seabass culture in brackish- and fresh-water earthen ponds

Experiment- 1: Comparative study on production and determination of stocking density of Seabass in brackish- and fresh-water earthen pond under monoculture system

Two different environments, such as brackish water and freshwater pond were experimented for the development of aquaculture techniques of Asian sea bass. Seabass was cultured both in coastal brackish water and freshwater ponds with the stocking density 20-30/decimal. Natural food productions in the ponds were enhanced by applying fertilizers (both organic and inorganic). Artificial feed with 40% protein were fed the fishes.

Environment	Brackish water			Freshwater		
Treatment	T1	T2	T3	T1	T2	T3
Replication	3	3	3	3	3	3
Stocking (Fish/Decimal)	20	25	30	20	25	30
Feed	Std. Regime: Artificial & Natural Feed			Std. Regime: Artificial & Natural Feed		
Salinity	5-10ppt			0 ppt		

Experiment- 2: Comparative study on production and determination of stocking density of Seabass in brackish- and fresh-water earthen ponds under mixed culture system

Seabass was cultured in both coastal brackish and freshwater ponds with Tilapia. This was an improvement over the traditional method, where the live fishes, shrimps were deliberately allowed to be fed by Seabass. Under mixed culture method, the feed in the form of forage fish were produced in the culture ponds itself and made available to the Seabass to prey upon as and when required. Tilapia were stocked at 1:3 male:female ratio, whereas Seabass was in constant number of 20 individual per decimal. Natural feed productions in the ponds were enhanced by applying fertilizers (both organic and inorganic). Artificial feed with 28.10% protein was supplied to Tilapia.

Environment	Brackish water			Freshwater		
Treatment	T1	T2	T3	T1	T2	T3
Replication	3	3	3	3	3	3
Stocking: (Seabass/decimal)	20	20	20	20	20	20
(Tilapia/decimal)	40	60	80	40	60	80
Ratio (Seabass:Tilapia)	1:2	1:3	1:4	1:2	1:3	1:4
Feed (at Std. Regime)	Natural Feed/Artificial Feed			Natural Feed/Artificial Feed		
Salinity	5-10 ppt			0 ppt		

Experiment- 3: Development of suitable artificial feed for Seabass aquaculture in captive culture system

Different available artificial feed with salt augmentation of different percentage and farm made feed of different protein percentage with salt augmentation were tested in this experiment to determine suitable artificial feed for Seabass in the brackish and freshwater condition. Natural feed production in ponds were enhanced by applying fertilizers (both organic and inorganic).

Environment	Brackish water				Freshwater			
Treatment	T1	T2	T3	T4	T1	T2	T3	T4
Replication	3	3	3	3	3	3	3	3
Stocking (Fish/Decimal)	20	20	20	20	20	20	20	20
Feed	Std. Regime: Artificial Feed				Std. Regime: Artificial Feed			
Protein 40-45%	NaCl 0%	NaCl 1.0%	NaCl 1.5%	NaCl 2.0%	NaCl 0%	NaCl 1.0%	NaCl 1.5%	NaCl 2.0%
Salinity	5-10 ppt				0 ppt			

10.7 Measurement of water quality parameter: A number of water quality parameters such as, temperature, dissolved oxygen (DO), pH, nitrate-nitrogen, phosphate-phosphorus, ammonia-nitrogen, alkalinity and salinity of experimental ponds were checked fortnightly. Water quality parameters temperature, dissolved oxygen (DO) pH and salinity were measured with respective meters. Nitrate-nitrogen, ammonia-nitrogen, phosphate-phosphorus of experimental ponds water were measured with HACH spectrophotometer, model: DR 6000. Alkalinity was measured with Hach alkalinity test kit.



Plate 3 Determination of physical parameters



Plate 4 Determination of chemical parameters

10.8 Proximate composition of fish feed: Proximate composition of feed was chemically analyzed according to the standard methods of Association of Official Analytical Chemists (AOAC) (2000) for moisture, crude protein, crude lipid, crude fibre and ash. The samples were analyzed in the Fish Nutrition Lab, Department of Aquaculture, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh, Bangladesh.



Plate 5 Feed application

10.9 Estimation of growth, yield and survival of fish

Fish were harvested at the end of the experiment in July 2018. During stocking and harvest, all fish were weighed and counted pond wise. The following parameters were used to determine fish yield:

Average final weight = Average final weight – Average initial weight

$$\text{Specific growth rate (SGR, \% bwd-1)} = \frac{\ln \text{ final weight} - \ln \text{ initial weight}}{\text{Culture Period}} \times 100$$

$$\text{Feed Conversion Ratio (FCR)} = \frac{\text{Feed fed (dry weight)}}{\text{Live weight gain}}$$

Survival rate (%) = (No. of fish caught / No. of fish released) × 100

Gross yield = No. of fish caught × Average final weight

Net Yield = No. of fish caught × Average weight gained



Plate 6 Sampling of Tilapia



Plate 7 Sampling of Seabass



Plate 8 Field visit by PIU-BARC, NATP-2 team



Plate 9 Harvesting of Seabass

10.10 Economic analysis

An economic analysis was performed to estimate the net benefit and benefit cost ratio (BCR) from different treatments. The cost of leasing ponds was not included in the total cost. The net benefit and benefit cost ratios (BCR) were calculated using the following formula:

Net benefit=Total revenue (Tk.)-Total cost (Tk.)

$$\text{BCR} = \frac{\text{Total revenue}}{\text{Total cost}}$$

The overall economics of different treatments were calculated on the basis of the expenditure incurred and the total return from the selling price of fish. All the expenditures and selling price of harvested fish were based on local market prices. The cost of labour, rotenone, lime, fertilizer, fish fingerling (including transportation) and commercial pellet feed was estimated. The interest rate on operating capital was estimated at the rate of 10% per annum for the duration of the culture period. At the end of the research, fishes were sold in a local market and the return was calculated. Values shown reflect combined data of all replicates within each treatment and returns were based on per hectare of fish production.

10.11 **Statistical analysis:** For the statistical analysis of the data, Duncan's Multiple Range Test was done by using the SPSS (Statistical Package for Social Science) version- 16.0. Significance was assigned at the 0.5% level and Microsoft excel 2007 was also used for data processing and analysis. DMRT was used to test the results of multiple ranges for comparisons of averages.

11. Results and discussion:

11.1 Comparative study on production and determination of stocking density of Seabass in brackish- and fresh-water earthen pond under monoculture system

11.1.1 Water quality parameters in brackishwater and freshwater under monoculture system

The water quality parameters such as, water temperature, dissolved oxygen (DO), pH, nitrate -N, phosphate-P, ammonia-N, alkalinity and salinity of brackishwater and freshwater under different treatments are shown in Table 1.

Water temperature (°C)

In brackishwater ponds, the water temperature during the experimental period was more or less equal in all treatment groups. The mean values of water temperature in treatments T1, T2 and T3 were computed as 30.25±1.26°C, 30.50±1.29°C and 30.25±1.26°C respectively (Table 1).

In freshwater ponds, the water temperature during the experimental period was more or less equal in all treatment groups. The mean values of water temperature in treatments T1, T2 and T3 were computed as 29.67±1.63°C, 30.83±1.60°C and 29.50±0.55°C respectively (Table 1).

Dissolved oxygen (mg/l)

In brackishwater environment, the values of dissolved oxygen were more or less similar in the three treatments and somewhat higher in the treatments T2 and T3. The mean values of dissolved oxygen contents under treatments T1, T2 and T3 were 4.75±0.96mg/l, 5.50±0.58mg/l and 5.50±0.58mg/l respectively (Table 1).

In freshwater environment, the mean values of dissolved oxygen contents under treatments T1, T2 and T3 were 5.83 ± 0.41 mg/l, 5.00 ± 0.90 mg/l and 5.33 ± 0.82 mg/l respectively (Table 1). The values of dissolved oxygen was higher in the treatment T1 than the other treatments.

pH

In brackishwater conditions, the mean values of pH in treatments T1, T2 and T3 were 7.75 ± 0.50 , 8.00 ± 0.00 and 7.25 ± 0.50 respectively (Table 1). The pH value in T2 was significantly higher than the values recorded in T1 and T3.

In freshwater conditions, the mean values of pH during the experimental period was more or less equal in all treatment groups. The mean values of pH in treatments T1, T2 and T3 were 7.68 ± 0.23 , 7.60 ± 0.27 and 7.65 ± 0.33 respectively (Table 1).

Nitrate-nitrogen (mg/l)

In brackishwater ponds, the mean values of nitrate-nitrogen ($\text{NO}_3\text{-N}$) content in treatments T1, T2 and T3 were 0.25 ± 0.50 mg/l, 0.10 ± 0.05 mg/l and 0.09 ± 0.04 mg/l respectively (Table 1). No significant differences were observed among the treatments.

In freshwater ponds, the mean values of nitrate-nitrogen ($\text{NO}_3\text{-N}$) content in treatments T1, T2 and T3 were 0.05 ± 0.02 mg/l, 0.08 ± 0.03 mg/l and 0.33 ± 0.52 mg/l respectively (Table 1). The values of nitrate-nitrogen ($\text{NO}_3\text{-N}$) was higher in the treatment T3 than the other treatments.

Phosphate-phosphorus (mg/l)

Under brackishwater ponds, the phosphate-phosphorus ($\text{PO}_4\text{-P}$) during the experimental period was more or less equal in all treatment groups. The mean values of phosphate-phosphorus ($\text{PO}_4\text{-P}$) contents in treatments T1, T2 and T3 were 1.25 ± 0.50 mg/l, 1.00 ± 0.00 mg/l and 1.25 ± 0.50 mg/l respectively (Table 1).

Under freshwater ponds, the mean values of phosphate-phosphorus ($\text{PO}_4\text{-P}$) contents in treatments T1, T2 and T3 were 0.69 ± 0.36 mg/l, 0.14 ± 0.08 mg/l and 0.14 ± 0.08 mg/l respectively (Table 1). The values of phosphate-phosphorus was higher in the treatment T1 than the other treatments.

Ammonia-nitrogen (mg/l)

In brackishwater conditions, the ammonia-nitrogen during the experimental period was more or less equal in all treatment groups. The mean values of ammonia in treatments T1, T2 and T3 were 0.20 ± 0.07 mg/l, 0.14 ± 0.08 mg/l and 0.16 ± 0.05 mg/l respectively (Table 1).

In freshwater conditions, the ammonia-nitrogen during the experimental period was more or less equal in all treatment groups. The mean values of ammonia in treatments T1, T2 and T3 were 0.17 ± 0.09 mg/l, 0.16 ± 0.07 mg/l and 0.25 ± 0.18 mg/l respectively (Table 1).

Alkalinity (mg/l)

In brackishwater ponds, the values of alkalinity were more or less similar in the three treatments and somewhat higher in the treatments T1 and T3. The mean values of alkalinity contents in treatments T1, T2 and T3 were 195.5 ± 41.79 mg/l, 174.38 ± 37.39 mg/l and 188.84 ± 61.84 mg/l respectively (Table 1).

In freshwater ponds, the values of alkalinity were more or less similar in the three treatments and somewhat higher in the treatments T3. The mean values of alkalinity contents in treatments T1, T2 and T3 were 165.44 ± 37.41 mg/l, 173.44 ± 31.40 mg/l and 189.33 ± 30.83 mg/l respectively (Table 1).

Salinity (ppt)

In brackish water ponds, the salinity contents during the experimental period was more or less equal in all treatment groups. The mean values of salinity contents in treatments T1, T2 and T3 were 6.10 ± 1.18 ppt, 6.07 ± 0.78 ppt and 6.39 ± 0.90 ppt respectively (Table 1).

In freshwater ponds, the salinity contents during the experimental period was 0 (zero) in all treatment groups.

Temperature of water condition in a fish pond is known to be one of the limiting factors for fish productivity. The mean values of water temperature in the fish ponds fluctuated between 29.50-30.83°C among the different treatments of the present study which are almost similar to the values of 26-31°C and 29-32 °C in Seabass ponds reported by Biswaset *al.* (2010) and Monwaret *al.* (2013).

Dissolved oxygen (DO) content is probably the single most important water quality parameter in aquaculture. Prolonged exposure to low DO concentration can be harmful for the aquatic life. In the present study, the DO levels of water ranged were between 4.75-5.83 mg/l which are lower than the values of 7.2-8.0mg/l in Seabass ponds reported by Biswaset *al.* (2010). Monwaret *al.* (2013) reported DO ranged were 3.9 to 8.9 in Seabass ponds which are higher than the values obtained in the present study.

The pH in the natural water has great importance as it regulates the productivity of water body. In the present study, the mean values of pH in the fish ponds ranged were 7.25 to 8.00 among the different treatments which are suitable condition for fish culture. Similar result was reported by Biswaset *al.* (2010) and the values was 7.70-8.07. Swingle (1967) reported that pH of water ranging from 6.5-9.0 is suitable for fish culture. Monwaret *al.* (2013) reported water pH ranged were 4.8 to 9.1 in Seabass ponds which indicated that lower range is somewhat lower than the suitable range.

To maintain good productivity of water body nitrate-nitrogen is very essential. The range of nitrate-nitrogen values recorded by Ali (1992) and Whittonet *al.* (1988) were 0.22-0.23 mg/l and 0.006-0.05 mg/l respectively. But in the present study the range of nitrogen concentration obtained 0.05-0.33 mg/l which was almost similar to those of the above studies. Azimet *al.* (1995) stated that near about 0.5 mg/l nitrate-nitrogen was suitable for fish culture. Alikunhi (1957) revealed that good productive water for fish cultivation should have a concentration of 0.06 ppm of nitrate. According to their statements the values of the nitrate-nitrogen recorded in the present study were suitable for fish culture.

Phosphate-phosphorus is an important nutrient for the productivity of a water body. In the present study the ranges of phosphate-phosphorus concentrations obtained were 0.14-1.25 mg/l which is almost similar to the range (0.51-1.23 mg/l) and (0.32-1.00) reported by Das (2002) and Kunda (2003). Alikunhi (1957) suggested that good productive pond water for fish cultivation should have a concentration of phosphate within the range of 0.02-0.4 ppm. Sarker (2005) also obtained relatively higher values of it in this study.

The ranges of ammonia-nitrogen (mg/l) obtained were 0.14-0.25 mg/l. Concentration of ammonia showed an increasing trend as the days of culture increased, probably due to higher metabolic deposition and organic load. The range of ammonia-nitrogen values recorded by Mohanty *et al.* (2004) in rice fields were 0.01-0.31 mg/l which are almost similar to the values obtained in the present study.

The ranges of alkalinity (mg/l) obtained were 165.44-195.41 mg/l in the present study. The range of alkalinity values recorded by Biswaset *al.* (2010) in Seabass ponds were 160-184 mg/l which are almost similar to the values obtained in the present study. Monwaret *al.* (2013) reported alkalinity ranged were 24 to 78 mg/l in Seabass ponds which are invariably lower than the values obtained in the present study. Bhatnagar and Devi (2013) stated that alkalinity of water ranging from 20-200 mg/l is acceptable for fish culture. According to their statements the values of the alkalinity recorded in the present study were suitable for fish culture.

The ranges of salinity (ppt) obtained were 6.07-6.39 ppt in brackish water ponds. The range of salinity values recorded by Biswaset *al.* (2010) in Seabass ponds were 3.2-4.1 ppt which are clearly lower than the values obtained in the present study. Monwaret *al.* (2013) reported salinity ranged were 0 to 6 ppt in Seabass ponds which are lower than the values obtained in the present study.

Table 1. Water quality parameters during the study period under monoculture (mean \pm SD).

Parameters	Brackish water			Freshwater		
	T1	T2	T3	T1	T2	T3
Water temperature (°C)	30.25 \pm 1.26	30.50 \pm 1.29	30.25 \pm 1.26	29.67 \pm 1.63	30.83 \pm 1.60	29.50 \pm 0.55
DO (mg/l)	4.75 \pm 0.96	5.50 \pm 0.58	5.50 \pm 0.58	5.83 \pm 0.41	5.00 \pm 0.90	5.33 \pm 0.82
pH	7.75 \pm 0.50 ^{ab}	8.00 \pm 0.00 ^b	7.25 \pm 0.50 ^a	7.68 \pm 0.23	7.60 \pm 0.27	7.65 \pm 0.33
Nitrate-N (mg/l)	0.25 \pm 0.50	0.10 \pm 0.05	0.09 \pm 0.04	0.05 \pm 0.02	0.08 \pm 0.03	0.33 \pm 0.52
Phosphate-P (mg/l)	1.25 \pm 0.50	1.00 \pm 0.00	1.25 \pm 0.50	0.69 \pm 0.36	0.14 \pm 0.08	0.14 \pm 0.08
Ammonia-N (mg/l)	0.20 \pm 0.07	0.14 \pm 0.08	0.16 \pm 0.05	0.17 \pm 0.09	0.16 \pm 0.07	0.25 \pm 0.18
Alkalinity (mg/l)	195.5 \pm 41.79	174.38 \pm 37.39	188.84 \pm 61.84	165.44 \pm 37.41	173.44 \pm 31.40	189.33 \pm 30.83
Salinity (ppt)	6.10 \pm 1.18	6.07 \pm 0.78	6.39 \pm 0.90	0	0	0

Differences between mean values carrying different superscript letters within one line are statistically significant by ANOVA and Duncan test at $p < 0.05$.

11.1.2 Growth performance of Seabass observed in different treatments under brackish vs fresh water pond

The Seabass production parameters in different treatments under brackish water and freshwater are shown in Table 2.

Initial weight (g)

In brackish water ponds, mean initial weights of Seabass were recorded 60.67 ± 2.08 g, 61.67 ± 5.77 g and 56.00 ± 7.55 g in T1, T2 and T3 respectively.

Mean initial weights of Seabass in freshwater ponds were found 66.00 ± 3.61 g, 65.00 ± 10.00 g and 52.33 ± 2.52 g in T1, T2 and T3 respectively (Table 2).

Final weight (g)

Mean final weights of Seabass in brackish water ponds were 417.07 ± 17.00 g, 440.07 ± 12.53 g and 432.20 ± 3.24 g in T1, T2 and T3 respectively (Table 2). Higher mean final weight of Seabass was obtained 440.07 ± 12.53 g in T2 (25 indi/dec) compared to other treatments without significant difference among treatments. Where, mean final weight of Seabass in freshwater ponds were 391.60 ± 16.93 g, 436.80 ± 30.57 g and 417.53 ± 16.64 g in T1, T2 and T3 respectively, with somehow higher final weight found 417.53 ± 16.64 g in T2 (25 individual/decimal) compared to other treatments without significant difference among treatments. All the treatments in brackish water contributed higher final weight of Seabass compared to those of freshwater ponds.

Survival rate (%)

In brackish water ponds, average survival rates (%) of Seabass were obtained $59.31 \pm 3.08\%$, $53.75 \pm 2.78\%$ and $39.99 \pm 2.09\%$ in T1, T2 and T3 respectively with significantly higher survival rate in T1 (59.31%) and lower in T3 (39.99%).

The survival rate (%) of Seabass in freshwater ponds were found $58.81 \pm 3.90\%$, $51.82 \pm 5.84\%$ and $39.59 \pm 2.06\%$ in T1, T2 and T3 respectively with significantly higher survival rate obtained in T1 (58.81%) and lower in T3 (39.59%) in Table 2.

Specific Growth Rate (SGR) (%/day)

Average Specific Growth Rates (SGR) of Seabass in brackish water ponds were $1.08 \pm 0.05\%/day$, $1.15 \pm 0.03\%/day$ and $1.14 \pm 0.02\%/day$ in T1, T2 and T3 respectively. The SGR of Seabass was somewhat higher in T2 (25 individual/decimal) without significant difference among the treatments.

In case of freshwater pond, average Specific Growth Rates (SGR) of Seabass were found $0.99 \pm 0.04\%/day$, $1.13 \pm 0.07\%/day$ and $1.11 \pm 0.05\%/day$ in T1, T2 and T3 respectively (Table 2). The SGR of Seabass was significantly higher in T2 and T3 than the treatment T1. But the highest SGR was recorded in T2 where stocking density of Seabass was 25 individual/decimal. The treatments carried out in brackish water ponds gained higher SGR than those of freshwater ponds.

Feed Conversion Ratio (FCR)

In brackish water conditions, average Feed Conversion Rates (FCR) of Seabass were calculated as 2.68 ± 0.61 , 2.85 ± 0.59 and 2.78 ± 0.85 in T1, T2 and T3 respectively. The FCR of Seabass was somehow lower in T1 where stocking density of Seabass was 20 individual/decimal than the other treatments. However, no significant difference of FCR was found among the treatments.

In freshwater ponds, average Feed Conversion Rates (FCR) of Seabass were 2.71 ± 0.41 , 2.78 ± 0.43 and 2.98 ± 0.32 in T1, T2 and T3 respectively. The FCR of Seabass was somehow lower in T1 (20

individual/decimal) without any significant difference among the treatments. The treatments conducted in freshwater gained somewhat higher FCR than the treatments conducted in brackish water (Table 2).

Yield of Fish

In brackishwater ponds, average gross yields in treatments T1, T2 and T3 were obtained 1220.73±42.47 kg/ha, 1460.78±86.46 kg/ha and 1280.43±57.63 kg/ha respectively. Average net yields in treatments T1, T2 and T3 were estimated as 1043.06±34.13 kg/ha, 1255.55±58.63 kg/ha and 1115.18±70.29 kg/ha respectively. The highest yield of Seabass was recorded in T2 (Gross yield 1460.78±86.46 kg/ha, Net yield 1255.55±58.63 kg/ha) compared to those of other treatments which might be associated with highest metabolic growth rate of fish obtained in this treatment.

In freshwater ponds, average gross yields in treatments T1, T2 and T3 were found 1139.02±115.55 kg/ha, 1392.46±114.00 kg/ha and 1223.26±30.21 kg/ha respectively. Average net yields in treatments T1, T2 and T3 were 946.96±93.73 kg/ha, 1186.79±113.46 kg/ha and 1069.86±33.04 kg/ha respectively. The highest yield of Seabass was recorded in T2 (Gross yield 1392.46±114.00 kg/ha, Net yield 1186.79±113.46 kg/ha) than the rest of the treatments which might be associated with highest specific growth rate of fish obtained in this treatment. Seabass monoculture contributed higher yield in brackishwater ponds compared to those of freshwater ponds (Table 2).

Table 2. Growth performance of Seabass observed in different treatments under monoculture.

Parameters	Brackish water			Freshwater		
	T1	T2	T3	T1	T2	T3
Stocking (/dec)	20	25	30	20	25	30
Initial weight (g)	60.67±2.08	61.67±5.77	56.00±7.55	66.00±3.61 ^b	65.00±10.00 ^b	52.33±2.52 ^a
Final weight (g)	417.07±17.00	440.07±12.53	432.20±3.24	391.60±16.93	436.80±30.57	417.53±16.64
Survival rate (%)	59.31±3.08 ^c	53.75±2.78 ^b	39.99±2.09 ^a	58.81±3.90 ^b	51.82±5.84 ^b	39.59±2.06 ^a
SGR (%/day)	1.08±0.05	1.15±0.03	1.14±0.02	0.99±0.04 ^a	1.13±0.07 ^b	1.11±0.05 ^b
FCR	2.68±0.61	2.85±0.59	2.78±0.85	2.71±0.41	2.78±0.43	2.98±0.32
Gross production (kg/ha)	1220.73±42.47 ^a	1460.78±86.46 ^b	1280.43±57.63 ^a	1139.02±115.55 ^a	1392.46±114.00 ^b	1223.26±30.21 ^{ab}
Net production (kg/ha)	1043.06±34.13 ^a	1255.55±58.63 ^b	1115.18±70.29 ^a	946.96±93.73 ^a	1186.79±113.46 ^b	1069.86±33.04 ^{ab}

Differences between mean values carrying different superscript letters within one line are statistically significant by ANOVA and Duncan test at $p < 0.05$.

The initial weight ranged 52.33-66.00g among in different treatments of the present study which were almost similar to the initial weight ranges 30-70g of Seabass reported by Monwaret *al.* (2013). Daet (2019) stocked Seabass in hapa-in-pond with initial weight of 3.27-3.61 g which were invariably lower than the present study. The average initial weight of Seabass stocked in the experimental ponds was 107.22 ± 8.44 g (Harpazet *al.*, 2005) which was higher than the values in the present study.

The final weight ranged 391.60-440.07g among the different treatments of the present study which was lower than the final weight range 200-1390g of Seabass reported by Monwaret *al.* (2013). Daet (2019) recorded final weight of Seabass in hapa-in-pond with initial weight of 139.59-152.34 g after 90 days rearing which was higher than the present study compared to the rearing period.

The survival rate of Seabass (39.59-59.31%) was found quite lower compared to the investigation carried out by Monwaret *al.* (2013). Daet (2019) recorded 48-90% survival rate of Seabass in hapa-in-pond with different stocking density which were higher than the present study (59.7-78.3%). However, Imelda-Joseph (2010) observed poor survival rate at the end of his study mainly due to cannibalism. Other factors which could possibly contribute to low survival rate of Seabass include space, presence of natural food to sustain the stock, feeding rate and food utilization and the feeding. Harpazet *al.* (2005) reported the survival rate of Seabass was 90-97% which was higher than the values in the present study. Kailasamet *al.* (2006) recorded survival rate after 45 days rearing and the maximum survival ($88.7 \pm 4.1\%$) in PUFA enriched *Artemia*, followed by non-enriched *Artemia* ($85.33 \pm 8.2\%$), PUFA enriched *Moina* ($84.0 \pm 6.5\%$), non-enriched *Moina* ($82.0 \pm 1.6\%$), egg custard ($71.3 \pm 6.6\%$) and fish meat ($60.3 \pm 5.7\%$).

The SGR range obtained 0.99-1.15 %/day among different treatments was lower than the SGR 1.51-1.65 %/day of Seabass reported by Daet (2019) who conducted research on Seabass in hapa-in-pond with different stocking density. Harpazet *al.* (2005) reported the SGR of Seabass was 0.98-1.19 %/day which was almost similar to the values in the present study. Biswaset *al.* (2010) reported the SGR of Seabass was 4.93-5.07 %/day when conducted a research on optimization of feeding frequency of Asian Seabass fry reared in net cages under brackish water environment which were invariably higher than the values in the present study.

The FCR ranged 2.68-2.98 of the present study which are invariably lower than the FCR range 33.97-66.55 of Seabass reported by Daet (2019) who conducted research on Seabass in hapa-in-pond with different stocking density. Biswaset *al.* (2010) reported the FCR of Seabass ranged 2.23-3.04 when conducted a research on optimization of feeding frequency of Asian Seabass fry reared in net cages under brackish water environment which are almost similar to the values in the present study.

The gross and net production ranged 1139.02-1460.78 kg/ha and 946.96-1255.55 kg/ha respectively among the different treatments of the present study. Monwaret *al.* (2013) recorded 899.26-1168.50 kg/ha production after 3 months culture period which are higher than the production of present study. Danakusumah and Ismail (1986) reported that average individual daily growth was 1.3 to 1.5 g for those cultured with formulated feed and 2.65 to 3.58 g for those with trash fish. Sugama and Eda (1986) showed that the average daily growth of 4.62 to 6.05g in net cage culture with trash fish. Growth and production are dependent on the amount of supplied feed (Bardachet *al.*, 1972). ICAR (2010) reported that Seabass attain 450 to 950 g after 270 days of culture from Seabass Tilapia polyfarming at Kakdwip, India. Similar types of works were also performed by the KAU (2012). Awang (1986) stated that Seabass were reared about 5 to 9 months in cages to raise market size of about 500 g (1.55 to 3.0 g/day) using trash fish. Genodepa (1986) also harvested 351.5 g of Seabass with a stocking size of 221.5 g having a culture period of 94 days (daily growth rate of 1.3 g) using trash fish in a monoculture pond. Singh *et al.*

(2012) stated that the stocking density of 1500 individual/ha was found to be superior as it gave the highest yield of Seabass(541.50 kg/ha/yr) as compared with 1000–2000 individual/ha stocking density, which could yield only 80.44 kg/ha/yr and 350.01 kg/ha/yr, respectively. The forage fish (Tilapia) should be in the ratio of 1:6 of Seabass to Tilapia for higher growth of Seabass.

11.2 Comparative study on production and determination of stocking density of Seabass in brackish- and fresh-water earthen pond under mixed culture system

Seabass were stocked in both coastal brackish and freshwater ponds with Tilapia. Tilapia were stocked at 1:3 male:female ratio, whereas Seabass were in constant number of 20 individual per decimal. Artificial feed with 28.10 % protein were supplied to Tilapia.

Table 3. Water quality parameters during the study period under mixed culture (mean \pm SD).

Parameters	Brackish water			Freshwater		
	T1	T2	T3	T1	T2	T3
Stocking: (Seabass/dec)	20	20	20	20	20	20
(Tilapia/dec)	40	60	80	40	60	80
Water temperature ($^{\circ}$ C)	29.95 \pm 1.21	30.15 \pm 1.25	29.45 \pm 2.29	30.00 \pm .00	30.60 \pm .89	29.85 \pm .90
DO (mg/l)	4.65 \pm 1.26	4.50 \pm 1.15	3.95 \pm 0.88	5.16 \pm 1.17	5.00 \pm 1.00	4.85 \pm 0.90
pH	7.72 \pm 0.40	7.52 \pm 0.50	7.15 \pm 1.10	7.65 \pm 0.13	7.65 \pm 0.25	7.35 \pm 0.33
Nitrate-N (mg/l)	0.22 \pm 0.54	0.40 \pm 0.54	1.05 \pm 0.65	0.17 \pm 0.41 ^a	1.60 \pm 0.55 ^b	0.29 \pm 0.76 ^a
Phosphate-P (mg/l)	0.95 \pm 0.60	1.05 \pm 0.40	1.25 \pm 0.60	1.00 \pm 0.00	0.80 \pm 0.45	1.29 \pm 0.49
Ammonia-N (mg/l)	0.20 \pm 0.07	0.25 \pm 0.10	0.32 \pm 0.15	0.17 \pm 0.11	0.17 \pm 0.07	0.23 \pm 0.13
Alkalinity (mg/l)	175.50 \pm 55.79	182.38 \pm 60.30	191.84 \pm 51.24	169.44 \pm 47.41	178.44 \pm 31.43	182.33 \pm 20.83
Salinity (ppt)	5.74 \pm 0.88	6.25 \pm 0.71	6.19 \pm 0.40	0	0	0

Differences between mean values carrying different superscript letters within one line are statistically significant by ANOVA and Duncan test at $p < 0.05$.

11.2.1 Water quality parameters during the study period under mixed culture

The water quality parameters such as, water temperature, dissolved oxygen (DO), pH, nitrate –N, phosphate-P, ammonia-N, alkalinity and salinity of brackishwater and freshwater under different treatments are shown in Table 3.

Water temperature (°C)

In brackishwater ponds, the water temperature during the experimental period was more or less equal in all treatment groups. The mean values of water temperature in treatments T1, T2 and T3 were computed as $29.95 \pm 1.21^\circ\text{C}$, $30.15 \pm 1.25^\circ\text{C}$ and $29.45 \pm 2.29^\circ\text{C}$ respectively (Table 3).

In freshwater ponds, the water temperature during the experimental period was more or less equal in all treatment groups. The mean values of water temperature in treatments T1, T2 and T3 were computed as $30.00 \pm .00^\circ\text{C}$, $30.60 \pm .89^\circ\text{C}$ and $29.85 \pm .90^\circ\text{C}$ respectively (Table 3).

Dissolved oxygen (mg/l)

Under brackishwater ponds, the values of dissolved oxygen were more or less similar in the three treatments and somewhat higher in the treatments T1 and T2. The mean values of dissolved oxygen contents under treatments T1, T2 and T3 were $4.65 \pm 1.26\text{mg/l}$, $4.50 \pm 1.15\text{mg/l}$ and $3.95 \pm 0.88\text{mg/l}$ respectively (Table 3). The Lowest dissolved oxygen was recorded in T3 where Tilapia were stocked at the rate of 80 individual/decimal.

In freshwater ponds, the mean values of dissolved oxygen contents under treatments T1, T2 and T3 were $5.16 \pm 1.17\text{mg/l}$, $5.00 \pm 1.00\text{mg/l}$ and $4.85 \pm 0.90\text{mg/l}$ respectively (Table 3). The values of dissolved oxygen was higher in the treatment T1 than the other treatments.

pH

In brackishwater conditions, the mean values of pH in treatments T1, T2 and T3 were 7.72 ± 0.40 , 7.52 ± 0.50 and 7.15 ± 1.10 respectively (Table 3). No significant differences were observed among the treatments.

In freshwater ponds, the mean values of pH during the experimental period was more or less equal in all treatment groups. The mean values of pH in treatments T1, T2 and T3 were 7.65 ± 0.13 , 7.65 ± 0.25 and 7.35 ± 0.33 respectively (Table 3).

Nitrate-nitrogen (mg/l)

In brackishwater ponds, the mean values of nitrate-nitrogen ($\text{NO}_3\text{-N}$) content in treatments T1, T2 and T3 were $0.22 \pm 0.54\text{mg/l}$, $0.40 \pm 0.54\text{mg/l}$ and $1.05 \pm 0.65\text{mg/l}$ respectively (Table 3). The highest $\text{NO}_3\text{-N}$ value was recorded in T3 where Tilapia were stocked at the rate of 80 individual/decimal. But the differences were not significant among the treatments.

In freshwater ponds, the mean values of nitrate-nitrogen ($\text{NO}_3\text{-N}$) content in treatments T1, T2 and T3 were $0.17 \pm 0.4\text{mg/l}$, $1.60 \pm 0.55\text{mg/l}$ and $0.29 \pm 0.76\text{mg/l}$ respectively (Table 3). The values of nitrate-nitrogen ($\text{NO}_3\text{-N}$) was significantly higher in the treatment T2 than the other treatments.

Phosphate-phosphorus (mg/l)

In brackishwater environment, the phosphate-phosphorus ($\text{PO}_4\text{-P}$) during the experimental period was more or less equal in all treatment groups. The mean values of phosphate-phosphorus ($\text{PO}_4\text{-P}$) contents in treatments T1, T2 and T3 were $0.95 \pm 0.60\text{mg/l}$, $1.05 \pm 0.40\text{mg/l}$ and $1.25 \pm 0.60\text{mg/l}$ respectively (Table 3).

In freshwater environment, the mean values of phosphate-phosphorus ($\text{PO}_4\text{-P}$) contents in treatments T1, T2 and T3 were $1.00 \pm 0.00 \text{ mg/l}$, $0.80 \pm 0.45 \text{ mg/l}$ and $1.29 \pm 0.49 \text{ mg/l}$ respectively (Table 3). The values of phosphate-phosphorus was higher in the treatment T3 than the other treatments.

Ammonia-nitrogen (mg/l)

In brackishwater ponds, the ammonia-nitrogen during the experimental period was more or less equal in all treatment groups. The mean values of ammonia in treatments T1, T2 and T3 were $0.20 \pm 0.07 \text{ mg/l}$, $0.25 \pm 0.10 \text{ mg/l}$ and $0.32 \pm 0.15 \text{ mg/l}$ respectively (Table 3).

In freshwater ponds, the ammonia-nitrogen during the experimental period was more or less equal in all treatment groups. The mean values of ammonia in treatments T1, T2 and T3 were $0.17 \pm 0.11 \text{ mg/l}$, $0.17 \pm 0.07 \text{ mg/l}$ and $0.23 \pm 0.13 \text{ mg/l}$ respectively (Table 3).

Alkalinity (mg/l)

In brackishwater ponds, the values of alkalinity were more or less similar in the three treatments and somewhat higher in the treatments T1 and T3. The mean values of alkalinity contents in treatments T1, T2 and T3 were $175.50 \pm 55.79 \text{ mg/l}$, $182.38 \pm 60.30 \text{ mg/l}$ and $191.84 \pm 51.24 \text{ mg/l}$ respectively (Table 3).

In freshwater ponds, the values of alkalinity were more or less similar in the three treatments and somewhat higher in the treatments T3. The mean values of alkalinity contents in treatments T1, T2 and T3 were $169.44 \pm 47.41 \text{ mg/l}$, $178.44 \pm 31.43 \text{ mg/l}$ and $182.33 \pm 20.83 \text{ mg/l}$ respectively in Seabass ponds (Table 3).

Salinity (ppt)

In brackishwater ponds, the salinity contents during the experimental period was more or less equal in all treatment groups. The mean values of salinity contents in treatments T1, T2 and T3 were $5.74 \pm 0.88 \text{ ppt}$, $6.25 \pm 0.71 \text{ ppt}$ and $6.19 \pm 0.40 \text{ ppt}$ respectively (Table 3).

In freshwater ponds, the salinity contents during the experimental period was 0 (zero) in all treatment groups.

Water temperature is one of the most significant parameters in natural surface water system. Temperature regulates the metabolism of aquatic plants and animals and is largely responsible for biochemical process and reactions. Moncrief and Jones (1997) stated that for 1°C rise of water temperature metabolic rate becomes double. Sudden changes of water temperature may fall a fish in stress. So, very low temperature in winter and high temperature in summer is a chief problem in fish culture. In Bangladesh fish grows all the year round and there is no problem of very low temperature but sometimes extremely high temperature kill fishes especially in a shallow and turbid water body (Rahman, 1992). The mean values of water temperature in the fish ponds fluctuated between $29.45\text{-}30.60^\circ\text{C}$ among the different treatments of the present study which are almost similar to the values of $26\text{-}31^\circ\text{C}$ and $29\text{-}32^\circ\text{C}$ in Seabass ponds reported by Biswas *et al.* (2010) and Monwar *et al.* (2013) respectively.

Dissolved oxygen (DO) is probably the single most important parameter in natural water bodies for determining the suitability of aquatic organism's survival. Fishes become susceptible to various bacterial and other diseases if they remain for a condition of insufficient oxygen for long time. Photosynthesis of phytoplankton and air are the sources of dissolved oxygen in pond. Oxygen reduction occurs in pond water through respiration of aquatic organisms and decomposition of dead organic matters and release to the atmosphere when the water temperature is higher. Necessity of dissolved oxygen by fish varies with temperature, physiological state, time of the day, age, species, season, food consumption etc. (Boyd, 1982). In the present study, the DO levels of water ranged were between $3.95\text{-}5.16 \text{ mg/l}$ which

are lower than the values of 7.2-8.0mg/l in Seabass ponds reported by Biswaset *al.* (2010). Monwaret *al.* (2013) reported DO ranged were 3.9 to 8.9 in Seabass ponds which are higher than the values obtained in the present study.

The pH in the natural water has great importance as it regulates the productivity of water body. In the present study, the mean values of pH in the fish ponds ranged were 7.15 to 7.72 among the different treatments which are suitable condition for fish culture. Somewhat higher result was reported by Biswaset *al.* (2010) and the values was 7.70-8.07. Monwaret *al.* (2013) reported water pH ranged were 4.8 to 9.1 in Seabass ponds which indicated that lower range is somewhat lower than the suitable range. Swingle (1967) stated that pH 6.5 to 9.0 is suitable for pond fish culture. The pH more than 9.5 is unsuitable because free CO₂ is not available in this situation. The pH less than 6.5 reduces fish growth, physiological activities and tolerance to toxic substances. Parasites and disease easily attack fish when pH is less than 6.5 (Rahman *et al.*, 1998). From the above discussion we may conclude that pH values of all the experimental ponds were slightly alkaline which indicate suitable pH condition for fish culture.

Nitrite plays a significant role in growth and production of fish. It is extremely important as a nutrient in supplying nitrogen for protein synthesis. Nitrite is most important to aquaculturists although different forms are available. It occurs in small concentration in unpolluted freshwater. The range of nitrate-nitrogen values recorded by Ali (1992) and Whitton *et al.* (1988) were 0.22-0.23 mg/l and 0.006-0.05 mg/l respectively. But in the present study the range of nitrogen concentration obtained 0.17-1.60 mg/l which was invariably higher to those of the above studies. Azim *et al.* (1995) stated that near about 0.5 mg/l nitrate-nitrogen was suitable for fish culture. Alikunhi (1957) revealed that good productive water for fish cultivation should have a concentration of 0.06 ppm of nitrate. Bhatnagar and Devi (2013) stated that nitrate-nitrogen of water ranging from 0.1-4.5 mg/l is desirable for fish culture. According to their statements the values of the nitrate-nitrogen recorded in the present study were suitable for fish culture.

Phosphate-phosphorus is an important nutrient for the productivity of a water body. In the present study the ranges of phosphate-phosphorus concentrations obtained were 0.80-1.29 mg/l which is almost similar to the range (0.51-1.23 mg/l) and (0.32-1.00) reported by Das (2002) and Kunda (2003). Alikunhi (1957) suggested that good productive pond water for fish cultivation should have a concentration of phosphate within the range of 0.02-0.4 ppm. Sarker (2005) also obtained relatively higher values of it in his study.

When feed is eaten by fish it is metabolized into the energy, nutrients and proteins used for survival and growth. Ammonia is the principal waste product excreted by fish. Ammonia is important but when it exist it high amount in the cultural environment it is toxic to fish if allowed to accumulate in fish production system. The unionized form of ammonia (NH₃) is extremely toxic while the ionized form (NH₄⁺) is not and both the forms are grouped together as total ammonia. When ammonia accumulates to toxic levels, fish cannot extract energy from feed efficiently. If the ammonia concentration gets high, the fish will become lethargic and eventually fall into a coma and die. The toxic levels for un-ionized ammonia for short-term exposure usually lie between 0.6 and 2.0 mg/l for pond fish, and sub-lethal effects may occur at 0.1 to 0.3 mg/l (EIFAC, 1973; Robinette, 1976). Maximum limit of ammonia concentration for aquatic organisms is 0.1 mg/l (Meade, 1989, Santhosh and Singh, 2007). According to Swann (1997) and OATA (2008) the levels below 0.02 ppm were considered safe. The ranges of ammonia-nitrogen (mg/l) obtained were 0.17-0.32 mg/l. Concentration of ammonia showed an increasing trend as the days of culture increased, probably due to higher metabolic deposition and organic load. The range of ammonia-nitrogen values recorded by Mohanty *et al.* (2004) in rice fields were 0.01-0.31 mg/l which are almost similar to the values obtained in the present study.

Alkalinity is the water's ability to resist changes in pH and is a measure of the total concentration of bases in pond water including carbonates, bicarbonates, hydroxides, phosphates and borates, dissolved calcium, magnesium, and other compounds in the water. Nutrients are found in higher alkalinity and this is the most important for higher biological productivity in alkaline waters than acidic waters. But excess alkaline water is not suitable for biological production (Rahman, 1992). Alkalinity may be several hundred mg/l in natural water bodies. The ranges of alkalinity (mg/l) obtained were 169.44-191.84 mg/l in the present study. The range of alkalinity values recorded by Biswaset *al.* (2010) in Seabass ponds were 160-184 mg/l which are almost similar to the values obtained in the present study. Monwaret *al.* (2013) reported alkalinity ranged were 24 to 78 mg/l in Seabass ponds which are invariably lower than the values obtained in the present study. Bhatnagar and Devi (2013) stated that alkalinity of water ranging from 20-200 mg/l is acceptable for fish culture. According to their statements the values of the alkalinity recorded in the present study were suitable for fish culture.

The ranges of salinity (ppt) obtained were 5.74-6.25ppt in brackish water ponds. The range of salinity values recorded by Biswaset *al.* (2010) in Seabass ponds were 3.2-4.1 ppt which are clearly lower than the values obtained in the present study. Monwaret *al.* (2013) reported salinity ranged were 0 to 6 ppt in Seabass ponds which are lower than the values obtained in the present study.

11.2.2 Growth performance of Seabass observed in different treatments under brackishwater and freshwater

Growth performance of Seabass under brackishwater and freshwater are shown in Table 4.

Initial weight (g)

In brackishwater, mean initial weights of Seabass were recorded 63.33±7.64g, 59.00±7.94g and 59.67±5.03g in T1, T2 and T3 respectively. The mean initial weight of Seabass was higher in T1 than the treatments T2 and T3.

In freshwater, mean initial weights of Seabass were recorded 71.00±3.61 g, 71.00±5.20 g and 64.33±6.03 g in T1, T2 and T3 respectively (Table 4).

Final weight (g)

In brackishwater, mean final weights of Seabass were obtained 472.53±24.41g, 488.00±20.84g and 549.17±5.30g in T1, T2 and T3 respectively. Mean final weight of Seabass was significantly higher in T3 compared to other treatments where the stocking density of Tilapia was 80 individual/decimal.

In freshwater, mean final weights of Seabass were observed 472.50±36.40g, 489.00±42.44g and 584.33±14.57g in T1, T2 and T3 respectively, with significantly higher mean final weight in T2 (Tilapia, 80 individual/decimal) compared to other treatments. Relatively, higher final weights of Seabass were observed in freshwater culture systems compared to those of brackish water (Table 4).

Survival rate (%)

In brackishwater condition, average survival rates (%) of Seabass were found 59.82±2.89%, 65.45±6.18% and 62.42±3.09% in T1, T2 and T3 respectively. The highest and lowest survival rates were obtained in T2 (65.45%) and in T1 (59.82%) respectively without significant difference among the treatments.

In freshwater, survival rates (%) of Seabass were 58.81±3.90%, 64.78±7.30% and 59.38±3.09% in T1, T2 and T3 respectively. Higher survival rate was obtained in T2 (64.78%) compared to other treatments.

Specific Growth Rate (SGR) (%/day)

In brackishwater, average Specific Growth Rates (SGR) of Seabass were calculated as $1.24 \pm 0.08\%$ /day, $1.30 \pm 0.09\%$ /day and $1.48 \pm 0.03\%$ /day in T1, T2 and T3 respectively with the highest SGR recorded in T3 (Tilapia, 80 individual/decimal) with significant difference

In freshwater, SGR of Seabass were $1.22 \pm 0.10\%$ /day, $1.27 \pm 0.13\%$ /day and $1.47 \pm 0.06\%$ /day in T1, T2 and T3 respectively (Table 4). SGR of Seabass was significantly higher in T3 compared to other treatments, where Tilapia was stocked at the rate of 80 individual/decimal. The treatments conducted in freshwater gained higher SGR compared to those of brackish water.

Yield of Fish

In brackishwater, gross and net yields of Seabass in treatments T1, T2 and T3 were found 1396.16 ± 96.04 kg/ha, 1209.73 ± 108.34 kg/ha; 1578.97 ± 175.97 kg/ha, 1388.20 ± 171.08 kg/ha and 1692.73 ± 67.34 kg/ha, 1508.38 ± 47.45 kg/ha respectively with higher yield recorded in T3 which might be associated with higher specific growth rate of seabass obtained in this treatment.

In freshwater, gross and net yields in treatments T1, T2 and T3 were found 1373.45 ± 154.66 kg/ha, 1167.51 ± 144.59 kg/ha; 1569 ± 264.47 kg/ha, 1343.65 ± 246.73 kg/ha and 1608.37 ± 92.60 kg/ha, 1420.10 ± 101.73 kg/ha respectively (Table 4). The highest yield of Seabass was recorded in T3 which might be associated with higher specific growth rate attained during the study. Higher yields were recorded in freshwater compared to those of brackishwater.

Table 4. Growth performance of Seabass observed in different treatments under mixed culture.

Parameters	Brackish water			Freshwater		
	T1	T2	T3	T1	T2	T3
Stocking (nos/dec)	20	20	20	20	20	20
Initial wt. (g)	63.33±7.64	59.00±7.94	59.67±5.03	71.00±3.61	71.00±5.20	64.33±6.03
Final wt. (g)	472.53±24.41 ^a	488.00±20.84 ^a	549.17±5.30 ^b	472.50±36.40 ^a	489.00±42.44 ^{ab}	584.33±14.57 ^b
Survival rate (%)	59.82±2.89	65.45±6.18	62.42±3.09	58.81±3.90	64.78±7.30	59.38±3.09
SGR (%/day)	1.24±0.08 ^a	1.30±0.09 ^a	1.48±0.03 ^b	1.22±0.10 ^a	1.27±0.13 ^a	1.47±0.06 ^b
Gross production (kg/ha)	1396.16±96.04 ^a	1578.97±175.97 ^{ab}	1692.73±67.34 ^b	1373.45±154.66	1569±264.47	1608.37±92.60
Net production (kg/ha)	1209.73±108.34 ^a	1388.20±171.08 ^{ab}	1508.38±47.45 ^b	1167.51±144.59	1343.65±246.73	1420.10±101.73

Differences between mean values carrying different superscript letters within one line are statistically significant by ANOVA and Duncan test at $p < 0.05$.

Table 5. Growth performance of Tilapia observed in different treatments under mixed culture.

Parameters	Brackish water			Freshwater		
	T1	T2	T3	T1	T2	T3
Stocking (Nos/dec)	40	60	80	40	60	80
Initial wt. (g)	166.00±10.15	164.33±8.14	163.67±4.16	166.00±3.61	165.00±10.00	160.67±6.03
Final wt. (g)	585.10±5.11	587.83±19.18	587.17±8.80	603.80±19.38	602.80±16.67	592.97±31.06
Survival rate (%)	81.31±2.28	80.59±4.15	79.30±6.24	82.32±2.55	80.70±2.65	80.82±2.71
SGR (%/day)	1.27±0.04	1.28±0.04	1.28±0.03	1.33±0.07	1.33±0.04	1.31±0.08
Gross production (kg/ha)	4700.75±159.66 ^a	7028.32±586.86 ^b	9195.47±629.05 ^c	4913.99±305.08 ^a	7207.35±222.22 ^b	9461.25±336.06 ^c
Net production (kg/ha)	3368.70±205.24 ^a	5062.75±400.24 ^b	6629.60±395.97 ^c	3564.22±285.89 ^a	5236.55±251.51 ^b	6896.26±265.16 ^c

Difference between mean values carrying different superscript letters within one line are statistically significant by ANOVA and Duncan test at $p < 0.05$.

The initial weight ranged were 59.00-71.00g among the different treatments of the present study which are almost similar to the initial weight ranges 30-70g of Seabass reported by Monwaret *al.* (2013). Daet (2019) stocked Seabass in hapa-in-pond with initial weight of 3.27-3.61 g which were invariably lower than the present study. The average initial weight of Seabass stocked in the experiment was 107.22 ± 8.44 g (Harpazet *al.*, 2005) which was higher than the values in the present study. The final weight ranged were 472.50-584.33 g among the different treatments of the present study which were lower than the final weight 200-1390g of Seabass reported by Monwaret *al.* (2013). Daet (2019) recorded final weight of Seabass in hapa-in-pond with initial weight of 139.59-152.34 g in 90 days culture period which were higher compared to culture period of the present study.

The survival rate ranged 58.81-65.45% were lower than the range of survival rate 59.7-78.3% of Seabass reported by Monwaret *al.* (2013). Daet (2019) recorded survival rate of Seabass in hapa-in-pond 48-90% with different stocking density which were higher than the present study. Imelda-Joseph (2010) observed poor survival rate at the end of the study mainly due to cannibalism. Low survival rate of Seabass could be due to insufficient grazing space, absence of sufficient natural food, low feeding rate and poor food utilization etc. Harpazet *al.* (2005) reported, the survival rate of Seabass was 90-97% which was higher than the values in the present study. Kailasamet *al.* (2006) recorded survival rate after 45 days rearing and the maximum survival ($88.7 \pm 4.1\%$) in PUFA enriched *Artemia*, followed by non-enriched *Artemia* ($85.33 \pm 8.2\%$), PUFA enriched *Moina* ($84.0 \pm 6.5\%$), non-enriched *Moina* ($82.0 \pm 1.6\%$), egg custard ($71.3 \pm 6.6\%$) and fish meat ($60.3 \pm 5.7\%$) which were higher than the findings of present study.

The highest SGR were 1.48%/day and 1.47%/day in T3 in brackish and freshwater environment respectively where the ratio of stocking density of Seabass and Tilapia were 1:4 which were supported by Monwaret *al.* (2013). They also gained higher yield where the ratio of Seabass and Tilapia were 1:4 than the ratio 1:5 and 1:6. Harpazet *al.* (2005) reported the SGR of Seabass was 0.98-1.19 %/day which was lower than the values in the present study. Biswaset *al.* (2005) reported the SGR of Seabass was 4.93-5.07%/day when conducted a research on optimization of feeding frequency of Asian Seabass fry reared in net cages under brackish water environment which were invariably higher than the values in the present study. Danakusumah and Ismail (1986) reported that average individual daily growth was 1.3 to 1.5 gm for those cultured fish with formulated feed and 2.65 to 3.58 gm for those with trash fish. Sugama and Eda (1986) showed that the average daily growth of 4.62 to 6.05 g in net cage culture with trash fish. Growth and production are dependent on the amount of supplied feed (Bardachet *al.*, 1972).

Gross and net production ranged 1373.45-1692.73 kg/ha and 1167.96-1255.55 kg/ha respectively among the different treatments of the present study. Monwaret *al.* (2013) recorded 899.26-1168.50 kg/ha production after 3 months culture period which were lower than the production of the present study. ICAR (2010) reported that Seabass attain 450 to 950g after 270 days of culture from Seabass-Tilapia polyfarming at Kakdwip, India. Similar types of research were also performed by the KAU (2012). Singh *et al.* (2012) stated that the stocking density of 1500 nos./ha was found to be superior as it gave the highest yield of Seabass (541.50 kg/ha/yr) as compared with 1000-2000 nos./ha stocking density, which could yield only 80.44 ka/ha/yr and 350.01 kg/ha/yr, respectively. The forage fish (Tilapia) should be in the ratio of 1:6 of Seabass to Tilapia for higher growth of Seabass. Awang (1986) stated that Seabass were reared about 5 to 9 months in cages to raise market size of about 500 g (1.55 to 3.0 g/day) using trash fish. Genodepa (1986) also harvested 351.5 g of Seabass with a stocking size of 221.5 g having a culture period of 94 days (daily growth rate of 1.3 g) using trash fish in a monoculture pond.

11.2.3 Growth performance of Tilapia in different treatments under brackishwater and freshwater

Growth performance of Tilapia under brackishwater and freshwater are shown in Table 5.

Initial weight (g)

Under brackishwater, mean initial weights of Tilapia were recorded 166.00 ± 10.15 g, 164.33 ± 8.14 g and 163.67 ± 4.16 g in T1, T2 and T3 respectively (Table 5). The mean initial weight of Tilapia was higher in T1 than the treatments T2 and T3.

Under freshwater, mean initial weights of Tilapia were recorded 166.00 ± 3.61 g, 165.00 ± 10.00 g and 160.67 ± 6.03 g in T1, T2 and T3 respectively. The mean initial weight of Tilapia was somewhat higher in T1 than the treatments T2 and T3.

Final weight (g)

In brackishwater, mean final weights of Tilapia were recorded 585.10 ± 5.11 g, 587.83 ± 19.18 g and 587.17 ± 8.80 g in T1, T2 and T3 respectively (Table 5). No significant difference of final weight was observed among the treatments.

In freshwater, mean final weights of Tilapia were observed as 603.80 ± 19.38 g, 602.80 ± 16.67 g and 592.97 ± 31.06 g in T1, T2 and T3 respectively (Table 5) with higher value obtained in T1 (Tilapia, 40 individual/decimal) among the treatments. Higher average final weights were observed in different treatments under freshwater compared to those of brackishwater.

Survival rate (%)

In brackishwater, average survival rates (%) of Tilapia were observed as 81.31 ± 2.28 %, 80.59 ± 4.15 % and 79.30 ± 6.24 % in T1, T2 and T3 respectively without any significant difference among the treatments.

In freshwater, average survival rates (%) of Tilapia were observed as 82.32 ± 2.55 %, 80.70 ± 2.65 % and 80.82 ± 2.71 % in T1, T2 and T3 respectively. Somewhat higher survival rate was obtained in T1 (82.32%) compared to other treatments.

Specific Growth Rate (SGR) (%/day)

In brackishwater, average specific growth rates (SGR) of Tilapia were found 1.27 ± 0.04 %/day, 1.28 ± 0.04 %/day and 1.28 ± 0.03 %/day in T1, T2 and T3 respectively without significant difference among the treatments.

In freshwater, SGR of Tilapia were found 1.33 ± 0.07 %/day, 1.33 ± 0.04 %/day and 1.31 ± 0.08 %/day in T1, T2 and T3 respectively (Table 5). The SGR of Tilapia was almost similar in all treatments. The treatments conducted in freshwater gained higher SGR than those of brackishwater.

Yield of Fish

In brackishwater, gross yields in treatments T1, T2 and T3 were recorded as 4700.75 ± 159.66 kg/ha, 7028.32 ± 586.86 kg/ha and 9195.47 ± 629.05 kg/ha respectively (Table 5). Net yields in treatments T1, T2 and T3 were found 3368.70 ± 205.24 kg/ha, 5062.75 ± 400.24 kg/ha and 6629.60 ± 395.97 kg/ha respectively. The highest yield of Tilapia was recorded in T3 where the stocking density of Tilapia was 80 individual/decimal.

In freshwater, average gross yields in treatments T1, T2 and T3 were estimated as 4913.99 ± 305.08 kg/ha, 7207.35 ± 222.22 kg/ha and 9461.25 ± 336.06 kg/ha respectively (Table 5). The net yield in treatments T1, T2 and T3 were 3564.22 ± 285.89 kg/ha, 5236.55 ± 251.51 kg/ha and 6896.26 ± 265.16 kg/ha respectively. The highest yield of Tilapia was recorded in T3 than the rest of the treatments where stocking density of

Tilapia was 80 individual/decimal. Higher gross and net yield of Tilapia were obtained in freshwater compared to brackishwater.

The initial weight ranged 160.67-166.00g in the present study were found higher than the initial weight 50-70 g of Tilapia recorded by Monwaret *al.* (2013). Bahnasawyet *al.* (2003) reported initial weight of Tilapia was 6.4 g which are lower than the present study. The final weight gain ranged 585.10-603.80g during the present study superseded the previous investigations carried out by Monwaret *al.* (2013) and Bahnasawyet *al.* (2003). But Bahnasawyet *al.* (2003) reported higher survival rate of Tilapia (87%) compared to the current investigation ranged 79.30-82.32%.

The SGR ranged 1.27-1.33%/day among the different treatments of the present study which were lower than the SGR of Tilapia 1.55%/day reported by Bahnasawyet *al.* (2003). The gross and net production ranged were 4700.75-9461.25 kg/ha and 3368.70-6896.26 kg/ha respectively among the different treatments of the present study. Monwaret *al.* (2013) recorded 899.26-1168.50 kg/ha production after 3 months culture period which were lower than the production of the present study. The growth of Seabass was significantly higher during the first 2 months in comparison to the later month, which could be explained by the presence of more Tilapia to be preyed upon during the first phase of the culture period (Advance, 1984). Bahnasawyet *al.* (2003) reported production of Tilapia 6880 kg/ha which was almost similar to the present study.

11.3 Development of suitable artificial feed for Seabass aquaculture in captive culture system

Different available artificial feed with salt augmentation of different percentage and farm made feed of different protein percentage with salt augmentation were tested in this experiment to determine suitable artificial feed for Seabass in the brackish and freshwater condition.

Table 6. Water quality parameters during the study period under development of suitable feed for Seabass (mean \pm SD).

Environment	Brackish water				Freshwater			
Treatment	T1	T2	T3	T4	T1	T2	T3	T4
Stocking (Fish/Dec)	20	20	20	20	20	20	20	20
Protein 40%	NaCl 0%	NaCl 1.0%	NaCl 1.5%	NaCl 2.0%	NaCl 0%	NaCl 1.0%	NaCl 1.5%	NaCl 2.0%
Temperature (°C)	30.25 \pm 1.26	29.65 \pm 2.05	29.87 \pm 3.86	29.42 \pm 1.04	29.67 \pm 1.63 ^a	30.17 \pm 1.17 ^{ab}	31.33 \pm 1.03 ^b	30.17 \pm 1.41 ^{ab}
DO (mg/l)	4.75 \pm 0.96	5.36 \pm 0.54	5.31 \pm 0.63	5.45 \pm 0.94	5.83 \pm 0.41 ^b	4.17 \pm 1.17 ^a	5.50 \pm 0.55 ^b	5.00 \pm 1.10 ^{ab}
pH	7.75 \pm 0.50	7.74 \pm 0.53	7.67 \pm 0.22	7.78 \pm 0.43	7.68 \pm 0.23	7.54 \pm 0.87	7.45 \pm 0.83	7.58 \pm 0.93
Nitrate-N (mg/l)	0.25 \pm 0.50	0.56 \pm 0.20	0.33 \pm 0.14	0.52 \pm 0.38	0.05 \pm 0.02	0.23 \pm 0.16	0.33 \pm 0.52	0.17 \pm 0.41
Phosphate-P (mg/l)	1.25 \pm 0.50	0.29 \pm 0.07	0.19 \pm 0.07	0.65 \pm 0.28	0.69 \pm 0.36	0.78 \pm 0.37	1.00 \pm 1.27	0.50 \pm 0.55
Ammonia-N (mg/l)	0.20 \pm 0.07	0.25 \pm 0.12	0.22 \pm 0.08	0.15 \pm 0.05	0.17 \pm 0.09	0.16 \pm 0.07	0.09 \pm 0.08	0.13 \pm 0.10
Alkalinity (mg/l)	195.50 \pm 41.79	185.50 \pm 54.79	170.38 \pm 37.39	184.84 \pm 51.84	165.44 \pm 37.41	169.44 \pm 47.41	178.44 \pm 31.40	186.33 \pm 32.43
Salinity (ppt)	6.10 \pm 1.18	6.18 \pm 1.38	6.13 \pm 0.78	5.89 \pm 0.30	0	0	0	0

Differences between mean values carrying different superscript letters within one line are statistically significant by ANOVA and Duncan test at $p < 0.05$.

11.3.1 Water quality parameters under development of suitable artificial feed for Seabass

The water quality parameters such as, water temperature, dissolved oxygen (DO), pH, nitrate -N, phosphate-P, ammonia-N, alkalinity and salinity of brackishwater and freshwater under different treatments are shown in Table 6.

Water temperature (°C)

In brackishwater ponds, the water temperature during the experimental period was more or less equal in all treatment groups. The mean values of water temperature in treatments T1, T2, T3 and T4 were computed as $30.25 \pm 1.26^\circ\text{C}$, $29.65 \pm 2.05^\circ\text{C}$, $29.87 \pm 3.86^\circ\text{C}$ and $29.42 \pm 1.04^\circ\text{C}$, respectively (Table 6).

In freshwater ponds, the mean values of water temperature in treatments T1, T2, T3 and T4 were computed as $29.67 \pm 1.63^\circ\text{C}$, $30.17 \pm 1.17^\circ\text{C}$, $31.33 \pm 1.03^\circ\text{C}$ and $30.17 \pm 1.41^\circ\text{C}$, respectively (Table 6). The values of water temperature was significantly higher in the treatment T3 than the other treatments.

Dissolved oxygen (mg/l)

In brackishwater conditions, the mean values of dissolved oxygen contents under treatments T1, T2, T3 and T4 were estimated as $4.75 \pm 0.96\text{mg/l}$, $5.36 \pm 0.54\text{mg/l}$, $5.31 \pm 0.63\text{mg/l}$ and $5.45 \pm 0.94\text{mg/l}$, respectively (Table 6).

In freshwater ponds, mean values of dissolved oxygen content under treatments T1, T2, T3 and T4 were $5.83 \pm 0.41\text{mg/l}$, $4.17 \pm 1.17\text{mg/l}$, $5.50 \pm 0.55\text{mg/l}$ and $5.00 \pm 1.10\text{mg/l}$, respectively (Table 6). The values of dissolved oxygen were significantly higher in the treatment T1 and T3 compared to the other treatments.

pH

In brackishwater conditions, the mean values of pH in treatments T1, T2, T3 and T4 were recorded as 7.75 ± 0.50 , 7.74 ± 0.53 , 7.67 ± 0.22 and 7.78 ± 0.43 , respectively (Table 6). No significant differences were observed among the treatments.

In freshwater ponds, mean values of pH during the experimental period were found very close to each other among the treatment groups. The mean values of pH in treatments T1, T2, T3 and T4 were 7.68 ± 0.23 , 7.54 ± 0.87 , 7.45 ± 0.83 and 7.58 ± 0.93 , respectively (Table 6).

Nitrate-nitrogen (mg/l)

In brackishwater ponds, the mean values of nitrate-nitrogen ($\text{NO}_3\text{-N}$) content in treatments T1, T2, T3 and T4 were $0.25 \pm 0.50\text{mg/l}$, $0.56 \pm 0.20\text{mg/l}$, $0.33 \pm 0.14\text{mg/l}$ and $0.52 \pm 0.38\text{mg/l}$, respectively (Table 6). The highest $\text{NO}_3\text{-N}$ value was recorded in T2 and the lowest of the same was recorded in T1. But the differences were not significant among the treatments.

In freshwater ponds, mean values of nitrate-nitrogen ($\text{NO}_3\text{-N}$) content in treatments T1, T2, T3 and T4 were found $0.05 \pm 0.02\text{mg/l}$, $0.23 \pm 0.16\text{mg/l}$, $0.33 \pm 0.52\text{mg/l}$ and $0.17 \pm 0.41\text{mg/l}$, respectively without any significant difference among treatments (Table 6).

Phosphate-phosphorus (mg/l)

In brackishwater environment, the mean values of phosphate-phosphorus ($\text{PO}_4\text{-P}$) contents in treatments T1, T2, T3 and T4 were $1.25 \pm 0.50\text{mg/l}$, $0.29 \pm 0.07\text{mg/l}$, $0.19 \pm 0.07\text{mg/l}$ and $0.65 \pm 0.28\text{mg/l}$, respectively (Table 6). The highest $\text{PO}_4\text{-P}$ value was recorded in T1 and the lowest of the same was recorded in T3. No significant difference was obtained among the treatments.

In freshwater ponds, mean values of phosphate-phosphorus ($\text{PO}_4\text{-P}$) contents in treatments T1, T2, T3 and T4 were estimated as $0.69 \pm 0.36\text{mg/l}$, $0.78 \pm 0.37\text{mg/l}$, $1.00 \pm 1.27\text{mg/l}$ and $0.50 \pm 0.55\text{mg/l}$ respectively (Table 6). The value of phosphate-phosphorus was highest in treatment T2 and the lowest of the same was recorded in treatment T4.

Ammonia-nitrogen (mg/l)

In brackishwater ponds, ammonia-nitrogen contents during the experimental period were almost equal in all treatment groups. The mean values of ammonia in treatments T1, T2, T3 and T4 were 0.20 ± 0.07 mg/l, 0.25 ± 0.12 mg/l, 0.22 ± 0.08 mg/l and 0.15 ± 0.05 mg/l, respectively (Table 6).

In freshwater ponds, the ammonia-nitrogen contents observed during the experimental period were more or less equal in all treatment groups. The mean values of ammonia in treatments T1, T2, T3 and T4 were recorded as 0.17 ± 0.09 mg/l, 0.16 ± 0.07 mg/l, 0.09 ± 0.08 mg/l and 0.13 ± 0.10 mg/l, respectively (Table 6).

Alkalinity (mg/l)

In brackishwater conditions, the values of alkalinity were more or less similar in three treatments and somewhat higher in the treatments T1 and T3. The mean values of alkalinity contents in treatments T1, T2, T3 and T4 were found 195.50 ± 41.79 mg/l, 185.50 ± 54.79 mg/l, 170.38 ± 37.39 mg/l and 184.84 ± 51.84 mg/l, respectively (Table 6).

In freshwater ponds, the values of alkalinity were more or less similar in treatment groups and somewhat higher in the treatments T4. The mean values of alkalinity contents in treatments T1, T2, T3 and T4 were 165.44 ± 37.41 mg/l, 169.44 ± 47.41 mg/l, 178.44 ± 31.40 mg/l and 186.33 ± 32.43 mg/l, respectively in Seabass ponds (Table 6).

Salinity (ppt)

In brackishwater ponds, salinity contents during the experimental period was more or less equal in all the treatment groups. The mean values of salinity contents in treatments T1, T2, T3 and T4 were 6.10 ± 1.18 ppt, 6.18 ± 1.38 ppt, 6.13 ± 0.78 ppt and 5.89 ± 0.30 ppt, respectively (Table 6).

In freshwater ponds, salinity contents during the experimental period was 0 (zero) in all the treatment groups.

Reproduction, growth and other activities of fish are largely depends on temperature. Therefore, temperature has a marked effect on overall production of fish. Moncrief and Jones (1997) stated that for 1°C rise of water temperature metabolic rate becomes double. Sudden changes of water temperature may fall a fish in stress. So, very low temperature in winter and high temperature in summer is a chief problem in fish culture. In Bangladesh fish grows all the year round and there is no problem of very low temperature but sometimes extremely high temperature kill fishes especially in a shallow and turbid water body (Rahman, 1992). The mean values of water temperature in the fish ponds fluctuated between 29.42 - 31.33°C among the different treatments of the present study which are almost similar to the values of 26 - 31°C and 29 - 32°C in Seabass ponds reported by Biswas *et al.* (2010) and Monwar *et al.* (2013) respectively.

Dissolved oxygen of water body is very important factor for fish culture. Fishes live in a water body of insufficient dissolved oxygen become physiologically weak and for this physiological weakness fishes become easily attacked by diseases. Obtaining sufficient oxygen is a greater problem for aquatic organisms than terrestrial ones, due to low solubility of oxygen in water and solubility decreases with factors like- increase in temperature; increase in salinity; low atmospheric pressure, high humidity, high concentration of submerged plants, plankton blooms. Oxygen depletion in water leads to poor feeding of fish, starvation, reduced growth and more fish mortality, either directly or indirectly (Bhatnagar and Garg, 2000). In the present study, the DO levels of water ranged were between 4.17 - 5.50 mg/l which are lower than the values of 7.2 - 8.0 mg/l in Seabass ponds reported by Biswas *et al.* (2010). Monwar *et al.*

(2013) reported DO ranged were 3.9 to 8.9 in Seabass ponds which are higher than the values obtained in the present study.

pH is considered as an important factor in fish culture. It indicates the acidity- alkalinity condition of a water body. It is also called the productivity index of a water body. pH between 7 to 8.5 is ideal for biological productivity, fishes can become stressed in water with a pH ranging from 4.0 to 6.5 and 9.0 to 11.0 and death is almost certain at a pH of less than 4.0 or greater than 11.0 (Ekubo and Abowei, 2011). In the present study, the mean values of pH in the fish ponds ranged were 7.45 to 7.78 among the different treatments which are suitable condition for fish culture. Somewhat higher result was reported by Biswaset *al.* (2010) and the values were 7.70-8.07. Monwaret *al.* (2013) reported water pH ranged were 4.8 to 9.1 in Seabass ponds which indicated that lower range is somewhat lower than the suitable range. Swingle (1967) stated that pH 6.5 to 9.0 is suitable for pond fish culture. The pH more than 9.5 is unsuitable because free CO₂ is not available in this situation. The pH less than 6.5 reduces fish growth, physiological activities and tolerance to toxic substances. Parasites and disease easily attack fish when pH is less than 6.5 (Rahmanet *al.*, 1998). From the above discussion we may conclude that pH values of all the experimental ponds were slightly alkaline which indicate suitable pH condition for fish culture.

Nitrite plays a significant role in growth and production of fish. It is extremely important as a nutrient in supplying nitrogen for protein synthesis. Nitrite is most important to aquaculturists although different forms are available. It occurs in small concentration in unpolluted freshwater. The range of nitrate-nitrogen values recorded by Ali (1992) and Whittonet *al.* (1988) were 0.22-0.23 mg/l and 0.006-0.05 mg/l respectively. But in the present study the range of nitrogen concentration obtained 0.05-0.56 mg/l which was higher to those of the above studies. Azimet *al.* (1995) stated that near about 0.5 mg/l nitrate-nitrogen was suitable for fish culture. Alikunhi (1957) revealed that good productive water for fish cultivation should have a concentration of 0.06 ppm of nitrate. Bhatnagar and Devi (2013) stated that nitrate-nitrogen of water ranging from 0.1-4.5 mg/l is desirable for fish culture. According to their statements the values of the nitrate-nitrogen recorded in the present study were suitable for fish culture.

Phosphate-phosphorus is an important nutrient for the productivity of a water body. In the present study the ranges of phosphate-phosphorus concentrations obtained were 0.19-1.25 mg/l which is almost similar to the range (0.51-1.23 mg/l) and (0.32-1.00) reported by Das (2002) and Kunda (2003). Alikunhi (1957) suggested that good productive pond water for fish cultivation should have a concentration of phosphate within the range of 0.02-0.4 ppm. Sarker (2005) also obtained relatively higher values of it in his study.

Ammonia is one of the most important pollutants in the aquatic environment because of its relatively highly toxic nature and its ubiquity in surface water systems. Ammonia is the by-product from protein metabolism excreted by fish and bacterial decomposition of organic matter such as wasted food, faeces, dead planktons, sewage etc. According to Swann (1997) and OATA (2008) the levels below 0.02 ppm were considered safe. The ranges of ammonia-nitrogen (mg/l) obtained were 0.09-0.25 mg/l. Concentration of ammonia showed an increasing trend as the days of culture increased, probably due to higher metabolic deposition and organic load. The range of ammonia-nitrogen values recorded by Mohantyet *al.* (2004) in rice fields were 0.01-0.31 mg/l which are almost similar to the values obtained in the present study.

Total alkalinity has little direct effect on fishes but indirectly the well-being of fish may be affected by total alkalinity, because water of low values of alkalinity are generally biologically less productive than

those with high values. According to Alikunhi (1957) total alkalinity more than 100 ppm should be present in more productive water bodies. According to Boyd (1990) total alkalinity should be more than 20 ppm in fertilized ponds as fish production increases with the increase of total alkalinity in fertilized ponds containing 0 to 20 ppm total alkalinity. Alkalinity may be several hundred mg/l in natural water bodies. The ranges of alkalinity (mg/l) obtained were 165.44-195.50 mg/l in the present study. The range of alkalinity values recorded by Biswaset *al.* (2010) in Seabass ponds were 160-184 mg/l which are almost similar to the values obtained in the present study. Monwaret *al.* (2013) reported alkalinity ranged were 24 to 78 mg/l in Seabass ponds which are invariably lower than the values obtained in the present study. Bhatnagar and Devi (2013) stated that alkalinity of water ranging from 20-200 mg/l is acceptable for fish culture. According to their statements the values of the alkalinity recorded in the present study were suitable for fish culture.

The ranges of salinity (ppt) obtained were 5.89-6.18ppt in brackish water ponds. The range of salinity values recorded by Biswaset *al.* (2010) in Seabass ponds were 3.2-4.1 ppt which are clearly lower than the values obtained in the present study. Monwaret *al.* (2013) reported salinity ranged were 0 to 6 ppt in Seabass ponds which are lower than the values obtained in the present study.

Table 7. Growth performance of Seabass observed in different treatments under development of suitable feed for Seabass.

Parameters	Brackish water				Freshwater			
	T1	T2	T3	T4	T1	T2	T3	T4
Stocking (indi/dec)	20	20	20	20	20	20		
Protein 40%	NaCl 0%	NaCl 1.0%	NaCl 1.5%	NaCl 2.0%	NaCl 0%	NaCl 1.0%	NaCl 1.5%	NaCl 2.0%
Initial weight (g)	60.67±2.08	64.00±8.54	65.00±10.00	61.33±14.84	64.33±6.03	61.33±11.85	55.33±7.57	60.33±12.60
Final weight (g)	417.07±17.00 ^a	442.40±18.33 ^{ab}	474.20±20.68 ^{bc}	509.03±24.91 ^c	389.93±19.25 ^a	429.83±17.57 ^b	440.33±27.53 ^{bc}	469.53±5.45 ^c
Survival rate (%)	59.31±3.08	63.70±2.03	63.43±5.09	63.70±6.17	58.81±3.90	61.40±4.78	59.92±3.06	60.45±2.29
SGR (%/day)	1.08±0.05 ^a	1.15±0.04 ^a	1.24±0.05 ^b	1.36±0.04 ^c	0.99±0.04 ^a	1.12±0.04 ^b	1.17±0.07 ^{bc}	1.24±0.05 ^c
FCR	2.68±0.61 ^a	2.53±0.55 ^{ab}	2.55±0.43 ^{ab}	2.38±0.08 ^b	2.71±0.41 ^a	2.75±0.56 ^a	2.56±0.69 ^{ab}	2.44±0.40 ^b
Gross production (kg/ha)	1220.73±42.47 ^a	1390.95±24.63 ^{ab}	1489.25±185.18 ^{bc}	1600.95±165.92 ^c	1134.18±118.77 ^a	1301.41±58.66 ^b	1300.67±22.07 ^b	1402.28±59.30 ^c
Net production (kg/ha)	1043.06±34.13 ^a	1189.93±2.04 ^{ab}	1284.58±148.75 ^{bc}	1407.07±116.44 ^c	946.96±93.73 ^a	1116.01±52.24 ^b	1137.53±28.98 ^b	1221.77±63.60 ^c

Differences between mean values carrying different superscript letters within one line are statistically significant by ANOVA and Duncan test at $p < 0.05$.

11.3.2 Growth performance of Seabass observed in different treatments under brackish water and freshwater

The Seabass production parameters in different treatments under brackish and freshwater conditions are shown in Table 7.

Initial weight (g)

In brackish water, the mean initial weights of Seabass were recorded 60.67 ± 2.08 g, 64.00 ± 8.54 g, 65.00 ± 10.00 g and 61.33 ± 14.84 g in T1, T2, T3 and T4 respectively (Table 7). The mean initial weight of Seabass was somewhat higher in T3 than the other treatments.

In freshwater, the mean initial weights of Seabass were 64.33 ± 6.03 g, 61.33 ± 11.85 g, 55.33 ± 7.57 g and 60.33 ± 12.66 g in T1, T2, T3 and T4 respectively. The mean initial weight of Seabass was higher in T1 compared to other treatments.

Final weight (g)

In brackish water, the mean final weights of Seabass were 417.07 ± 17.00 g, 442.40 ± 18.33 g, 474.20 ± 20.68 g and 509.03 ± 24.91 g in T1, T2, T3 and T4 respectively, with significantly higher final weight obtained in T4 where Seabass feed was incorporated with 2.0% NaCl.

In freshwater, the mean final weights of Seabass were recorded 389.93 ± 19.25 g, 429.83 ± 17.57 g, 440.33 ± 27.53 g and 469.53 ± 5.45 g in T1, T2, T3 and T4 respectively, with significantly higher final weight in T4 (feed with 2.0% NaCl). Culture of Seabass in brackish water ponds demonstrated higher final weight than those of freshwater (Table 7).

Survival rate (%)

In brackish water, average survival rates (%) of Seabass were 59.31 ± 3.08 %, 63.70 ± 2.03 %, 63.43 ± 5.09 % and 63.70 ± 6.17 % in T1, T2, T3 and T4 respectively, without any significant difference among the treatments.

In freshwater, average survival rates (%) of Seabass were 58.81 ± 3.90 %, 61.40 ± 4.78 %, 59.92 ± 3.06 % and 60.45 ± 2.29 % in T1, T2, T3 and T4 respectively. No significant difference of survival rates was found among the treatments (Table 7).

Specific Growth Rate (SGR) (%/day)

In brackish water, average SGR of Seabass were 1.08 ± 0.05 %/day, 1.15 ± 0.04 %/day, 1.24 ± 0.05 %/day and 1.36 ± 0.04 %/day in T1, T2, T3 and T4 respectively. The SGR of Seabass was significantly higher in T4 where Seabass feeds were prepared with 2.0% NaCl.

In freshwater, average SGR of Seabass was 0.99 ± 0.04 %/day, 1.12 ± 0.04 %/day, 1.17 ± 0.07 %/day and 1.24 ± 0.05 %/day in T1, T2, T3 and T4 respectively. The SGR of Seabass was significantly higher in T4 where Seabass feed were prepared with 2.0% NaCl compared to other treatments. The treatments conducted in brackish water demonstrated higher SGR of Seabass compared to those of freshwater (Table 7).

Feed Conversion Ratio (FCR)

In brackish water, average Feed Conversion Ratios (FCR) of Seabass were 2.68 ± 0.61 , 2.53 ± 0.55 , 2.55 ± 0.43 and 2.38 ± 0.08 in T1, T2, T3 and T4 respectively, with significantly lower FCR of Seabass found in T4 where Seabass feed were prepared with 2.0% NaCl.

In freshwater, FCR of Seabass were 2.71 ± 0.41 , 2.75 ± 0.56 , 2.56 ± 0.69 and 2.44 ± 0.40 in T1, T2, T3 and T4 respectively (Table 7). The FCR of Seabass was significantly lower in T4 (feed with 2.0% NaCl) than other treatments. The treatments conducted in freshwater were gained higher FCR than the treatments conducted in brackish water. Higher FCR of Seabass was observed in brackish water than those of freshwater (Table 7).

Yield of Fish

In brackishwater, the gross and net yields in treatments T1, T2, T3 and T4 were 1220.73±42.47kg/ha and 1043.06±34.13kg/ha; 1390.95±24.63kg/ha and 1189.93±2.04kg/ha; 1489.25±185.18kg/ha and 1284.58±148.75kg/ha; and 1600.95±165.92kg/ha and 1407.07±116.44kg/ha respectively. The highest gross and net yields of Seabass were found in T4 among the treatments which might be associated with the highest specific growth.

In freshwater, the gross and net yields in treatments T1, T2, T3 and T4 were 1134.18±118.77kg/ha and 946.96±93.73 kg/ha; 1301.41±58.66 kg/ha and 1116.01±52.24kg/ha; 1300.67±22.07 kg/ha and 1137.53±28.98 kg/ha; and 1402.28±59.32 kg/ha and 1221.77±63.67kg/ha respectively. The highest yield of Seabass was recorded in T4 among the treatments which could be due to the highest specific growth rate of fish obtained in this treatment. The treatments conducted in brackish water achieved higher gross and net yield than those of freshwater (Table 7).

The final weight, SGR, gross yield and net yield were significantly higher with significantly lower FCR where Seabass feed were prepared with 2.0% NaCl than those of other treatments. Harpazet *et al.* (2005) reported that in the freshwater phase, the addition of salt to the diet resulted in a significantly better feed conversion ratio and a higher (yet not significant) growth rate. In the saltwater phase, the addition of salt to the diet did not result in an improvement of growth or feed conversion ratio. The survival rate in the freshwater phase was very high (97%) and all, except for one tank. Survival in the saltwater phase was lower (90%) and the variability in growth in this phase was much higher.

The addition of salt to the diet of freshwater carp at a level of 1.5% resulted in significantly higher growth and is in widespread use in India (Nandeesh *et al.*, 2000). In an experiment conducted with juvenile red drum, it was clearly shown that the addition of 2% NaCl to the diet resulted in greater feed efficiency and greater weight gain (Gatlin *et al.*, 1992) which are similar to the findings of the present study. In the same experiment, fish kept in brackish water of 5x and fed a salt-enhanced diet showed an increase in weight gain over the basal diet, but this increase was not significant.

11.4 The economic analysis

The economics of different experiments had been calculated (Tables 8, 9, 10, 11, 12, 13). Operational costs involved were the cost of the labour, rotenone, lime, fertilizers, fingerlings and commercial pellet feed. Total costs were estimated as Tk. 334547, 413485 and 408981/ha in treatments 1, 2 and 3 (Table 8).

Table 8: Benefit cost ratio (BCR) of different treatments in brackishwater environment under monoculture of Seabass.

	Treatment 1	Treatment 2	Treatment 3
VARIABLE COSTS (TAKA)			
Labor cost (Taka)			
Pond preparation	4000	4000	4000
Fertilization	800	800	800
Liming	800	800	800
Fish Harvest	4000	4000	4000
Cash cost (Taka)			
Rotenone	7500	7500	7500
Lime	7719	7719	7719
Fertilizer	2800	2800	2800
Fingerlings	98800	123500	148200
Feed	167714	214776	185982
Others	10000	10000	10000
Interest (10% p.a.)	30413	37590	37180
Total variable costs (Taka)	334547	413485	408981
Total cost (Taka)	334547	413485	408981
RETURNS (TAKA)			
Total Fish production (kg)	1220	1460	1280
Income (from fish sales)	396500	474500	416000
Total revenue (Taka)	396500	474500	416000
Net benefit (return)	61953	61016	7019
Benefit Cost Ratio (BCR)	1.19	1.15	1.02

The total revenues were calculated as Tk. 396500, 474500 and 416000/ha brackishwater ponds in treatments 1, 2 and 3 respectively. The highest total revenue was observed in T2 where highest Seabass yield was obtained. Net benefits were calculated by subtracting the expenditures of pond management from the values of the harvested fish. Among three treatments, the highest net benefit of Tk. 61953/ha was observed in T1, followed by Tk. 61016/ha in T2 and Tk. 7019/ha in T3 respectively. Benefit cost ratios (BCR) were obtained 1.19, 1.15 and 1.02 in T1, T2 and T3, respectively with higher BCR found in T1 because of the lower operational costs incurred in T1 compared to other treatments.

Table 9: Benefit cost ratio (BCR) of different treatments in freshwater environment under monoculture of Seabass.

	Treatment 1	Treatment 2	Treatment 3
VARIABLE COSTS (TAKA)			
<i>Labor cost (Taka)</i>			
Pond preparation	4000	4000	4000
Fertilization	800	800	800
Liming	800	800	800
Fish Harvest	4000	4000	4000
<i>Cash cost (Taka)</i>			
Rotenone	7500	7500	7500
Lime	7719	7719	7719
Fertilizer	2800	2800	2800
Fingerlings	98800	123500	148200
Feed	153982	197992	191316
Others	10000	10000	10000
Interest (10% p.a.)	29040	35911	37714
Total variable costs (Taka)	319441	395022	414849
Total cost (Taka)	319441	395022	414849
RETURNS (TAKA)			
Total Fish production (kg)	1139	1392	1223
Income (from fish sales)	370175	452400	397475
Total revenue (Taka)	370175	452400	397475
Net benefit (return)	50734	57378	-17374
Benefit Cost Ratio (BCR)	1.16	1.15	0.96

During monoculture of Seabass in freshwater condition, total costs were obtained Tk. 319441/ha, 395022/ha and 414849/ha in treatments 1, 2 and 3, respectively. The total revenues were calculated Tk. 370175/ha, 452400/ha and 397475/ha in treatments 1, 2 and 3 respectively. Higher total revenue was observed in T2 where the higher Seabass yield was obtained. Among three treatments, T2 achieved net benefit of Tk. 57378/ha followed by T1 Tk. 50734/ha and T3 didn't earn any net benefit. In T3 total cost was higher than the total revenues i.e. the extra cost was Tk. 17374. BCR were obtained 1.16 and 1.15 in T1 and T2 which were almost similar (Table 9).

Table 10: Benefit cost ratio (BCR) of different treatments in brackishwater environment under mixed culture of Seabass and Tilapia.

	Treatment 1	Treatment 2	Treatment 3
VARIABLE COSTS (TAKA)			
Labor cost (Taka)			
Pond preparation	4000	4000	4000
Fertilization	800	800	800
Liming	800	800	800
Fish Harvest	4000	4000	4000
Cash cost (Taka)			
Rotenone	7500	7500	7500
Lime	7719	7719	7719
Fertilizer	2800	2800	2800
Seabass fingerlings	98800	98800	98800
Tilapia fingerlings	395200	592800	790400
Feed for Tilapia	242496	364536	477288
Others	10000	10000	10000
Interest (10% p.a.)	82351	114315	145350
Total variable costs (Taka)	856466	1208070	1549457
Total cost (Taka)	856466	1208070	1549457
RETURNS (TAKA)			
Total Seabass production (kg)	1396	1579	1693
Total Tilapia production (kg)	4701	7028	9195
Income from Seabass sales	453700	513175	550225
Income from Tilapia sales	752160	1124480	1471200
Total revenue (Taka)	1205860	1637655	2021425
Net benefit (return)	349394	429585	471968
Benefit Cost Ratio (BCR)	1.41	1.36	1.30

In mixed culture of Seabass and Tilapia in brackishwater condition, total production costs, total revenues and net benefits were calculated as Tk. 856466/ha, 1205860/ha and 349394/ha; 1208070/ha, 1637655/ha and 429585/ha; and 1549457/ha, 2021425/ha and 471968/ha in treatments 1, 2 and 3, respectively with the highest net return from T3. Benefit cost ratio (BCR) was obtained 1.41, 1.36 and 1.30 in T1, T2 and T3, respectively. BCR was higher in T1 because of the lower operational cost was involved in T1 than the other treatments.

Table 11: Benefit cost ratio (BCR) of different treatments in freshwater environment under mixed culture of Seabass and Tilapia.

	Treatment 1	Treatment 2	Treatment 3
VARIABLE COSTS (TAKA)			
Labor cost (Taka)			
Pond preparation	4000	4000	4000
Fertilization	800	800	800
Liming	800	800	800
Fish Harvest	4000	4000	4000
Cash cost (Taka)			
Rotenone	7500	7500	7500
Lime	7719	7719	7719
Fertilizer	2800	2800	2800
Seabass fingerlings	98800	98800	98800
Tilapia fingerlings	395200	592800	790400
Feed for Tilapia	256608	377064	496512
Others	10000	10000	10000
Interest (10% p.a.)	83762	115568	147273
Total variable costs (Taka)	871989	1221851	1570604
Total cost (Taka)	871989	1221851	1570604
RETURNS (TAKA)			
Total Seabass production (kg)	1373	1569	1608
Total Tilapia production (kg)	4914	7207	9461
Income from Seabass sales	446225	509925	522600
Income from Tilapia sales	786240	1153120	1513760
Total revenue (Taka)	1232465	1663045	2036360
Net benefit (return)	360476	441194	465756
Benefit Cost Ratio (BCR)	1.41	1.36	1.30

Mixed culture of Seabass and Tilapia in freshwater conditions, total costs, total revenues and net benefits were observed Tk. 871989/ha, 1232465/ha, 360476/ha; 1221851/ha, 1663045/ha, 441194/ha; and 1570604/ha, 2036360/ha, 465756/ha in treatments 1, 2 and 3, (Table 11). The highest total revenue was observed in T3 where the highest yield of Seabass and Tilapia were obtained. BCR was obtained 1.41, 1.36 and 1.30 in T1, T2 and T3, respectively. BCR was higher in T1 because of the lower operational costs incurred in T1 compared to other treatments.

Table 12: Benefit cost ratio (BCR) of different treatments in brackishwater environment under development of suitable artificial feed for Seabass.

	Treatment 1	Treatment 2	Treatment 3	Treatment 4
VARIABLE COSTS (TAKA)				
Labor cost (Taka)				
Pond preparation	4000	4000	4000	4000
Fertilization	800	800	800	800
Liming	800	800	800	800
Fish Harvest	4000	4000	4000	4000
Cash cost (Taka)				
Rotenone	7500	7500	7500	7500
Lime	7719	7719	7719	7719
Fertilizer	2800	2800	2800	2800
Fingerlings	98800	98800	98800	98800
Feed	167714	180642	196452	200920
Others	10000	10000	10000	10000
Interest (10% p.a.)	30413	31706	33287	33734
Total variable costs (Taka)	334547	348767	366158	371072
Total cost (Taka)	334547	348767	366158	371072
RETURNS (TAKA)				
Total Fish production (kg)	1220	1391	1489	1601
Income (from fish sales)	396500	452075	483925	520325
Total revenue (Taka)	396500	452075	483925	520325
Net benefit (return)	61953	103308	117767	149253
Benefit Cost Ratio (BCR)	1.19	1.30	1.32	1.40

In brackishwater, total costs were observed Tk. 334547/ha, 348767/ha, 366158/ha and 371072/ha in treatments 1, 2, 3 and 4, respectively (Table 12). The total revenue was calculated Tk. 396500/ha, 452075/ha, 483925/ha and 520325/ha in treatments 1, 2, 3 and 4, respectively. The highest total revenue was observed in T4 where 2% NaCl was added with feed. Among three treatments, T4 was made Tk. 149253/ha net benefit then T3 was earned Tk. 117767/ha, T2 earned Tk. 103308/ha and T1 earned Tk. 61953/ha. BCR was obtained 1.19, 1.30, 1.32 and 1.40 in T1, T2, T3 and T4, respectively. BCR was higher in T4 because of the highest yield was obtained in T4 than the other treatments.

Table 13: Benefit cost ratio (BCR) of different treatments in freshwater environment under development of suitable artificial feed for Seabass.

	Treatment 1	Treatment 2	Treatment 3	Treatment 4
VARIABLE COSTS (TAKA)				
Labor cost (Taka)				
Pond preparation	4000	4000	4000	4000
Fertilization	800	800	800	800
Liming	800	800	800	800
Fish Harvest	4000	4000	4000	4000
Cash cost (Taka)				
Rotenone	7500	7500	7500	7500
Lime	7719	7719	7719	7719
Fertilizer	2800	2800	2800	2800
Fingerlings	98800	98800	98800	98800
Feed	153982	184140	174643	178901
Others	10000	10000	10000	10000
Interest (10% p.a.)	29040	32056	31106	31532
Total variable costs (Taka)	319441	352615	342168	346852
Total cost (Taka)	319441	352615	342168	346852
RETURNS (TAKA)				
Total Fish production (kg)	1139	1301	1300	1402
Income (from fish sales)	370175	422825	422500	455650
Total revenue (Taka)	370175	422825	422500	455650
Net benefit (return)	50734	70210	80332	108798
Benefit Cost Ratio (BCR)	1.16	1.20	1.23	1.31

The total cost was observed Tk. 319441/ha, 352615/ha, 342168/ha and 346852/ha in treatments 1, 2, 3 and 4, respectively (Table 12). The total revenue was calculated Tk. 370175/ha, 422825/ha, 422500/ha and 455650/ha in treatments 1, 2, 3 and 4, respectively. The highest total revenue was observed in T4 where 2% NaCl was added with feed. Among three treatments, T4 was made Tk. 108798/ha net benefit then T3 was earned Tk. 80332/ha, T2 earned Tk. 70210/ha and T1 earned Tk. 50734/ha. BCR was obtained 1.16, 1.20, 1.23 and 1.31 in T1, T2, T3 and T4, respectively. BCR was higher in T4 because of the highest yield was obtained in T4 than the other treatments.

In monoculture system, BCR ranges were 1.02-1.19 and BCR obtained 1.30 to 1.41 under mixed culture system. BCR ranges were 1.16 to 1.40 for the experiment of development of suitable artificial feed for Seabass. The highest BCR was obtained from mixed culture and experiment conducted for development of suitable artificial feed for Seabass. Bozoglu and Ceyhan (2009) obtained BCR 1.1003 for Seabass in Black sea which is lower than the present findings. Aswathy and Joseph (2018) calculated BCR for Seabass was 1.04–1.26 in their experimental period which was somewhat lower than the present study. Gammanpila and Singappuli (2012) observed BCR 1.12 for Seabass which was lower than present study.

11.5 Proximate composition of fish feed

11.5.1 Proximate composition of Seabass feed

Proximate composition analysis of Seabass feed (Quality feed Ltd) was done and their composition in percentage are shown in Table 14

Table 14: Proximate composition of Seabass feed (% dry basis)

Parameters	Amount (%)
Moisture	11.00
Crude protein	40.00
Crude lipid	8.00
Ash	10.00
Crude fibre	3.00
Carbohydrate	28.00

The observed moisture, crude protein, crude lipid, ash and crude fibre level were 11.00, 40.00, 8.00, 10.00, 3.00% respectively. Biswaset *al.* (2010) applied Seabass feed with 55% crude protein, 9% lipid, 1.9% fibre and 8% moisture which performed better than the feed applied in the present study. Harpazet *al.* (2005) demonstrated that Seabass feed in the form of sinking extruded pellets—3 mm in diameter, containing 48% protein, 12% fat, 1.6% fiber results higher growth performance compared to the present study.

11.5.2 Proximate composition of Tilapia feed

Proximate composition analysis of fish diet (Quality fish feed) was done and their percentage compositions are shown in Table 15.

Table 15: Proximate composition of Tilapia feed (% dry basis)

Parameters	Amount (%)
Moisture	12.77
Crude protein	28.10
Crude lipid	6.65
Ash	11.14
Crude fibre	5.30
Carbohydrate	36.04

The observed moisture, crude protein, crude lipid, ash, crude fibre and carbohydrate level were 12.77, 28.10, 6.65, 11.14, 5.30, 36.04% respectively.

Providing favorable rearing condition is necessary for successful fish culture especially, feed quality and stocking density. In addition, artificial feed plays an important role under conditions of high stocking density when natural feed supply decline or completely disappear. Fish require diets relatively high in protein content because of their poor utilization of carbohydrate as energy source, thus sufficient supply of dietary protein is needed for rapid growth (Lovell, 1989). In the present research, proximate composition analysis of diet was done to verify the feed quality. The observed protein content in

fingerling diet was 28.10%. Ferdouset *al.* (2014) analyzed the supplied diet and found 27.94% protein content. Santiago *et al.* (1982) recommended that, the optimum protein requirement for growth of Nile Tilapia is 25-35%. El-Sayed and Teshima (1991) reported that the dietary protein requirements of several species of Tilapia have been estimated to range from 20 to 56%. Therefore, protein content of the test diet used in this study was within the suitable range for Tilapia culture.

12. Research highlight/findings

- The Specific Growth Rate (SGR) (%/day), gross and net yield (kg/ha) of Seabass were higher in treatments conducted in brackish water than those of freshwater.
- In monoculture: SGR) (%/day), gross and net yield (kg/ha) 1.15±0.03, 1460.78±86.46 and 1255.55±58.63 respectively were higher in treatments T2 where stocking density of Seabass was 25 individual/decimal in brackish water.
- In mixed culture: SGR) (%/day), gross and net yield (kg/ha) 1.48±0.03, 1692.73±67.34 and 1508.38±47.45 respectively were found higher in treatments T3 where stocking density of Seabass was 20 individual/decimal and 1.28±0.03, 9195.47±629.05 and 6629.60±395.97 respectively were higher in treatments T3 where stocking density of Tilapia was 80 individual/decimal.
- Preparation of Seabass feeds with 2% NaCl provided higher SGR (%/day), gross and net yield (kg/ha).
- The higher survival rates were achieved with large-sized fingerlings of Seabass.

B. Implementation Position

1. Procurement:

Description of equipment and capital items	PP Target		Achievement		Remarks
	Phy (#)	Fin (Tk)	Phy (#)	Fin (Tk)	
(a) Office equipment					
1) Laptop	1	60,000	100%	100%	
2) Desktop computer	1	60,000	100%	100%	
3) Printer	1	20,000	100%	100%	
4) Refrigerator	1	80,000	100%	100%	
5) File Cabinet	1	20,000	100%	100%	
(b) Lab & field equipment					
1) Weighing Balance	1	25000	100%	100%	
2) Plankton Net	1	20000	100%	100%	
3) Portable DO Meter	1	40000	100%	100%	
4) Portable pH Meter	1	25000	100%	100%	
5) SR Cell	1	20000	100%	100%	
(c) Other capital items					

2. Establishment/renovation facilities:N/A

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	

3. Training/study tour/ seminar/workshop/conference organized:N/A

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training					
(b) Workshop					

C. Financial and physical progress

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Contractual staff salary	3,38,400.00	299479	299479	0		
B. Field research/lab expenses and supplies	22,10,000.00	2176856	2176856	0	100%	
C. Operating expenses	2,50,000.00	233110	233110	0	100%	
D. Vehicle hire and fuel, oil & maintenance	1,80,000.00	167165	167165	0	100%	
E. Training/workshop/seminar etc.	0.00	0	0	0		
F. Publications and printing	95,000.00	46468	45548	920	100%	
G. Miscellaneous	40,000.00	28260	28260	0		
H. Capital expenses	6,10,000.00	594960	594960	0	100%	

D. Achievement of Sub-project by objectives: (Tangible form)

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output(i.e. product obtained, visible, measurable)	Outcome(short term effect of the research)
To compare growth and survival of Asian Seabass in brackish and freshwater pond	-Water quality parameters were measured -Growth performance and survival rate were measured	-Specific Growth Rate (SGR) (%/day), gross and net yield (kg/ha) were higher in treatments conducted in brackish water than the treatments conducted in freshwater	-Seabass could be cultured both in fresh and brackish water. -Seabassculture is more suitable in brackish water than freshwater.
To determine optimum stocking density of Seabass in captive aquaculture syem	-Water quality parameters were measured -Seabass were stocked with different stocking densities in earthen ponds.	-In monoculture: SGR) (%/day), gross and net yield (kg/ha) were higher in treatments T2 where stocking density of Seabass was 25 individual/decimal. -In mixed culture: SGR) (%/day), gross and net yield	-Higher yield of Seabass obtained in polyculculture than monoculture system.

		(kg/ha) were higher in treatments T3 where stocking density of Seabass was 20 and Tilapia was 80 individual/decimal.	
To develop suitable feeding regime for Seabass aquaculture	-Water quality parameters were measured -Seabass feeds were prepared with different concentrations of Salts	-SGR (%/day), gross and net yield (kg/ha) were higher in treatment T4 where Seabass feeds were prepared with 2% NaCl.	-Addition of NaCl to Seabass feed contributed higher yield of Seabass both in brackish and freshwater.

E. Materials Development/Publication made under the Sub-project:

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.			
Journal publication	03		
Information development			
Other publications, if any	MS Thesis: 01	Bachelor Dissertation: 04	<i>MS Thesis Title: Comparative study on production and determination of stocking density of Seabass in brackish- and fresh-water earthen pond under monoculture system</i>

F. Technology/Knowledge generation/Policy Support (as applied):

i. Generation of technology (Commodity & Non-commodity)

Culture of Asian Seabass (*Latescalcarifer*) in brackish and freshwater earthen ponds under natural and artificial feeding regime

ii. Generation of new knowledge that help in developing more technology in future

Preparation of Seabass feeds with 2% NaCl provided higher SGR, gross and net yield.

iii. Technology transferred that help increased agricultural productivity and farmers' income

Mixed culture of Seabass and Tilapia @20 Seabass/decimal and 80 Tilapia/decimal tremendously enhances coastal fish productivity and farmers, income.

iv. Policy Support

Mixed culture of Seabass and Tilapia in south-west coastal zone of Bangladesh could be huge contributing to the national production of fisheries.

G. Information regarding Desk and Field Monitoring

- i) Desk Monitoring (monitoring workshops/seminars etc.):**
CRG Sub-Project Final output Workshop held in BARC, Farmgate Dhaka on 19-20 September 2018. Found satisfactory

- ii) Field Monitoring (time& No. of visit, Team visit and output):**
Internal: 2 times by Research and Training Centre (RTC), PSTU during 15 November 2017 and 10 June 2018. Better office activities.
External: 1 time by 3 members from PIU-BARC during 16-17 February 2018. Better field and office activities

H. Lesson Learned (if any)

- i) Addition of NaCl to the diet of Asian Seabass reared in brackish and freshwater at a level of up to 2% leads to better SGR, gross and net yield.

I. Challenges (if any)

- i) Timely collection of Seabass fingerlings was difficult to initiate the experiments.
- ii) Diseases outbreak occurred in the winter season.

Signature of the Principal Investigator
Date
Seal

Counter signature of the Head of the
organization/authorized representative
Date
Seal

References

- Ali, A. B. 1992. Some ecological aspect of fish population in tropical rice fields. *Hydrobiol.*, 190: 215-222.
- Alikunhi, K. H. 1957. Fish culture in India. Farm Bull. *India Counc. Agric. Res.*, 20: 144 p.
- Almendras, J.M., C. Duenas, J. Nacario, N.M. Sherwood and L.W. Crim. 1988. Sustained hormone release III. Use of gonodotropin releasing hormone analogue to induce multiple spawnings in sea bass, *Lates calcarifer*. *Aquacult*, 74: 97-111.
- AOAC (Association of Official Analytical Chemists) 2000. Official methods of Analysis. 17th edn. Association of Official Analytical Chemist, Washington DC. 2200 pp.
- Aswathy, N. and I. Joseph. 2018. Economic viability of cage farming of Asian Seabass in the coastal waters of Kerala. *International Journal of Fisheries and Aquatic Studies*, 6(5): 368-371.
- Awang, A.B. 1986. Status of Seabass (*Lates calcarifer*) culture in Malaysia. Eds: Copland and Grey. Proceeding of an International Workshop held at Darwin, Australia, 24-26 Sep., 1986 on Management of Wild and Culture Sea Bass/Barramundi. pp. 165-167.
- Azim, M. E., G. S. Talukder, M. A. Wahab, M. M. Haque and M. S. Haque. 1995. Effect of liming and maintenance of total hardness levels on fish production in fertilized ponds. *Progress. Agric.*, 6 (2): 7-14.
- Bahnasawy, M.H., T.E. Abdel-Baky, G.A. Abd-Allah. 2003. Growth performance of Nile Tilapia (*Oreochromis niloticus*) fingerlings raised in an earthen pond. *Archives of Polish Fisheries*, 11(2): 277-285.
- Bardach, J.E., J.H. Ryther and W.O. McLaren. 1972. *Aquaculture; The Farming and Husbandry of Freshwater and Marine Organisms*. Science Editions, New York, USA. pp. 351-386.
- Bhatnagar A and Garg SKP, 2000. Causative factors of fish mortality in still water fish ponds under sub-tropical conditions, *Aquaculture*, 1(2), pp. 91-96.
- Bhatnagar, A. and P. Devi. 2013. Water quality guidelines for the management of pond fish culture. *I. J. Environ. Sci.*, 3(6).
- Biswas, G., A.R. Thirunavukkarasu, J.K. Sundaray and M. Kailasam. 2010. Optimization of feeding frequency of Asian Seabass (*Lates calcarifer*) fry reared in net cages under brackishwater environment. *Aquacult*, 305:26-31.
- Boyd CE, 1982. Water quality in warm water fish ponds. Alabama Agricultural Research Station, Alabama, pp. 362.
- Bozoglu, M. and V. Ceyhan. 2009. Cost and profitability analysis for trout and sea bass production in the Black sea, Turkey. *J. Anim. Vet. Adv.*, 8(2): 217-222.
- Cheung, W.W.L., T.J. Pitcher and D. Pauly. 2005. A fuzzy logic expert system to estimate intrinsic extinction vulnerability of marine fishes to fishing. *Biol Conserv* 124, 97-111. <http://dx.doi.org/10.1016/j.biocon.2005.01.017>.
- Daet, I. 2019. Study on culture of sea bass (*Lates calcarifer*, Bloch 1790) in hapa-in-pond environment. IOP Conf. Series: Earth and Environmental Science 230, 012115, doi:10.1088/1755-1315/230/1/012115.
- Danakusumah, E. and A. Ismail. 1986. Culture of Seabass (*Lates calcarifer*) in Earthen Brackishwater Ponds. Eds: Copland and Grey. Proceeding of an International Workshop held at Darwin, Australia, 24-26 Sep., 1986 on Management of Wild and Culture Seabass. pp. 156-157.
- Das, B. C. 2002. Studies on the effects of stocking density on growth, survival and yield of *Amblypharyngodon mola* and the performance of *Rohtee cotio* in combination with *Barbodes gonionotus* and with *Cyprinus carpio* in rice fields. M. Sc. thesis submitted to the Deptt. of Aquaculture, Bangladesh Agricultural University, Mymensingh. 113 pp.
- Ekubo AA and Abowei JFN, 2011. Review of some water quality management principles in culture fisheries, *Research Journal of Applied Sciences, Engineering and Technology*, 3(2), pp. 1342-1357.

- El-Sayed, A. F. M. and S. Teshima, 1991. Tilapia nutrition in aquaculture, *Rev. Aquacul. Sci.* 5: 247-265 pp.
- European Inland Fisheries Advisory Commission (EIFAC). 1973. Water quality criteria for European freshwater fish: report on chlorine and freshwater fish. Food and Agriculture Organization of the United Nations, Italy, Rome, T20.
- FAO (2006). Cultured Aquatic Species Information Programme. Text by Rimmer MA In: FAO Fisheries and Aquaculture Department, Rome. Available at: http://www.fao.org/fishery/culturedspecies/Lates_calcarifer/en.
- Ferdous, Z., Nahar, N., Hossen M. S., Sumi K. R. and Ali, M. M. 2014. Performance of different feeding frequency on growth indices and survival of monosex Tilapia, *Oreochromis niloticus* (teleostei: cichlidae) fry. *International Journal of Fisheries and Aquatic Studies* 1(5): 80-83 pp.
- Gammanpila and Singappuli. 2012. Economic viability of asian sea bass (*Lates calcarifer*) and Tilapia (*Oreochromis niloticus*) small scale aquaculture systems in srilanka. *Sri lanka j. Aquat. Sci.* 17: 47-57.
- Genodepa, J.G. 1986. Seabass (*Lates calcarifer*) research at the Brackish Water Aquaculture Centre, Philippines. Eds: Copland and Grey. Proceeding of an International Workshop held at Darwin, Australia, 24-26 Sep., 1986 on Management of Wild and Culture Seabass. pp. 161-164.
- Harpaz, S., Y. Hakim, T. Slosman, O. T. Eroldogan. 2005. Effects of adding salt to the diet of Asian sea bass *Lates calcarifer* reared in fresh or salt water recirculating tanks, on growth and brush border enzyme activity. *Aquacult*, 248:315– 324.
- ICAR. 2010. Demonstration of polyfarming of Asian Seabass and Tilapia. Indian Council of Agricultural Research (ICAR). Available at: http://www.ciba.res.in/index.php?option=com_content&view=article&id=371&Itemid=72&lang=en.
- Imelda-Joseph, S. J. 2010. A pilot study on culture of Asian sea bass *Lates calcarifer* (Bloch) in open sea cage at Munambam, Cochin coast, India. *Indian J. Fish.* 29-33.
- Kailasam, M., A.R. Thirunavukkarasu, J.K. Sundaray, M. Abraham, R. Subburaj, G. Thiagarajan and K. Karaiyan. 2006. Evaluation of different feeds for nursery rearing of Asian Seabass *Lates calcarifer* (Bloch). *Indian J. Fish.*, 53(2): 185-190.
- KAU. 2012. Culture Fisheries: Sea Fishes, Pond culture of Seabass. Kerala Agricultural University (KAU), Centre for E learning. Available at: http://www.celkau.in/Fisheries/CultureFisheries/Seafishes/Seabass/growout_sys.aspx.
- Kunda, M. 2003. Performance of *Amblypharyngodon mola* with *Barbodes gonionotus*, *Cyprinus carpio* and *Macrobrachium rosebergii* in rice fields. An M.Sc. thesis submitted to the Deptt. of Fisheries Management, Bangladesh Agricultural University, Mymensingh. pp. 117.
- Lovell, R. T. 1989. Nutrition and feeding of fish. An AVI Book, Van Nostrand-Reinhold., New York, 260 pp.
- Meade U, 1989. Aquaculture Management. Van Nostrand Reinhold, New York.
- Mohanty, R.K., H.N. Verma and P.S. Brahmanand. 2004. Performance evaluation of rice-fish integration system in rainfed medium land ecosystem. *Aquaculture*, 230: 125-135.
- Moncrief JW and Jones WH 1977: Elements of physical chemistry, Addition-Wesley Publication Company, Calcutta. pp80.
- Monwar, M. M., A. K. M. R. A. Sarker and N. G. Das. 2013. Polyculture of Seabass with Tilapia for the utilization of brown fields in the coastal areas of Cox's Bazar, Bangladesh. *International Journal of Fisheries and Aquaculture*, 5(6):104-109.
- Nandeesh, M.C., B. Gangadhar, P. Keshavanath and T.J. Varghese. 2000. Effect of dietary sodium chloride supplementation on growth, biochemical composition and digestive enzyme activity of young *Cyprinus carpio* (Linn) and *Cirrhinus mrigala* (Ham). *J. Aquac. Trop.*, 15: 135–144.

- Ornamental Aquatic Trade Association (OATA) 2008: Water Quality Criteria-ornamental fish. Company Limited by Guarantee and Registered in England No. 2738119 Registered Office Wessex House, 40 Station Road, Westbury, Wiltshire, BA13 3JN, UK.
- Rahman MK 1992: Aquaculture of *Pangasinus pangasius*. Annu. Rep. (1989-1991). Fisheries Research Institute, Riverine station, Chandpur, Bangladesh, 20 p.
- Rimmer, M.A., A.W. Read, M.S. Levitt and A.T. Lisie. 1994. Effects of nutritional enhancement of live food organisms on growth and survival of Barramundi, *Lates calcarifer* (Bloch) larvae. *Aquacult. Fish. Management*, 25: 143-156.
- Robinette HR 1976: Effect of Selected Sublethal Levels of Ammonia on the Growth of Channel Catfish (*Ictalurus punctatus*), *Progressive Fish Culturist*, 38, pp 26-29.
- Santhosh B and Singh NP 2007: Guidelines for water quality management for fish culture in Tripura, ICAR Research Complex for NEH Region, Tripura Center, Publication no.29
- Santiago, C.B., Banes-Aldaba, M. and Laron, M.A. 1982. Dietary crude protein requirement of *Tilapia nilotica* fry. *Kalikasan Philipp. J. Biol.*, 11: 255-265 pp.
- Sarker, B. 2005. Cultural suitability of mola with major carps, Thai sarputi and giant freshwater prawn in simultaneous and alternate methods in farmers rice fields. An M.Sc. thesis submitted to the Deptt. of Fisheries Management, Bangladesh Agricultural University, Mymensingh. pp. 109.
- Singh, R.K., A.P. Khandagale, V. Vartak, A. S. Desai and S. Chavan. 2012. Aquatic environment and yield of sea bass (*Lates calcarifer*, Bloch) in ponds. *Int. J. Environment and Waste Management*, 10(1).
- Sugama, K. and H. Eda. 1986. Preliminary study on rearing of giant sea perch, *Lates calcarifer* in the floating net cages, Research Station for Coastal aquaculture, Bojonegara, Indonesia. p. 9.
- Swann LD 1997: A Fish Farmer's Guide to Understanding Water Quality, Aquaculture Extension Illinois, Purdue University, Indiana Sea Grant Program Fact Sheet AS-503.
- Swingle, H. S. 1967. Standardization of chemical analyses for waters and pond muds. *FAO Fish. Rep.*, 4 (44): 397-421.
- Thirunavukkarasu, A.R., M. Kailasam, P. K. Chandra, P. Shiranee, M. Abraham, A.V.K. Charles and R. Subburaj. 2001. Captive Broodstock development and breeding of Seabass *Lates calcarifer* (Bloch) in India. In : *Perspectives in Mariculture*. N.G.Menon and P.P.Pillai (Eds.) P. 111-124.
- Whitton, B.A., A. Aziz, P. Franeis, J.A. Rother, T. W. Simon and Z.N. Tahmida. 1988. Ecology of deep water rice in Bangladesh (Physical and Chemical environment). *Hydrobiol.*, 169: 3-67.