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PLANKTON ABUNDANCE AND PRIMARY PRODUCTIVITY IN AN INDUSTRIAL SCALE IN POND RACEWAY SYSTEM

Ruma Khatun[1], Mohammad Hasnal Alam[2], S.M. Nahid Jobayer[1], Rahat Bin Shahid[1], Md. Shamsul Kabir[2], Manjurul Karim[2], Sk. Mustafizur Rahman[1] and Md. Golam Sarower[1,*]

[1]*Fisheries and Marine Resource Technology Discipline, Khulna University, Khulna-9208, Bangladesh*
[2]*Feed the Future Bangladesh Aquaculture and Nutrition Activity, World Fish*

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Abstract
An in-pond raceway system (IPRS) is an efficacious aquaculture approach confining a limited land resources with flowing water system. Several studies have been conducted on IPRS culture systems in various parts of the world. This study was executed to evaluate the plankton abundance and primary productivity in an industrial scale in pond raceway system. The quantitative enumeration of plankton was carried out with the use of a Sedgwick-Rafter (S-R) counting cell, and the identification of distinct kinds of plankton were done using a range of bibliographic references, with the help of books and journals. 90% acetone method with spectrophotometric analysis was performed to determine the concentrations of chlorophyll-a in the microalgae as a means of primary productivity. One-way analysis of variance was conducted to determine the variation of plankton abundance as well as primary productivity among the study sites. Relationship between plankton availability and primary productivity was assessed by Pearson correlation

Keywords: In-Pond Raceway System, Phytoplankton, Zooplankton, Chlorophyll a, Productivity

Introduction

Primary productivity is a means of providing nourishment for heterotrophic organisms. Phytoplankton act as the basic promotor of primary productivity of all types of water reservoir. Production of zooplankton basically depends on level of the primary production. The in-pond raceway recirculating culture system (IPRS) is an improved variant of RAS that has been successfully applied in freshwater aquaculture (Wang *et al*., 2019). The intensive culture area covers 2–5% of the entire pond area (Li *et al*., 2019; Wang *et al*., 2019). After mechanical and biological filtration, the water is reused to turn down the utilization of water and upgrading resource application capability in the culture ponds (Zhang *et al*., 2011). Compared to traditional methods, IPRS system exposes an economic means of producing a higher number of fish accompanying other co-culture species with better survival and lower feed conversion ratio. It is predicted that production efficiency will boost up and setting up costs will reduce more as the IPRS and related manipulations are further purified properties for aquaculture where we can develop the horizontal expansion of aquaculture. So, the main reason to introduce this technology in our country is to enhance the vertical extension of aquaculture in an intensive method. Because the productive lands are degrading day by day with the growing population. People are using their lands for residential issues moreover than agriculture. So, we need an alternative technology to face the increasing protein demand by a new intensive method that will help to face the demand for fish protein. IPRS opens opportunities to take the challenge. It can produce ten times better than an ordinary culture method by using minimum land. However, IPRS system is still in the experimental stage in several districts of Bangladesh for the selection of suitable species. There were no studies on primary productivity or plankton abundance in IPRS. So, a thorough investigation of primary productivity and plankton abundance in IPRS is required for fish production.

*Corresponding author: <sarower@yahoo.com>
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Materials and Method

Study area and period

The experiment was run at Afil Aqua Fish Ltd, Sharsha, Jashore (Figure 1). Experimental period was from summer to late autumn season. Determination of plankton abundance and chlorophyll-a concentration were conducted at Laboratories of Fisheries and Marine Resource Technology Discipline, Khulna University, Khulna.

Plankton Sample Collection and Preservation

Both types of plankton were sampled from the surface zone. A bucket was used to collect the water from three locations, two samples from IPRS (from production zone and purification zone) and one sample from traditional pond culture system. A total 30 L of the collected water was transfused through a conical plankton net. After filtering, the representative samples were put in bottles and diluted with 80 ml of pond water and fixed in using two to four drops of 10% Lugol's solution for preservation.

Plankton counting and identification

Sedgwick -Rafter (S-R) counting cell method was used for the quantitative enumeration of plankton. Cover classes were diagonally placed across the and sample were transferred with a dropper so that no air bubbles in the cell can be formed. The plankton at the bottom of the S-R cell was then measured using a sophisticated microscope. For quantitative analysis, 10 cells were counted randomly.

The following formula was used to determine the plankton abundance in individuals/mL.

$$\frac{No.of\ the\ field\ in\ sedgwick-Rafter\ cells \times ml\ of\ concentration}{No.of\ sedgwick-Rafter\ fields\ examined \times total\ ml\ filtered} = Multiplier\ .$$

(Ingram et al, 1952)

Identification of various groups of plankton were done by using a variety of bibliographic references, with the help of books and journal. Water samples were covered with foil paper to avoid light penetration. The collected samples were stowed in the refrigeration below 4 °C as the samples were not analyzed immediately.

Measurement of Primary Productivity

90% acetone method with spectrophotometric analysis was performed to determine the concentrations of chlorophyll-a in the microalgae and to evaluate the level of primary productivity. A volume of 1Lwater was filtered by using filter paper of each sample. Each filter was placed into an individual 15 mL falcon tube. Then sample tubes were filled with 5 mL of 90% acetone and preserved overnight in darkness, at -4°C. Before spectrophotometric analysis, 10 min centrifugation at 4000 rpm in centrifuge machine was performed to extract all microalgae. Absorbance of microalgae was measured with preferred wavelengths at 750 nm, 664 nm microalgae., 647 nm, and 630 nm. In the spectrophotometer, 90% acetone was used as a blank. To give the turbidity-corrected value, the absorbance at 750 nm was removed from all three wavelengths.On the other hand, primary productivity will be evaluated by calculating the concentration of chlorophyll-a equivalent in the original water sample through this formula:

[chl. a] extract = 11.85(A664)/I – 1.54(A647)/I – 0.08(A630)/I …………(i)

[chl.a] sample = [chl.a] extract * (v/V)……………… (ii)

Where, A = corrected absorbance, I= path length of cuvette (10cm), v = volume of extract (5 mL), V = volume of water filtered in (0.025 L)

Statistical Analysis

The data obtained all along the experiment was statically analyzed using Microsoft excel 2013.0, SPSS Version-24.0. One-way analysis of variance was conducted to determine the variation of plankton abundance as well as primary productivity among the study sites. Relationship between plankton availability and primary productivity was assessed by Pearson correlation analysis. When doing statistical tests, a value of 5% ($P < 0.05$) was considered to be significant.

Results

During the studying period, the occurrence and abundance of different groups of plankton population (phytoplankton and zooplankton) as well as the level of primary productivity in both In Pond Raceway System (IPRS) and traditional pond culture system were analyzed. Statistical analysis revealed that there was no significant variation (F2,9=1.03, p>0.05) of plankton abundance in IPRS system and traditional pond culture system. Statistical analysis also revealed that there was no significant variation (F2,9=,0.36 p>0.05) of primary productivity in IPRS system and traditional pond culture system.

Plankton abundance

In the current study, a total 16 species of phytoplankton under 6 groups and 12 species of zooplankton under 6 groups were observed in IPRS system and traditional pond culture system (Table 1).

Table 1. A list of identified species of phytoplankton and zooplankton in the study areas

Plankton	Class	Species
Phytoplankton	Cyanophycea	*Nostoc pruniforme, Oscilatoria* sp, *Anabaeca flosaqua, Sprirulina laxxisima, Microcystis* sp
	Chlorophycea	*Spirogyra* sp, *Ulothrix aequalies, Closterium gracile, Ooleochaete* sp
	Bacillariophycea	*Diatom* spp, *Chaetocerus indicus, Pleurosigma normani*
	Euglenophycea	*Phacus* sp
	Chrysophycea	*Chromulina* sp
	Dianophycea	*Ceratim lanula, Dinophiscus caudate*
Zooplankton	Copepod	*Cyclops naupilus, Diaptomus calanus, Mesocyclops leuckari, Acanthocyclops* sp.
	Rotifer	*Tricotria tetractis, Branchionus* spp, *Fillinea longiseta*
	Cladocera	*Moina, Daphnia* sp, *Alona affinis*
	Protozoa	*Volvox* sp., *Urostyla* sp.

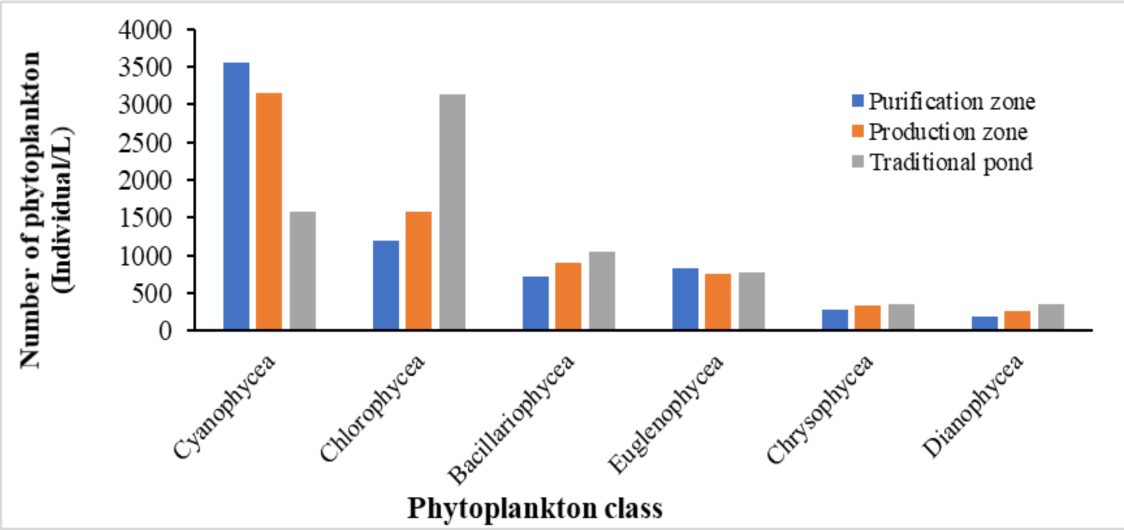

Figure 1. Abundance of different group of phytoplankton in IPRS purification zone, production zone and traditional pond.

In case of IPRS system (both purification zone and production zone), cyanophycea was most the dominating group followed by chlorophycea and chrysophycea was found as less dominant (Figure 1). Traditional pond culture system showed chlorophycea was the most abundant group whereas dianophycea contributed to the lowest. Figure 2 shows that Abundance of Phytoplankton in IPRS system and Traditional Pond culture system at various season.

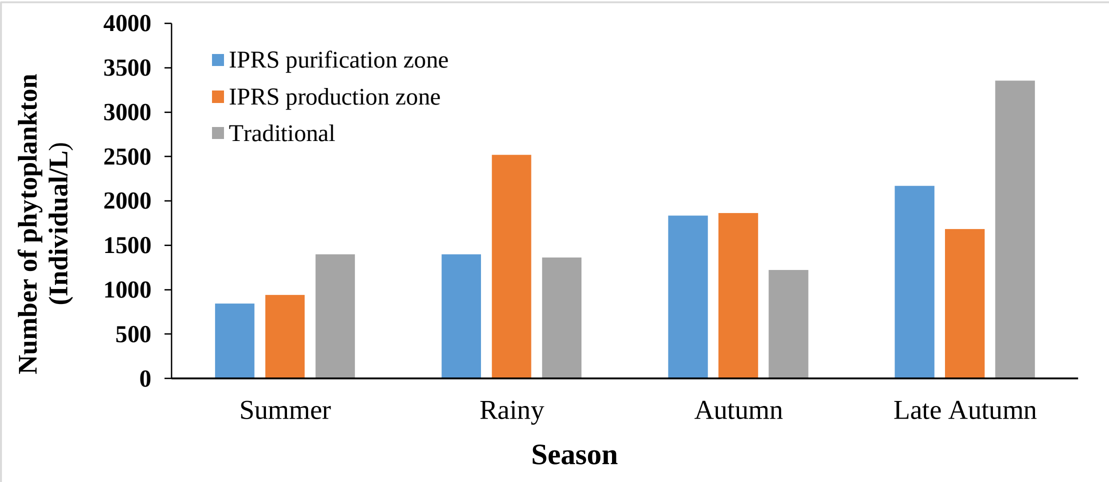

Figure 2. Abundance of phytoplankton in IPRS system (purification and production zone) and traditional pond culture system at various season.

The maximum number of phytoplankton was found in traditional pond culture system during the late autumn season, and minimum number of planktons was found in IPRS purification zone during the summer season.

Figure 3. Abundance of different groups of zooplankton in in IPRS purification zone, production zone and traditional pond.

In case of IPRS system (both purification and production zone), copepoda was the dominating group and protozoa was found to the lowest (Figure 3). Traditional pond culture system showed rotifer was the most abundant groups whereas protozoa contributed to the lowest.

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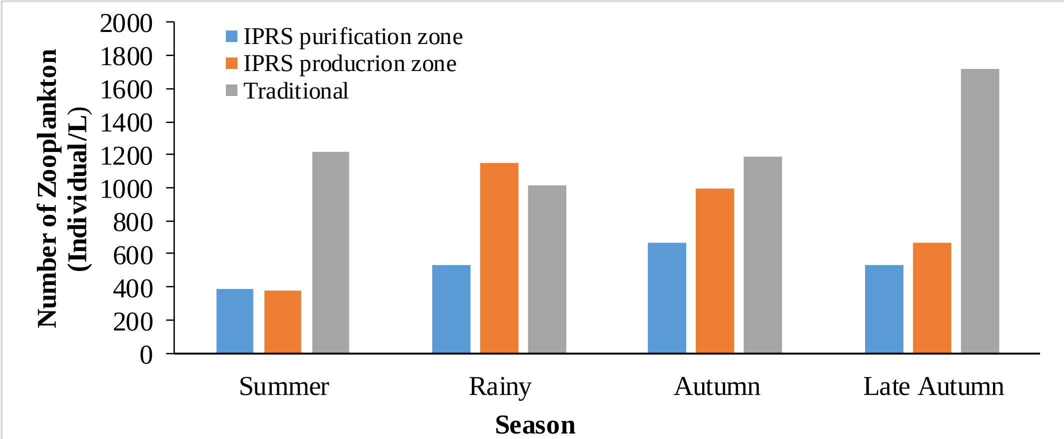

Figure 4. Abundance of zooplankton in IPRS (purification and production zone) and Traditional Pond culture system at various season.

Abundance of zooplankton in IPRS system and traditional pond culture system at various season is shown in Figure 4. The maximum number of zooplanktons was found in traditional pond culture system during the late autumn season, and the minimum number of plankton was found in IPRS cell during the summer season.

Chlorophyll a concentration assessment

Figure 5 shows the chlorophyll-a concentration in the water sample. The maximum chlorophyll-a concentration was observed in traditional pond culture system during the late autumn season, which was 6.2 mg/L and the minimum chlorophyll-a concentration was found in outside IPRS cell which was 2.6 mg/L during the summer season.

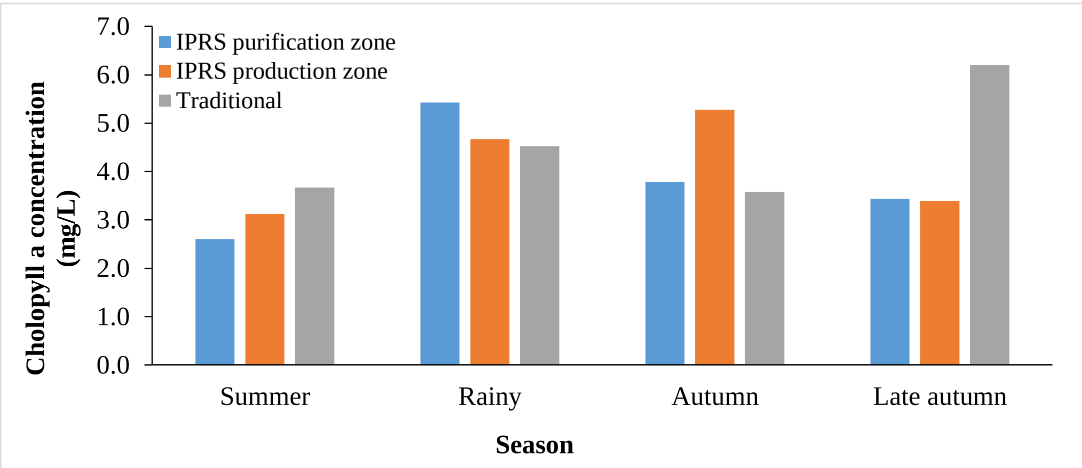

Figure 5. Chlorophyll a concentration of water sample at various season.

Relationship between plankton abundance and primary productivity

A limited degree positive correlation(r=0.24) was assumed between plankton abundance and primary productivity in IPRS purification zone (Figure 6)

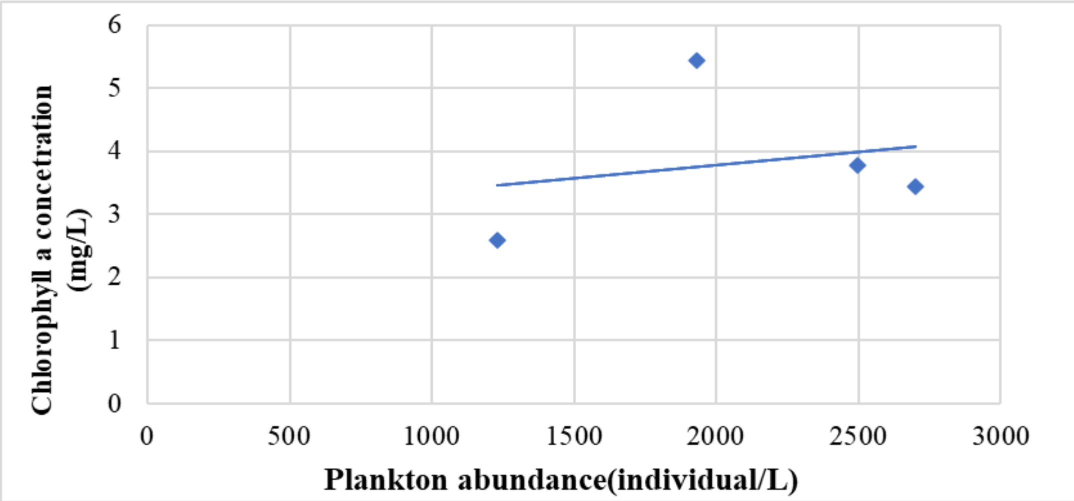

Figure 6. Scatter diagram showing correlation between plankton abundance and primary productivity in IPRS purification zone.

A moderate degree positive correlation(r=0.75) was assumed between plankton abundance and primary productivity in IPRS production zone (Figure 7).

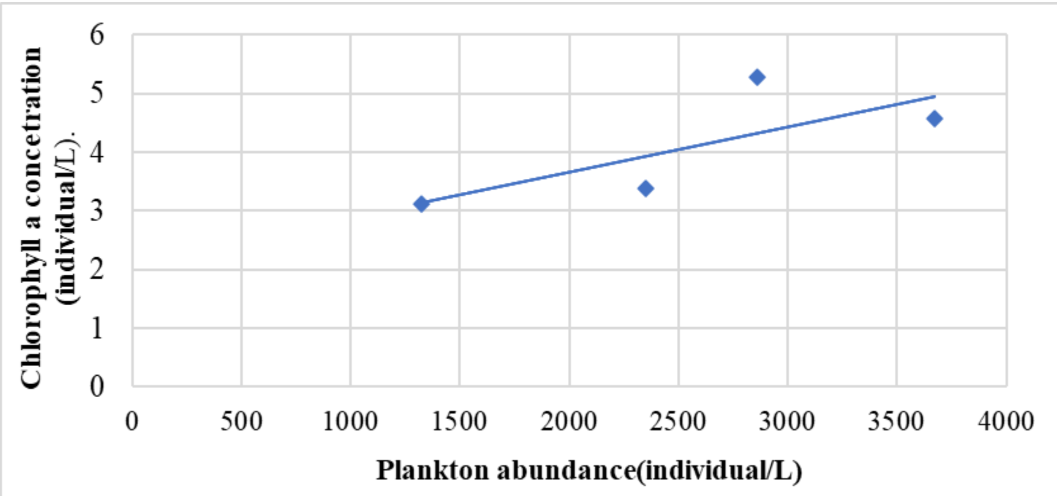

Figure 7. Scatter diagram showing correlation between plankton abundance and primary productivity in IPRS purification zone.

A strong positive correlation(r=0.92) was assumed between plankton abundance and primary productivity in traditional pond culture system (Figure 8).

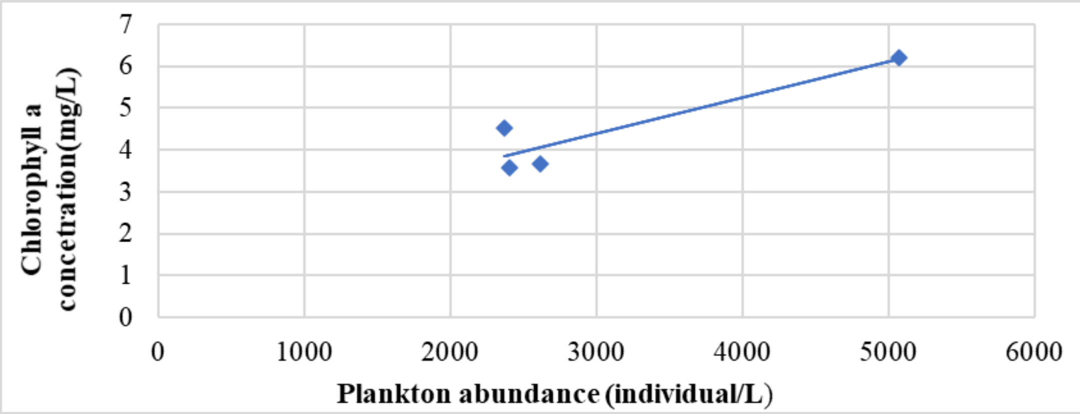

Figure 8. Scatter diagram showing correlation between plankton abundance and primary productivity in traditional pond culture system.

Figure 9 shows that above all there was a positive correlation(r=0.71) between plankton abundance and primary productivity in the study area

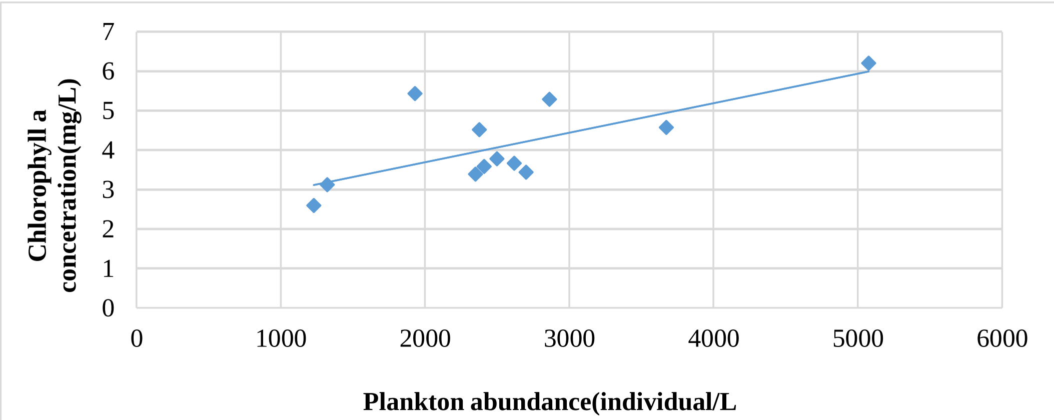

Figure 9. Scatter diagram showing overall correlation between plankton abundance and primary productivity.

Discussion

Plankton forms the basis of food chain and a close association between plankton abundance and fish production exists (Bhatnagar and Devi, 2013). Phytoplankton use Chlorophyll-a in photosynthesis to transform nutrients and carbon dioxide. In the current study a total of 16 phytoplankton species belonging to cyanophyceae, chlorophyceae, bacillariophyceae and euglenophyceae, dianophycea and chrysophyta and a total of 12 zooplankton species belonging to copepoda, rotifer, cladocera and protozoa were recorded. Almost similar findings have also been reported by Chowdhury and Mamun (2006). In traditional pond culture phytoplankton trends is similar with Akter *et al.*, (2015). These result match with Affan *et al.* (2005) also. During the late autumn season, the highest number of phytoplankton (3357 individual/L) was found in traditional pond culture system and the lowest number of plankton was found in purification zone of IPRS during the summer season (845 Individual/L). In production zone of the IPRS phytoplankton abundance was highest in rainy season (2518 individual/L). The abundance of phytoplankton in the production zone was slightly higher than that of the purification zone, but lower than in the typical pond system. But statistically there was no significant variation of phytoplankton abundance between the IPRS system and traditional pond culture system. About 34 genera of phytoplankton and 12 taxa of zooplankton has been reported by Kohinoor (2000). Galvez (2015) finds that cyanobacteria are the most abundant organisms, followed by chlorophyta, heterokontophyta, euglenophyta and dinophyta in case of integrated shrimp biofloc system. Hossain *et al.* (2022) reports that among chlorophyceae, cyanophyceae, bacillariophyceae and euglenophyceae are the most dominant group in aquaponics system. The abundance, distribution and species composition of phytoplankton in the Bay of Bengal were also investigated by Booonyapiwat *et al.* (2008), who conducted their research at three different stations in the bay: the north, west, and east and found cyanophyta (68.12%), bacillariophyta (27.67%), dinophyta (2.63%) and dictyochophyta (1.59 %) in ocean ecosystem. The highest number of zooplankton was found in traditional pond culture system during the late autumn season (1719 individual/L), the number of planktons found in the purification and production zone of IPRS cell was almost similar during the summer season. In the production zone, zooplankton abundance was highest in rainy season (1154 individual/L). Zooplankton abundance in production zone was slightly higher than the purification zone but lower than the traditional pond system. But statistically there was no significant variation of zooplankton abundance between the IPRS system and traditional pond culture system. Kabir *et al.* (2014) have studied on zooplankton of harda baor of Meherpur district; composition and seasonal succession and found rotifers (38.02%), copepods (50.78%), cladocerans (5.66%) and protozoans (5.54 %) of total zooplankton. Copepod (40.46%) was the dominant group in IPRS system among the zooplankton during the study period which supports Kabir *et al*., (2014). Khaniani *et al* (2002) have studied on microorganisms in biofloc aquaculture system and found Rotifers (43.10 %) copepoda (33.21 %), protozoa (13.52 %) and cladocera (10.16 %). Mozumder *et al.* (2014) have looked at a polyculture fish pond in Manikganj, Bangladesh, and counted the zooplankton and measured the pond's physico-chemical characteristics. They conducted study during June 2003 to May 2004 and found copepoda 56.07%, rotifera 27.49% nauplii 11.96%, cladocera 1.49% and protozoa 2.99% of total zooplankton. Nair *et al*., (2015) have found that water temperature has a favorable impact on rotifera population abundance, as did pH and soluble organic content.

In summer season, the chlorophyll a concentration was found to be lowest in both the purification and production zone of IPRS system and traditional pond culture system which was 2.6 mg/L, 3.12 mg/L and 3.37 mg/L respectively. Brainwood *et al* (2004) has reported almost the similar findings. Though, there seemed to be a slight season variation between the IPRS system and traditional pond culture system, statically there was no significant variation of primary productivity between the IPRS system and the traditional pond culture system ($P>0.05$). Primary productivity and chlorophyll a content were found to have a substantial positive association. Higher Concentration indicated higher level of primary productivity. So, in this study, highest level of primary productivity was found in the traditional pond system during the late autumn season and lowest in the purification zone of IPRS cell. In production zone, productivity is always optimum. However, a range of 50 – 200 μg/l is usually considered to be index of good productivity. Zhang *et al.* (2004) reports that the rate of chlorophyll a content and primary productivity results high in spring and summer. Chlorophyll-a concentration in microalgae is useful for analyzing and investigating the biomass and density of microalgae in the ecosystem. That's why microalgae are considered as primary producer in any aquatic food web. (Johan *et al*, 2015).

In this study, a positive relationship between plankton abundance and primary productivity was found both in IPRS system and traditional pond culture system. An increase or decrease in plankton abundance resulted in a concomitant variation in the chlorophyll a concentration as a means of primary productivity. Though a limited degree positive correlation($r=0.24$) was assumed between plankton abundance and primary productivity in the purification zone of IPRS cell, a relatively strong positive correlation($r=0.75$) was assumed between plankton abundance and primary productivity in the production zone of IPRS cell. A strong positive correlation ($r=0.92$) was assumed between plankton abundance and primary productivity in traditional pond culture system that may be due to the highest abundance of plankton species. So, it was concluded that a strong relationship exists ($r=0.71$) between plankton abundance and primary productivity in the study areas. Plankton availability result in increase or decrease in nutrient availability, which may be the cause of variation of primary productivity in response to plankton abundances in the study areas.

Conclusion

In pond raceway system is a proven intensive aquaculture technology to produce a huge quantity of quality fish in less water. A little study was conducted on the plankton abundance and primary productivity level in IPRS system in a comparison with traditional pond culture system. Statistical analysis revealed that there was no significant variation of plankton abundance and primary productivity between IPRS system and traditional pond culture system. In the production zone of IPRS, both groups of plankton abundance were highest in the rainy season. An optimum level of chlorophyll a concentration as a means of primary productivity was observed in the IPRS system. The conditions for growth and production depends on the availability of food. So, it is necessary to maintain an optimum level of plankton abundance as well as primary productivity along with artificial feeding all the year round to ensure the maximum fish production.

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Conflict of interest

The authors declare no conflict of interest.

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