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# Sustainable Fish Production Through Ecological and Fisheries Management of Canals in Indian Sundarbans (West Bengal)

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## Abstract

The canal systems in Indian Sundarbans, West Bengal cover 907.33 ha area and offers a huge resources for fisheries development and livelihood. Naturally, fish enter to these canals from the source waters and form natural populations. Despite having vast resources, a little attention is paid to boost Inland fish production from canals. To understand the ecology and development of suitable practices/ techniques in canal systems, an effort was made for the sustainable fish production. Bharua canal a tidal fed canal connected with river Hooghly at Shibpur, Fraserganj of Sundarbans was selected to enhance fish production. The total length of canal is 2 km, average width of 45 m and water depth ranged from 3 to 8 feet. Three numbers of net partition system (NPS) were constructed with dimension of 50m × 45m covering an area of 2,250 $m^2$ each partition system. Water temperature (27.50±0.49°C), transparency (27.71±2.10 cm), Dissolved oxygen (5.61±0.13$mgL^{-1}$), pH (7.68±0.04), salinity (2.28±0.11$gL^{-1}$) were recorded during the trial. Diatoms (Bacillariophyceae) were dominated across the seasons. The quantitative abundance of phytoplankton and Zooplankton in the canal was 9522±2170 $cellsl^{-1}$ and1918±97ind/l respectively. Rotifera shared dominance (45%) followed by crustacean nauplii (20%) and cladocera (12%). A total of 16 species of fish under 7 orders and 10 families were recorded. With the native fishes, fingerlings of Indian Major Carps *Labeo catla, Labeo rohita* and exotic carp *Ctenopharyngodon idella* were stocked @2 nos./$m^2$ in a ratio of 50: 40: 10 in a net partition system (NPS) installed in the canal. After a culture period of 180 days, the average size recorded for *Labeo catla, Labeo rohita* and *Ctenopharyngodon idella* were 265.61 ± 25.44 g, 184.63 ± 26.13 g and 221.57 ± 21.94g respectively. In addition to stocked fishes, considerable quantity of small indigenous fish (SIF'S) like *Puntius sophore*, *Puntius ticto, Amblypharngyodon mola, Salmostomo bacaila* were caught from NPS. In the present study, culture of fish in NPS showed feasible option in the canal. Hence, the NPS can be look upon as a potential culture practice to enhance the fish production and productivity from the unutilized canal resources. Adoption of this culture practice will provide a nutritional security, generate employment opportunity, and improve the livelihood and socioeconomic status of the rural populace of Indian Sundarbans.

**Keywords:** Canal Ecology; Carps Culture; Net Partition System; Indian Sundarbans

## Introduction

Canals are the second most important (26%) source of irrigation covering 17 million ha in India (Agricultural Census 2010- 2011) which has considerable potential for fish production. The canal systems in Sundarbans covered area 907.33 ha and having vast potential for fish culture [1]. Various countries are producing fish from irrigations canals. Studies reported that around 16% of the freshwater fishery production comes from river Nile and its irrigation canals in Egypt while in Sudan, the fish biomass in minor canals of Geizira irrigation system with an average 660 kg/ha [2]. The practice of simple release of species *Oreochromis* spp., *Channa striata* and *Puntius gonionotus* in to irrigation canals reflected 350 kg/ha without supplementary feeding in Thailand [2]. Furthermore, the channelization or irrigation canals exhibit lower species diversity than the static water bodies which is primarily influenced by temperature and low primary producers [3, 4]. According to the published literature of FAO [5], fish biomass is 31% lower as compared to an unchannelised stream with 78% reduction of macro-invertebrate biomass. In Thailand, the extensive culture of bighead carp, grass carp and Nile tilapia in irrigation canals with the utilization of vegetable crops was successful [6, 2]. Physicochemical parameters in canals are strongly correlated with the phytoplankton abundance [7, 8]. The $NO_2$, $NO_3$, $SIO_3$, $HCO_3$, $PO_4$, $Ca^{2+}$ and $Mg^{2+}$ are the key variables in the shaping of benthic fauna assemblage in Upper Ganga Canal (Matta, 2015); zooplankton primarily dominated by rotifers, cladocerons and protozoans in Ganga canal [10]. Limnological variations of Sirhind feeder channel (Hanumangarh) characterized by shallow with turbid, alkaline and well oxygenated water [10]. The study on fish culture practices in Indian canals are limited. In order to understand the ecology and development of suitable techniques in canal systems; research effort is necessary to achieve the sustainable production from these resources. Fisheries from canals are poorly documented. The information on trophic status of canal habitat, biotic community structure and hydrological parameters are lacking. Hence, the present study aimed to generate baseline data of canal ecosystem and development of suitable enhancement practices in canal ecosystem of Sundarbans, West Bengal.

## Materials and Methods

The current study was carried out in Bharua canal which is located in Shibpur, Fraserganj of Sundarbans (21°36'39.3"N 88°15'21.6"E) West Bengal India, and is a tidal fed canal connected with river Hooghly. The total length of canal is 2.0 km and width are ~ 45 m, and having a water depth ranges from 3 to 8 feet. Three sampling locations were chosen at an equal distance with the station 1 at near river mouth (S1), then in the amidst of the canal (S2) and station 3 (S3) at the end point of the canal from river mouth (Figure 1). Sampling was carried out at bimonthly from April 2018 to March 2019, constituting three different seasons [11] i. e. pre-monsoon, monsoon and post-monsoon.

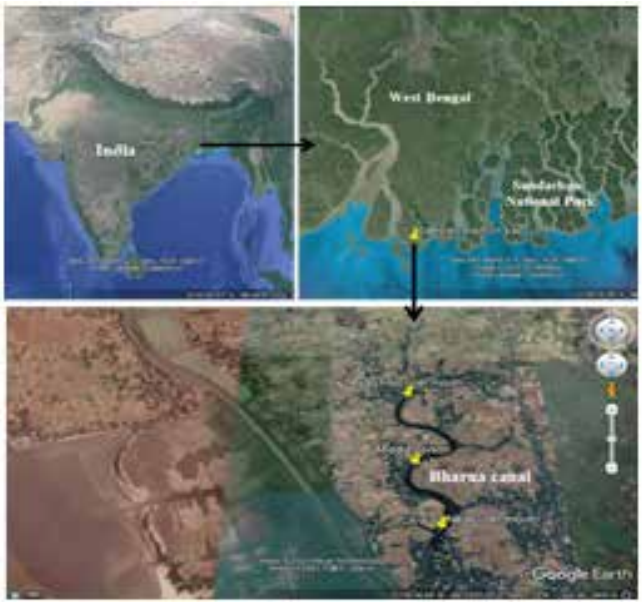



**Figure 1:** A Map of Bharua Canal, Bakkhali

## Environmental Parameters Measurement

For physical and chemical analysis of water, with the help of standard water sampler based on the design of 'Ruttner water sampler [1], water samples were collected from subsurface (0.5 m depth) and instantly shifted into clean polythene bottles (1.0 L) from the predefined locations. Water temperature (°C), transparency (cm), pH, dissolved oxygen ($mgL^{-1}$), specific conductivity (m S/cm), salinity (ppt), total alkalinity ($mgL^{-1}$), and total hardness ($mgL^{-1}$) were measured *in-situ*. For the analysis of other parameters such as total dissolved solids (TDS), and nutrients (phosphate, nitrate, sulphate, silicate), water samples were brought to the laboratory in cold conditions. A degree centigrade (-10 to 50 °C) thermometer (P-601466) were used for measuring temperature, digital pH meter (Hanna Instruments) for recording water pH, a digital conductivity meter (Multiline P4-82362) for measuring specific conductivity, and Secchi disk was used for recording transparency (Strickland and Parsons, 1972). Analysis of total dissolved solids, dissolved oxygen, total alkalinity, total hardness, salinity and nutrients were determined by following the standard methods APHA (2012).

## Sediment Quality Parameters

For sediment analysis, sediment samples were collected at about 30 cm depth and transferred in polyethylene bags, and brought to the laboratory for analysis. For the chemical analysis, the samples were initially dried, made into finely powdered and sieved. The particle size of sediment was determined by hydrometer method. Value of sediment pH was determined by glass electrode pH meter in water using sediment/water ratio of 1:10. Specific conductivity calculated by conductivity meter. Organic carbon in the sample was determined by using wet oxidation method of Walkley and Black [12]. The available phosphorous and available nitrogen in the sample was determined by Brays II method [13] and alkaline potassium permanganate method [14], respectively. And, free calcium carbonate was measured volumetrically with HCL soluble $CaCO_3$ method.

## Phytoplankton Sample Collection

Phytoplankton samples were collected by filtering 50 L sub-surface water from the selected locations using plankton net (20 µm silk bolting mesh). The collected samples were preserved by adding 4% buffered formalin solution to it. For the quantitative analysis of plankton, a Sedgwick Rafter counting cell was used. The total number of phytoplankton cells present was calculated and expressed in terms of cells per litre (cells $l^{-1}$) [15]. Phytoplankton was identified by employing a trinocular microscope (Nikon Eclipse-50i) and with the help of published standard literatures [16, 17]. The genera of plankton were arranged according to the AlgaeBase, [18].

## Fish diversity

Fish specimens were collected by experimental fishing using gears such as cast net, seine net, gill net and bamboo traps in the canal. In addition, fish samples were also collected from the local fishermen and markets nearby in the canal. The collected fish samples were preserved in 10% formalin solution. Identification of fishes was done by standard taxonomic keys and literatures [19, 20, 21].

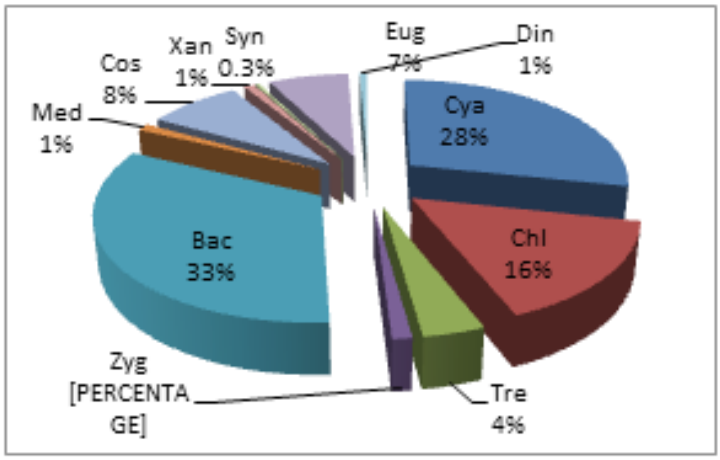
## Livelihoods and Ecosystem services

Data was also collected regarding the contribution of canal fisheries in the livelihoods of the rural populace living adjoin to the Bharua canal. A semi-structured interview schedule was prepared and data was collected through direct questioning. Data was collected from 20 households and also from the community leaders of that area. Ecosystem services rendered by the canal was also listed out based on the Millennium Ecosystem Assessment, 2005 synthesis report.

## Installation of Net Partition System (NPS)

In collaboration with the local stakeholders of the Bharua canal, a net screen barrier as a net partition system (NPS) was installed in the canal. Three net partitions were constructed with the dimension of 50m × 45m (L × B); each covering an area of 2,250 $m^2$. Net partition

system is a kind of pen structure made from locally available bamboo poles and HDPE net. The erected structure of net partition system is shown in Figure 1. Fingerlings of Indian major carps *Labeo catla, Labeo rohita* and exotic carp *Ctenopharyngodon idella* with average weight of 5.83±0.13 g, 5.65±0.33 g and 6.50±0.41g were stocked @2nos./m$^2$ with the stocking ratio of 50: 40: 10 respectively. The fishes were provided with an artificial feed (28% crude protein and 5% crude lipid) twice a day @4% of body weight for 180 days.




BAC: Bacillariophyceae; Cya: Cyanophyceae; Chl: Chlorophyceae; Cos: Coscinodiscophyceae; Eug: Euglenophyceae; Tre: Trebouxiophyceae; Zyg: Zygnematophyceae; Xan: Xanthophyceae; Din: Dinophyceae; Med: Mediophyceae; Syn: Synurophyceae

**Figure 1(a):** Compositions of phytoplankton in Bharua canal, Sundarbans

Growth performance analysis was carried out at bimonthly interval. The growth performances as recorded by means of length and weight of individual fish to determine weight gain (WG), relative growth rate (RGR %), specific growth rate (SGR %), and survival rate (SR %). These parameters were calculated as follows: WG (g) = $W_f$ - $W_i$; RGR (%) = $(W_f - W_i)/W_i \times 100$; SGR (%/day) = $(\ln W_f - \ln W_i)/t \times 100$: Where, $W_i$ and $W_f$ are initial and final weights (g), respectively, and t is the time of the experiment (days); survival rate (%) = (no. of fish harvested /no. stocked) x 100. Total fish yield was calculated as yield (kg) = Avg. final weight x total no. of survivors.

### Statistical Analysis

Parameters in this study were analysed using SPSS (version 23). Data are shown as means ± standard deviation. Fish diversity has been measured by the number of species (species richness) and by using the three indices - (1) Shannon–Weiner index ($H'$) (Shannon and Weiner, 1949): $H' = -\sum [Pi \times \log (Pi)]$; Where 'Pi' is the proportion of the individuals belonging to the 'i'$^{th}$ species and $H'$ is the species diversity (2) Margalef richness index ($d$) (Margalef, 1958): $d = (S-1)/\log N$, where $N$ = total number of individuals and $S$ = total number of species and (3) Pielou's evenness or equitability index ($J'$) (Pielou, 1977): $J' = H'/\text{Log}(S)$; where $H'$ = Shannon–Weinner diversity and $S$ = total number of species. The diversity indices were also followed for phytoplankton population. One way analysis of variance (ANOVA) was performed to understand the significant heterogeneity of phytoplankton between seasons.\

## Results and Discussion

### Environmental parameters measurement

#### Physical and chemical parameters of water

Seasonal variations in the physical and chemical parameters of Bharua canal are presented in Table 1. Salinity variation was wide in the canal between the season's ranges from 0.37 – 3.54 ppt and highest salinity was recorded during pre-monsoon season. The pH of surface water ranged from 7.27 – 8.5. Overall, the pH of the canal was alkaline. Dissolved oxygen ranges from 4.4 – 6.5 mgL$^{-}$1, were favourable for good production of fish. Total alkalinity in Bharua canal ranges from 64 – 111 mgL$^{-1}$. Over all, the canal had a very good "buffering" capacity.

| Parameters | Pre-monsoon | Monsoon | Post-monsoon |
|---|---|---|---|
| Depth (cm) | 121.67 ± 6.01 | 175.00 ± 6.45 | 310.00 ± 15.68 |
| Air temperature ( °C) | 26.10 ± 0.06 | 29.40 ± 0.14 | 26.08 ± 0.05 |
| Water temperature (°C) | 26.70 ± 1.35 | 28.45 ± 0.06 | 27.35 ± 0.06 |
| Transparency (cm) | 27.70 ± 1.88 | 40.00 ± 1.87 | 15.43 ± 2.56 |
| Specific conductivity (m S/cm) | 6.08 ± 0.16 | 5.74 ± 0.17 | 0.93 ± 0.01 |
| TDS ($mgL^{-1}$) | 536.67 ± 50.44 | 5003.50 ± 417.91 | 657.90 ± 44.39 |
| pH | 7.75 ± 0.05 | 7.95 ± 0.03 | 7.34 ± 0.03 |
| DO ($mgL^{-1}$) | 5.70 ± 0.12 | 6.28 ± 0.11 | 4.85 ± 0.17 |
| Free $CO_2$ ($mgL^{-1}$) | 7.07 ± 0.23 | 5.35 ± 0.39 | 8.60 ± 1.15 |
| Total Alkalinity ($mgL^{-1}$) | 130.00 ± 2.89 | 66.00 ± 1.35 | 108.25 ± 1.55 |
| Salinity (ppt) | 3.29 ± 0.16 | 3.18 ± 0.16 | 0.39 ± 0.01 |
| Total hardness ($mgL^{-1}$) | 164.67 ± 4.33 | 705.25 ± 18.28 | 138.50 ± 13.84 |
| Total N ($mgL^{-1}$) | 0.08 ± 0.01 | 0.56 ± 0.06 | 0.04 ± 0.00 |
| Nitrate ($mgL^{-1}$) | 0.01 ± 0.00 | 0.01 ± 0.00 | 0.02 ± 0.00 |
| Total phosphate ($mgL^{-1}$) | 1.90 ± 0.55 | 0.49 ± 0.03 | 2.57 ± 0.86 |
| Phosphate - P ($mgL^{-1}$) | 0.07 ± 0.01 | 0.15 ± 0.01 | 0.06 ± 0.00 |
| Silicate ($mgL^{-1}$) | 5.41 ± 0.35 | 7.07 ± 0.15 | 4.38 ± 0.77 |
| Sulphate ($mgL^{-1}$) | 2.98 ± 0.41 | 145.21 ± 2.67 | 0.57 ± 0.16 |

The values are means ± SD

**Table 1:** Physico-chemical parameters of Bharua canal, Sundarbans (W.B)

## Soil Quality Parameters

Sediment size fraction of Bharua canal showed that major percentage of the sediment is contributed by silt (43.50 ± 1.76%) followed by sand (42.50 ± 0.87%) and clay (14.00 ± 2.61%). Organic carbon content in soil was low to medium (1.58 ± 0.07%); which means there is a less organic matter accumulation at the bottom. The soil pH of the canal was 7.08 ± 0.025. In this canal, an accumulation of available nitrogen and phosphorus were found in good quantity, especially available phosphorus. Sediment quality parameters of Bharua canal is presented in Table 2.

| Parameters | Value |
|---|---|
| Sand (%) | 42.50 ± 0.87 |
| Silt (%) | 43.50 ± 1.76 |
| Clay (%) | 14.00 ± 2.61 |
| pH | 7.08 ± 0.025 |
| Specific conductivity (mS/cm) | 7.35 ± 0.29 |
| Available nitrogen (mg $100g^{-1}$) | 18.62 ± 0.74 |
| Available $P_2O_5$ (mg $100g^{-1}$) | 3.23 ± 0.47 |
| Organic carbon (%) | 1.58 ± 0.07 |
| Free $CaCO_3$ (%) | 1.44 ± 0.16 |

The values are means ± SD

**Table 2:** Sediment quality of Bharua canal, Sundarbans

## Plankton Diversity of Canal

The Bharua canal exhibited significant heterogeneity of plankton abundance across the seasons ($p<0.05$). A total of 71 species (63 genera) of phytoplankton were recorded. Out of 11 algal groups, Bacillariophyceae (33%) excelled as major microfloral community. Algal group Cyanophyceae (28%) emerged as second conspicuous group (Figure 1 (a)). On the whole, three algal groups Bacillariophyceae, Cyanophyceae, and Chlorophyceae showed major contributions to the total phytoplankton community. The diatoms were dominated in terms of diversity (31 species) dominated by pennales. Seasonal abundance of phytoplankton revealed peak during post-monsoon season (10,110±2696) and lowest in pre-monsoon season (6385±1233). Eight groups of zooplankton were recorded where Rotifera was dominant (45%) followed by Crustacean nauplii (20%) and Cladocera (12%). (Figure 2). The abundance of zooplankton observed maximum in monsoon season (1,089±646). The quantitative spectrum of phytoplankton and Zooplankton was 9,522±2170 cellsl$^{-1}$ and 1,043±410 ind.$^{-1}$, respectively in the canal. The Shannon- Weinner diversity (*H'*) of phytoplankton was maximum in monsoon (3.2±0.23) and lowest during pre-monsoon (3.1±0.11). While, *H'* and Margalef richness (*d'*) of zooplankton showed maximum during post-monson season. The richness and Shannon diversity indicated a rich phytoplankton diversity with a value of >3.1 in the canal. Pielou's eveness index (*J'*) reflected an even distribution of phytoplankton with mean value 0.88.

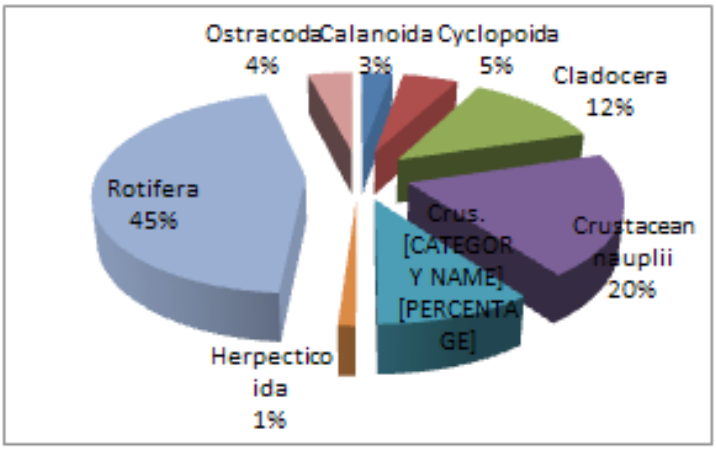



**Figure 2:** Compositions of zooplankton in Bherua canal

## Fish Diversity of Bharua Canal

A total of 17 fish species recorded under 8 orders and 11 families and is presented on table 3. The catch structure revealed the dominance of family Cyprinidae (59%) followed by Bagridae (13%), Ambassidae (9%), Channidae (7%), Notopteridae (4%), Mastacembelidae(2%), Gobiidae(2%), Megalopidae (1%), Schilbeidae (1%), Anabantidae (1%) and Megalopidae(1%) respectively. The major component of fish catch was contributed bysmall indigenous fish (SIF) like *Puntius sophore*, *Puntius ticto, Amblypharngyodon mola, Rasbora daniconius* and *Salmostomo bacaila*. Seasonal fish diversity was observed highest during monsoon season. The mean value of Shannon diversity (H')index and Margalef richness index (d') was found to be 2.32 and 2.62, respectively indicated a moderate diversity in the system. The distribution of fishes was evenly distributed in the canal as evident from the calculated value (0.71) of evenness index (J').

| Sl. No. | Species | Order | Family | ICUN status | Utilization |
|---|---|---|---|---|---|
| 1 | *Channa punctata* (Bloch, 1793) | Channiformes | Channidae | LC | FF & OF |
| 2 | *Channa striatus* (Bloch, 1793) | | | LC | FF & OF |
| 3 | *Pethia ticto* (Hamilton, 1822) | Cypriniformes | Cyprinidae | LC | OF |
| 4 | *Puntius sophore* (Hamilton, 1822) | | | LC | OF |
| 5 | *Rasbora daniconius* (Hamilton, 1822) | | | LC | OF |
| 6 | *Amblypharyngodon mola* (Hamilton, 1822) | | | LC | FF |
| 7 | *Salmostoma bacaila* (Hamilton, 1822) | | | LC | FF |
| 8 | *Chanos chanos* (Forsskal, 1775) | Gonorynchiformes | Chanidae | NE | FF |
| 9 | *Macrognathus pancalus* (Hamilton, 1822) | Synbranchiformes | Mastacembelidae | LC | FF & OF |
| 10 | *Parambasis ranga* (Hamilton, 1822) | Perciformes | Ambassidae | LC | FF & OF |
| 11 | *Anabus testudineus* (Bloch, 1792) | | Anabantidae | DD | FF |
| 12 | *Glossobogius giuris* (Hamilton, 1822) | | Gobiidae | LC | FF & OF |
| 13 | *Mystus gulio* (Hamilton, 1822) | Siluriformes | Bagridae | LC | FF |
| 14 | *Mystus vittatus* (Bloch, 1794) | | | LC | FF & OF |
| 15 | *Pachypterus atherinoides* (Bloch, 1794) | | Schilbeidae | LC | FF |
| 16 | *Notopterus notopterus* (Pallas, 1769) | Osteoglossiformes | Notopteridae | LC | FF & OF |
| 17 | *Megalops cyprinoides* (Broussonet, 1782) | Elopiformes | Megalopidae | DD | FF |

Where, LC = Least count; NE = Not evaluated; DD = Data deficient

FF = Food fish; OF = Ornamental fish

**Table 3:** Fish species diversity of Bharua canals of Indian Sundarbans, along with their IUCN status and utilization

## Contribution of The Canal On Livelihoods and for Rendering Ecosystem Services

Bharua canal is located in Shibpur village in Namkhana Block of Sundarbans. Scattered human settlement is found by the side of the canal. The people living by the side of the canal often harvest fishes from the canals by using various traps and gears. People put bamboo made rectangular shaped traps traps like *Guni, Chero, Atal , Chokhia or* Triangular shaped trap *Banki/Mugri* to harvest fishes from marshy areas, water channels or canals in Sundarbans [22]. It was reported by the sampled populace that during monsoon, they are getting better catch and more types of high value fishes which lead an average income of INR 3,850/- during monsoon months(June, July, August, September). However, other than the monsoon months, during lunar periods (*Bhara Kotal*) the people are getting more fish from this canals which contributes around INR 1260/- in their monthly income (during October-April). A similar study conducted in Frezarganj area of Sundarbans shows that fish catch from the water channels, canals, water bodies, paddy fields contribute 15.65 percent in the household income of the fishermen [23]. It was also reported by the sampled population that; the women of the adjoining households often collect Small Indigenous Fishes(SIFs) or prawns through small dragnets/scoop nets for the household consumptions.

Canals are rendering important ecosystem services both directly and indirectly. Fisher et al. 2009 has defined ecosystem services 'the aspects of ecosystems utilized (actively or passively) to produce human well-being'. The ecosystem services rendered by the canal has given below:

1. Provisioning services:
    a. Source of fresh water
    b. Provide 'Fin fish' and 'shell fish' as food
    c. Irrigation water for crop production
    d. Aquatic weeds as leafy vegetables
    e. Agricultural diversity
    f. Drainage of excess water
2. Regulating services:
    a. Flood control
    b. Carbon sequestration
    c. Habitat for rare aquatic weeds and animals
    d. Protection for coastal storm surges
    e. Aquifer recharge/ ground water recharge
3. Cultural services
    a. Site foe ecological or environmental education
    b. Human relaxation, walking trails
4. Supporting services
    a. Primary productivity
    b. Hydric soil development

## Growth performance of fishes stocked in net partition system

The detail growth performance of stocked fishes is given table 4. The intent of present study was to observe the feasibility of Indian major carps and exotic carp culture in the slightly saline water canal of Sundarbans. After 180 days of culture, the average. mean weight of *L. catla, L. rohita* and *C. idella* was 265.61 ± 25.44 g, 184.63 ± 26.13 g and 221.57 ± 21.94g respectively. *L. catla* performed well in canal system than the other two species and attended highest weight gain (Fig. 2). Relative growth rate (RGR %) were highest in *L. catla* followed by *C. idella* and *L. rohita.* Specific growth rate (SGR %) of *L. catla* was 2.10 ± 0.33 followed by *C. idella* 1.95 ± 0.06 and *L.rohita* 1.91 ± 0.06 respectively. Highest survival % were recorded in *C. idella* 89.7 ± 2.02 % followed by *L. rohita* 82.85 ± 2.71 whereas, lowest in *L. catla* 77.53 ± 1.60.

| Parameters | *Labeo catla* | *Labeo rohita* | *Ctenopharyngodon idella* |
|---|---|---|---|
| Initial weight (g) | 5.83 ± 0.13 | 5.65 ± 0.33 | 6.50 ± 0.41 |
| Final weight (g) | 454.85 ± 46.35 | 380.73 ± 19.55 | 339.88 ± 29.17 |
| Weight gain (g) | 449.02 ± 46.38 | 375.08 ± 19.67 | 333.38 ± 28.98 |
| Relative Growth Rate (RGR %) | 7765.89 ± 871.77 | 6975.69 ± 832.85 | 5205.32 ± 400.70 |
| Specific Growth Rate (SGR %) | 2.40 ± 0.06 | 2.34 ± 0.05 | 2.19 ± 0.05 |
| Survival rate (%) | 77.53 ± 1.60 | 82.85 ± 2.71 | 89.7 ± 2.02 |

The values are means ± standard errors (n = 3)

**Table 4:** Growth performance of fishes stocked in Net Partition System

Previous studies were conducted on seed raising of IMC as stocking material for wetlands. The fingerlings of *L. rohita*, *Cirrhinus mrigala* and *Hypophthalmichthys molitrix* reared up to the advance fingerling size for 59 days in pen with 4% body weight of supplementary feeding. The fishes attended the size from 50 to 71.5 g, 60 to 74 g and 30 to 75 g, respectively [24]. The advanced fry of IMC i.e. *L. rohita* and *Labeo catla* were reared in pen at Sareni wetland of Uttar Pradesh for 120 days. The mean weight attended by the fishes was 2.88±1.41 g to 57.2±13.84 g and 2.1±1.16 g to 67.38±25.79 g respectively [25].

In the present study, the fish yield in net partition system was recorded around 2484.34 kg from three partition unit, it means approximately 3,680 kg of fish biomass per hectare (Table 5). In Bihar, the study was conducted in ox-bow lakes to produce table size fish of IMC from pens by stocking advanced fingerlings, the result showed a yield of 3362-3962 kg/ha within a six month of culture period [26]. The fish yield in the present study found to be similar with their report. However, fish yield in the net partition system showed much higher than the yield (2106 and 1780 kgha$^{-1}$) reported from pen culture in two Wetlands of Assam [21].

| Species | No. of fishes stocked | No. of fishes Harvested | Yield (kg) | Yield(kg/m$^2$) |
|---|---|---|---|---|
| *Labeo catla* | 6750 | 5233 | 1390.01 | 0.206 |
| *Labeo rohita* | 5400 | 4474 | 826.02 | 0.122 |
| *Ctenopharyngodon idella* | 1350 | 1211 | 268.31 | 0.040 |
| **Total** | 13500 | 10918 | 2484.34 | 0.368 |

**Table 5:** Yield of the Stocked fishes in Net Partition System in Canal of Sundarbans

The economic analysis of net partition system is presented in table 6. In the present experiment, benefit-cost ratio for the Net Partition System operation for rearing single crop was estimated to be 1.16, which is in agreement with the studies conducted in the wetland of Assam by [21] and flood plain wetland of Uttar Pradesh [25]. The return on investment estimated was 0.16.

Literature on culture of Indian major carps (IMC) in pen from Indian waters is limited whereas there is no report about pen culture in canal system. Previous studies were conducted for the culture of IMC seed for raising stocking material in the wetlands. [27] reported that *in-situ* raising of IMC fingerlings in pen enclosures in the floodplain wetlands of Uttar Pradesh is economically feasible. [25] reported that intervention through pen culture resulted in the increase in fish productivity of Sareni Jheel of Uttar Pradesh from 310 to 833 kg ha$^{-1}$. Inland fish production can sustainably increase by rational stocking in inland open water bodies such as wetlands, reservoirs and canals [28, 29, 30].

Result of the present study showed that culture of Indian Major Carps and exotic carp in net partition system in the canals of Sundarbans may provide the suitable alternative to the tribal fishers of Sundarbans to improve their livelihood and socioeconomic status.

| | Particulars | Rate (₹) | Unit | Amount (₹) |
|---|---|---|---|---|
| | **Capital costs** | | | |
| | Cost of bamboo poles (number) | 300 | 45 | 13500 |
| | Cost of HDPE net screen (meter) | 400 | 50 | 20000 |
| **A** | Sub total | | | **33500** |
| **B** | Capital costs per crop (assuming that the materials will last for 3 crops) | | | 11166.67 |
| | | | | |
| | **Operational costs** | | | |
| | Cost of fingerlings (kg) | 200 | 27 | 5400 |
| | Cost of Feed (kg) | 32.5 | 2000 | 65000 |
| | Labour charges for construction of NPS | 350 | 7 | 2450 |
| **C** | Sub-total | | | **72850** |
| | Total costs (B+C) | | | **84016.67** |
| | | | | |
| | **Gross income** | | | |
| | Sale value/ price of fish | | | |
| | *L. catla* (kg) | 120 | 463.34 | 55600.80 |
| | *L. rohita* (kg) | 120 | 275.34 | 33040.80 |
| | *C. idella* (kg) | 100 | 89.44 | 8944 |
| **D** | Sub-total | | | **97585.60** |
| | | | | |
| **E** | **Net income (Gross income - Total costs)** | | | **13568.93** |
| | Benefit-cost ratio | | | 1.16 |
| | Return on investment | | | 0.16 |

**Table 6:** Economics of IMC & EC rearing in Net Partition System in Bharua canal

## Conclusion

As the canals system in Sundarbans are holds great potential for the fish production but since long time they are unutilized or underutilized. The canal is a source of livelihood for the local populace and also mitigate their nutritional needs. Moreover, the present study showed that culture of fish in net partition system in canal is a feasible option. Adoption of net partition system in canal system can provides the alternate livelihood option to the fisher's community as the Indian major carp has good demand in local markets in addition to the native fishes of the canal.

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