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Developing mola (*Amblypharyngodon mola*) based fish culture practices for addressing livelihood and nutritional security of rural populace of Indian Sundarban

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Abstract
The present study was carried out to establish a viable culture system of Mola (*Amblypharyngodon mola)* with other edible fishes in Sundarban area. The study was designed in four treatments *viz.* mola with polyculture (T1), mola with pabda (T2), mola with prawn (T3) and only mola (T4). Mola were stocked @ 20,000 nos. per ha in all the treatments whereas *Labeo rohita, Catla catla, Cirrhinus mrigala* and *Ctenopharyngodon idella* were stocked @ 3000, 2000, 1750, 2500 nos. per ha in T1; pabda @ 10000 nos. per ha in T2 and fresh water prawn @ 3750 nos. per ha in T3. The production and economic return in term of profit was also highest from T1 followed by T2. The present study recommends the mola with polyculture as suitable option for improving the fish production and livelihoods as well as mitigating the nutritional needs of artisanal fishers of Sundarbans.

Keywords: SIFs, polyculture, livelihood, Mola, benefit cost ratio, fish production

Introduction
Sundarbans, the largest deltaic region protect the wildlife and marine sanctuaries and support economically prized faunal diversity [1]. The climate pattern, vast water resource and fertile soil of Sundarbans area are suitable for aqua farming. Small indigenous fish species (SIFs) are generally the freshwater fish species which attain maturity at the length of about 25 cm [2]. Small indigenous fishes (SIFs) mola (*Amblypharyngodon mola*), chela (*Salmostoma bacaila*), puti (*Puntius sophore*), darikana (*Esomus danrica*) etc. were abundant in river, channels, canal, beels of Sundarbans which were caught for subsistence fishing. In conventional polyculture system, these species are considered as unwanted species or trash fish and usually eradicated during pond management [3]. However, the small indigenous fishes are important source of animal protein as well as micronutrients for the rural people [4, 5, 6]. Sundarbans is a fragile ecoregion, and vulnerable to rise in sea level, storms, coastal erosion, and freshwater availability. There is a drastic reduction of these small fishes in that area due to these adverse impacts [7]. Therefore, to conserve these valuable species, there is need to develop suitable culture and sustainable management practices. India is well known for carp production both Indian major carps (rohu, catla, mrigal) and exotic carp (silver carp, grass carp and common carp) which contribute 87% production of total aquaculture [8]. Freshwater prawn (*Macrobrachium rosenbergii*) is also a valuable species in aquaculture for its faster growth, good taste and higher market price. Prawn in polyculture system has a successful higher economic return than that in its monoculture system [9]. In recent years, the priority has been given to Indian butter catfish (*Ompok bimaculatus*) known as pabda, an indigenous catfish, popular for its soft flesh and excellent taste [10]. SIFs are self-recruiting species and can be culture as climate resilient species in Sundarbans. The present study was conducted to study the introduction of an indigenous SIFs, mola in polyculture system with carp as well as other economically important species to standardize and popularize the culture practices for ensuring livelihood, providing nutritional security and through generation of income of rural population.

Materials and Methods
Study site
The study was conducted for six months (20th September, 2016 to 22th March, 2017) in 4 ponds at Madanganj village under Namkhana block, Sundarbans, South 24 Parganas,

West Bengal, India. The size of ponds was in the range of about 0.1 ha. with an average water depth of 1.5 to 2 m. All ponds were rainfed and well exposed to sunlight.

Study design
The trials for standerdization and popularization of fish farming were conducted in four ponds following the types of fish culture systems as mola with polyculture (T1), mola with pabda (T2), mola with prawn (T3) and only mola (T4).

Pond preparation
Water from selected ponds was completely drained out and embankments of the ponds were repaired. Lime was applied @350 kg ha^{-1} (150 kg ha^{-1}) and cow dung @ 5000 kg ha^{-1} (500 kg ha^{-1}) at monthly interval. Supplementary feed was provided @ 5% body weight in all the treatments except T4 (only mola).

Analysis of water sample of experimental ponds
Physico-chemical parameters of water were recorded between 8.30 to 10 am on monthly basis. Temperature, pH, specific conductivity, transparency, Nitrate-N and phosphate-P, DO and alkalinity were analysed by following standard methods [11].

Stocking and harvesting of fish
Mola were stocked @ 20,000 nos. per ha in all the treatments. *Labeo rohita*, *Catla catla*, *Cirrhinus mrigala* and *Ctenopharyngodon idella* were stocked @ 3000, 2000, 1750, 2500 nos. per ha in T1 respectively; whereas pabda in T2 and fresh water prawn in T3 were stocked @ 10000 nos. per ha and @ 3750 nos. per ha respectively.
Random sampling was done once in a month to collect live fish sample using drag net to monitor the growth and health of fish and prawn. The length and weight were measured and recorded for 20 individuals of each fish/prawn species. After two months of stocking, partial harvesting of only SIF, mola was done. Complete harvest of fish was done at the end of the experiment.

Results and Discussion
The mean values of water quality parameters of different ponds recorded during the study (Table 1) are within desirable range for the fish culture and growth. The value of temperature ranged between 29.67 to 31.1^{0}C in all the treatments. Transparency varied from 28.9 to 36.62 cm in the ponds. Dissolved oxygen varied from 4.9 to 5.98 ppm. pH was slightly alkaline, ranging from 7.69 to 7.85. During the study specific conductivity was recorded as 322.88 to 1367.6 µs/cm. Alkalinity was in the range of 110 to 124 ppm. Oneway ANOVA (Duncan method) showed statistically significant differences ($p < 0.05$) for temperature, transparency, DO, pH, alkalinity and specific conductivity among the treatments (Fig 1, 2, 3, 4, 5, 6).
The growth and production of all species are given in Table 2. The mean stocking weight of mola was 3.2 g in all the treatments. The production of mola was highest in T4 followed by T1 and T2 whereas lowest production was obtained in T3. The mean stocking weight of rohu, catla, mrigal, grass carp were 5.67 g, 7.55 g, 6.60 g and 6.43 g respectively in T1. Mean highest harvesting weight of 459.55±17.42 g was recorded in grass carp followed by catla (438.17±11.97 g), mrigal (312.63±18.30 g) and rohu (281.92±19.02 g.). Survival rate was found moderate to good and specific growth rate was highest in all the species except catla of T1 (Table2). The mean stocking and harvesting weight was 3.47 g and 26.13 g for pabda in T2. The mean individual stocking weight of fresh water prawn (*M. rosenbergii*) was 3.71±0.11 and mean harvesting weight was recorded 90.68±15.34 in T3. Mola showed highest survival in T4 followed T1, T3 and T2 (Table 2).
Total fish production was 2125, 389, 233 and 366 kg/ha from T1, T2, T3 and T4 respectively after six month of culture. The highest production was obtained from T1, where carps were stocked with mola followed by T2 (Mola+ Pabda culture) and T4 (only mola culture) (Table 3). Highest production in T1 was obtained from carp fish grown with mola. Lowest production was obtained in T3 where galda was culture with mola. The lowest mola production was also observed in T3. The economic return from the ponds were calculated as (Rs.33,727, Rs.12,205, Rs.10,063, Rs. 8,418 from T1, T2, T3 and T4 respectively (Table 3). Investment details, input cost and financial returns of each experiment (Table 4) indicated highest benefit and highest benefit cost ratio in T1 followed by T2, T3 and T4.

Table 1: Water Quality Parameters in (mean ±S.D.) different Fish culture trial

Parameters	T1	T2	T3	T4
Temperature (^{0}C)	29.67±0.9	31.1±2.12	30.25±1.4	29.97±1.6
Transparency (cm)	28.9±2.82	35.21±2.13	30.26±13.53	36.62±2.44
Dissolved Oxygen (ppm)	5.98±0.42	5.43±0.16	5.1±0.18	4.9±0.37
pH	7.85±0.12	7.75±0.13	7.69±0.11	7.73±0.08
Alkalinity (ppm)	112±2.25	124±3.26	120±1.69	110±2.54
Conductivity (mµs/cm)	1367.6±25.5	409±40.4	322.88±63.45	434.38±58.33

Table 2: Growth and production under different treatments

Species name	Average weight at stocking (g)	Average weight at harvesting (g)	Survival rate (%)	Specific growth rate (% bw/d)	Production (kg in 0.1 ha)	Total production (kg/0.1 ha)
T1(Mola + Carp culture)						
Mola	3.26±0.22	-	88.9	-	21	
Rohu	5.67±0.12	281.92±19.02	56.8	2.17±0.04	40.8	
Catla	7.55±0.20	438.17±11.97	37.5	2.25±0.06	11.4	212.5
Mrigal	6.60±0.10	312.63±18.30	97.2	2.14±0.03	54.9	
Grass carp	6.43±0.18	459.55±17.42	74	2.36±0.03	84.4	
T2 (Mola+ Pabda culture)						
Mola	3.24±0.23	-	86	-	20.8kg	38.9
Pabda	3.47±0.57	26.13±5.35	69	1.15±0.03	18.1kg	
T3 (Mola+ Fresh water prawn, galda culture)						
Mola	3.28±0.23	-	88.5	-	8.6 kg	23.27
Galda	3.71±0.11	90.68±15.34	44	1.8±0.02	14.67 kg	
T4(Mola culture)						
Mola	3.28±0.23	-	97.8	-	36.57 kg	36.57

Table 3: Production and fish sale under different treatment

Species name	Production (kg in 0.1 ha)	Production (kg in 0.1 ha)	Selling Price (₹/kg)	Fish sale(₹)	Fish sale (₹)	Total cost/Financial returns
T1						
Mola	21	21	230	4830	4830	33727
Rohu	40.8	191.5	200	8160	28898	
Catla	11.4		145	1653		
Mrigal	54.9		137	7521.4		
Grass carp	84.4		137	11563.6		
T2						
Mola	20.8	20.8	230	4784	4784	12205
Pabda	18.1	18.1	410	7421	7421	
T3						
Mola	8.6	8.6	230	1978	1978	10063
Galda	14.7	14.7	550	8085	8085	
T4						
Mola	36.6	36.6	230	8418	8418	8418

Table 4: Cost benefit analysis of fish produce from different treatments (0.1 ha.) (all the value is in Rs.)

Head	T1	T2	T3	T4
Input cost				
Renovation and maintenance of pond	1100	1100	1100	1100
Lime	150	150	150	250
Cow dung	500	500	500	500
Hired Labour	400	400	400	400
Total	2150	2150	2150	2250
Seed	8736	2078	1827	4178
Feed	3600	3040	2480	0
Total	12336	5118	4307	
Total Investment	14486	7268	6457	6428
Financial returns from fish sale				
Gross revenue from fish sale	33727	12205	10063	8418
Benefit (Net revenue)	19242	4937	3606	1852
Benefit Cost ratio	2.3	1.6	1.5	1.3

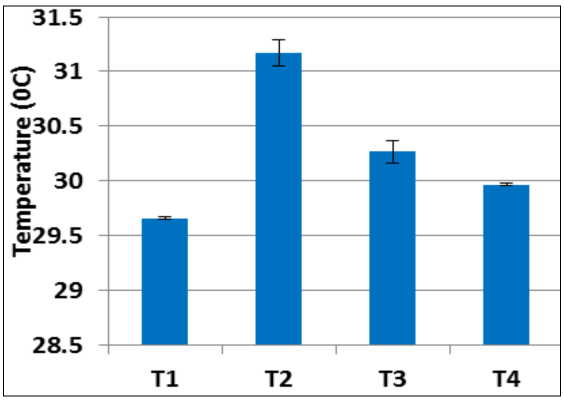

Fig 1: Mean water temperature ±SE in different treatments

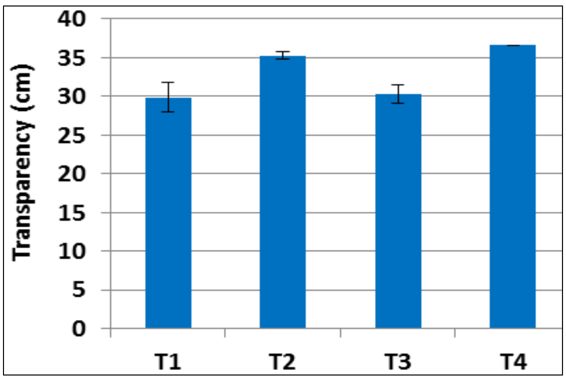

Fig 2: Mean transparency ±SE in different treatments

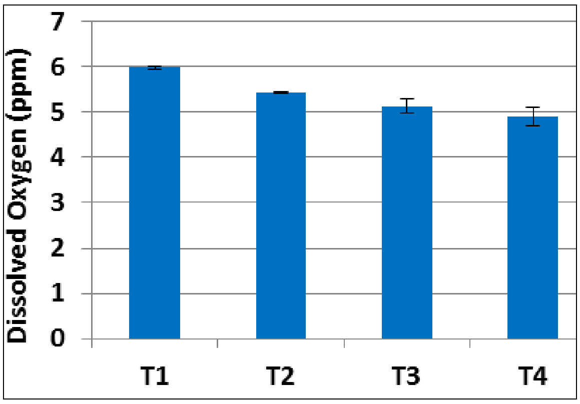

Fig 3: Mean DO±SE in different treatments

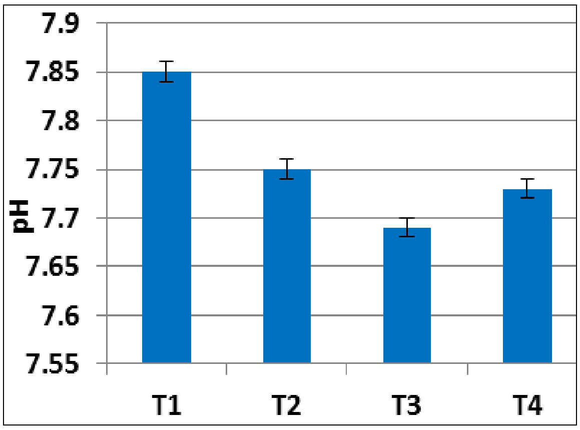

Fig 4: Mean pH±SE in different treatments

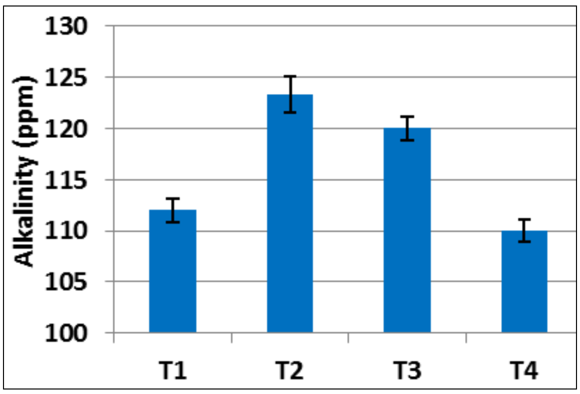

Fig 5: Mean alkalinity ±SE in different treatments

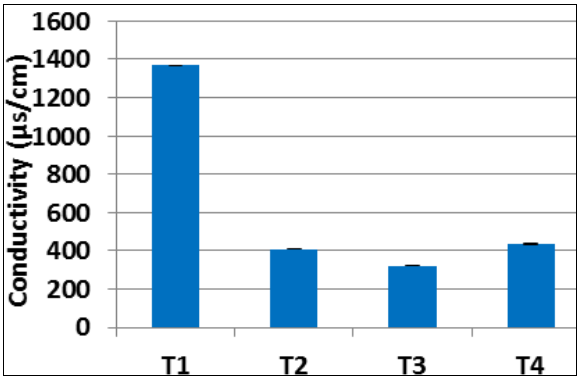

Fig 6: Mean conductivity ±SE in different treatments

Water quality parameter

Management of water quality is one of the important aspect of culture practices for optimum survival and growth of cultured fish species. Monitoring and maintenance of physico-chemical parameters of water play keep pond ecosystem healthy for production of natural fish food organisms [12].In the present study, range of different water parameter like water temperature (29 to 31^{0c}), dissolved oxygen (4.9 to 5.9 ppm), pH (7.69 to 7.85), alkalinity (110 to 124 ppm), specific conductivity (322 to 1367 ms/cm), transparency (28 to 36 cm) recorded among the ponds was found in the suitable range of fish production. For tropical major carp culture, temperature range was found suitable as 28-32^{0}C [13, 14]. Transparency should not be less than 30 cm for fish culture [15] which was quiet similar to present findings. In the present study, pH range was neutral to slightly alkaline which was good for fish health. Different range of pH was reported earlier for fish culture like 7.03 to 9.03 [16], 7.18 to 7.24 [17], 6.5 to 8.5 [18]. Wide range of dissolved oxygen for fish culture was reported by several researchers as 5.10 to 7.15 ppm [19], 4.12 to 6.80 ppm [20], 3.65 to 7.65 ppm [16].The variations in the range of total alkalinity were observed in productive range among the ponds [16]. Transparency indicates the ability of light penetration in water and the range of value was similar with the report by [21]. Secchi disk depth of 30 to 40 cm indicates the productivity level in optimum range in pond for fish culture [19] which is different with present study. Specific conductivity is often used as indicator of chemical nutrient richness for primary production [14]. The desirable range and acceptable range are 100-2,000 µS/cm and 30-5,000 µS /cm recommended for fish culture [22] which supports the present findings.

Growth and production of fish

The total production after six month culture period, from different treatments, shows that highest production was obtained from T1, where carps were stocked with mola. Selection of suitable carp species along with introduction of mola into the culture system may be the cause of enhanced fish production. SIF introduction in carp polyculture [3, 4, 8, 23] not only enhanced the fish production but also improved the livelihood of the practicing fishers. Small indigenous species (SIS) with carp polyculture have increased production, improved economic returns, and secured nutritional well-being for farmers [22, 23]. The growth of catla along with grass carp were recorded comparatively well in T1 than other species. The reason might be less stocking number of species leading to less competition for space availability [24]. Rohu attended slower growth compared to other carps, in T1, due to intra-species competition of space and food [24, 25]. Success of carp-mola polyculture is due to selection of economically prized fish along with mola and less competition among the species for food and space. The production and growth of mola in T4 was also observed excellent as this treatment have only mola without any competition for food and space. Production from T2 was higher than T3. The higher production from T2 was mainly due to more production of mola and more pabda production than mola and galda production in T3. Stocking of pabda with mola give better production due to different feeding habits of mola and pabda which may be competitive for mola nad galda in T3. Culture of Pabda with rajpunti (*Barbonymus gonionotus*) and mirror carp [17] as well as with gulsha (*Mystus cavasius*) [10] were reported earlier. The study recommended that economically prized fish like pabda can be cultured with nutritious SIF like mola without affecting the growth and survival rate. Culture of *galda* (fresh water prawn) with mola is another option for rural people in terms of economic as well as nutritional improvement. Polyculture of galda with IMC was documented by several researchers [26, 27]. The financial gain in term of profit was highest in T1 followed by T2, T3 and T4. The input cost was highest in T1 i.e. carp-mola polyculture followed by pabda-mola, galda-mola and only mola culture. But the benefit cost ratio showed higher benefit in the order of T1 >T2>T3> T4 opposite direction indicating higher return by spending more money as input cost. Net return in terms of economic in carp-mola poly culture system is predominantly influenced by the cost of fingerlings and feed which have been reported previously [8, 28, 29]. Overall the mola-carp culture is remunerative for the fishers due to higher benefit but due to higher input cost marginal fishers may face problem in adopting the culture system. Similarly galda and pabda culture incur more input cost due to feed and seed and have less benefit that may lead to their less adoption by poor fishers. However, mola culture alone can be practiced by marginal and poor fisherfolk having small household ponds. Culture system T1, T2 and T3 can be practiced or adopted by resource rich farmers those who can afford input cost. Major share of input cost in mola culture is seed cost (65%) as this is brought from other's pond may be far off areas that causes a good amount of investment in transportation. As Mola is a self-recruiting species and the fish species covers a minimum of two spawning season in a year [30] within a few cycles of culture in an area, plenty of seed will be available that will reduce the input cost and improve the benefit. Mola culture alone can be popular fish culture practice in the scenario when seed cost can be reduced by supplying seed from nearby ponds. Modified culture system with mola integrated with carp to the level of natural uncompetitive state can be a viable option for improving household income, nutrion and conserving the mola species in local condition and ultimately culture and conservation of SIFs will lead to livelihood and nutritional security of the rural populace of Sundarbans [31].

Conclusion

Carp polyculture with small indigenous fish, mola is a unique culture system for improvement of household income for rural people in term of providing better benefit to cost ratio and ease of management of culture operation in household ponds. Mola with carp culture can ensure micronutrient and vitamin A for household nutrition. Self-recruiting breeding characteristics of mola provides extra edge to rear in small household ponds both for their conservation and livelihood improvement of rural villagers both in normal and extreme climatic conditions of Indian Sundarbans. From this study, it can be suggested that appropriate stocking density and suitable physico-chemical parameters can be encouraging factors for sustainable production and profit maximization. From both the economical and nutritional view of point, carp-mola polyculture is novel approach that can be adopted especially in Indian Sundarban areas for improvement of nutritional and socioeconomic condition of the rural folk. It can also be concluded that the culture system experimented in this study provide multiple options of adoption to varied types of stakeholders based on their investment capacity and benefit accrued.

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