Polyculture of *Osteobrama belangeri* with major carps in pen enclosures in Takmu lake of Manipur

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Abstract: Feasibility of culturing pengba (*Osteobrama belangeri*) as a candidate species in polyculture along with other carps in the net-pen enclosure was studied in Takmu Lake, Manipur. A net-pen measuring 0.1 ha was constructed using a nylon net supported by bamboo poles. The average length and weight of stocked fingerlings (@5 no. m^{-2}) were as follows: pengba (9.4±0.26 cm, 10.6±0.33 g), *Labeo catla* (16.1±0.88 cm, 39.0±2.19 g), *Labeo rohita* (14.8±0.15 cm, 38.6±2.19 g), *Cirrhinus mrigala* (16.2±0.32 cm, 41.9±2.17 g), *Hypophthalmichthys molitrix* (14.2±0.64 cm, 30.3±1.45 g), *Ctenopharyngodon idella* (22.4±0.29 cm, 115.2±4.15 g) and *Cyprinus carpio* (14.8±0.81 cm, 55.1±1.39 g). Fishes were fed with pelleted feed having 23.4% crude protein @ 5% of body weight twice-a-day for 180 days. Highest growth, in terms of weight gain % and specific growth rate, was recorded in pengba followed by *C. idella*, *L. catla*, *C. mrigala*, *L. rohita*, *C. carpio* and *H. molitrix*. The pen aquaculture system was found to be economically viable with a benefit-cost ratio of 1.37. The present study established that net-pen aquaculture of pengba along with other carps is economically viable and technically feasible in floodplain wetlands of Manipur.

Key words: Pen aquaculture; Takmu Lake; Polyculture; *Osteobrama belangeri*, Major carps; Exotic carps

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Introduction

Osteobrama belangeri (Valenciennes, 1844), the State fish of Manipur and locally called "pengba", is a minor carp belonging to the family Cyprinidae and endemic to Manipur of Northeast India. In the past, the species formed a sizeable fishery in the Loktak lake, the largest freshwater lake of Northeast India, contributing about 40% to the natural fishery of Manipur (Behera *et al*., 2009). However, its population has declined significantly over the last few decades and the species is currently listed among the endangered fish species of India and classified as 'extinct in the wild' (CAMP reports, 1998). In a survey conducted by Loktak Development Authority, Manipur, pengba was reported to be found in Loktak lake (Singh, 1999), and later on it was classified as 'near threatened' (IUCN, 2010). Pengba used to migrate from the Chindwin river of Myanmar to the upstream of the Imphal river of Manipur for breeding in floodplains in early monsoon. After construction of Ithai barrage on Imphal river there has been decline of the fishery of this particular fish in Loktak, possibly due to blockade of breeding migration. Another possible contributor to the decline of this fishery was the introduction of common carp in the lake. The fish has been declared as the 'state fish of Manipur' by the Government considering its value in the social and cultural life of Manipuri people and various efforts have been made to revive this pengba fisheries in the state. Trials on induced breeding of *O. belangeri* have been successful (Reddy, 2000; Devi *et al*., 2009; Behera *et al*., 2010, Das *et al*., 2016a) and many farmers in Manipur have started culturing this fish in ponds. However, no study has been conducted to assess the feasibility of this high-value species in pen aquaculture in the

floodplain wetlands of Manipur, where it occurred in the past in good numbers.

Manipur has vast fisheries resources in the form of 24,433 ha beels (wetlands), 4,728 ha derelict waters, 2,142 ha reservoirs and 11,442 ha tanks/ponds and 3360 km rivers/canals as well (DoF-GoI, 2019). The present fish production from these aquatic resources is far below their potential. For example, the present productivity of wetlands of Manipur is estimated at 75 kg ha^{-1} y^{-1} against their potential productivity of 1000 kg ha^{-1} y^{-1} (Das *et al.*, 2017b). Most of the wetlands are heavily weed-choked and are encroached for agriculture and allied activities. Habitat restoration as well as fish stock enhancement following scientific methods are required to increase the productivity of such wetlands. Rational stocking of the wetlands with suitable fish fingerling of 10 cm and above size in adequate numbers (3000-3600 no. ha^{-1}) can increase fish production and livelihood support from these wetlands (Das *et al.*, 2017b). However, major constraints in stocking such waterbodies are non-availability of fingerlings of the desired size in required quantities nearby the sites, high cost of fingerlings, and high mortality associated with long-distance transportation stress. As such, pen aquaculture in these wetlands can be a suitable technological option to increase fish production especially for raising fry to fingerlings for their subsequent release in the wetlands and also for producing table fish wherever feasible. In Assam, *in situ* raising of fingerlings in pens proved to be technologically feasible and economical in the floodplain wetlands of the state (Bhattacharjya *et al.*, 2015; Das *et al.*, 2017a).

The most common species of fish cultured in the Northeast region are the Indian major carps (*Labeo catla*, *Labeo rohita,* and *Cirrhinus mrigala*) and exotic carps (*Cyprinus carpio*, *Hypophthalmichthys molitrix* and *Ctenopharyngodon idella*). Efforts are made from various research and developmental agencies to encourage the culture of indigenous fish species on a wider scale. Pengba is a highly demanded and prized fish in Manipur, and at times consumers are willing to pay any price for this fish. Herbivorous nature of pengba makes it suitable for polyculture. Recently, compatibility of pengba with either *L. rohita* or *L. catla* or three IMCs together was studied in ponds by Das *et al.* (2020). They observed better growth of rohu and catla when pengba was incorporated with either species (at 1:1 ratio to a combined stocking density of 6500 fingerlings ha^{-1}) compared to when rohu and catla were cultured together. They also determined that pengba can be incorporated with all three species of IMCs at 20% level over and above the standard stocking density of 6500 fingerlings ha^{-1} substantially improving biomass yield in major carp polyculture systems. In the present study, our objective was to assess the feasibility of culturing *O. belangeri* along with IMCs and exotic carps in net-pen enclosure in a floodplain wetland of Manipur, India.

Materials and methods

Experimental site

Takmu pat (N 24°30'54" & E 93°47'06"), a part of Loktak lake in Manipur, under the administrative control of the Department of Fisheries, Manipur and with a water-spread area of 500 ha in Bishnupur district of Manipur was selected for the pen culture experiment (Fig. 1). The actual site of pen culture was located in the north-western part of the lake having relatively low water current and protected by the Sendra Island on the south-eastern side and Sendra road on the northern side. The selected site had sandy-loam soil and had moderate macrophyte infestation with free-floating (*Eichhornia crassipes*) and submerged (mainly *Hydrilla* sp.) macrophytes. The site had a gentle gradient with an average depth of 2.5 m.

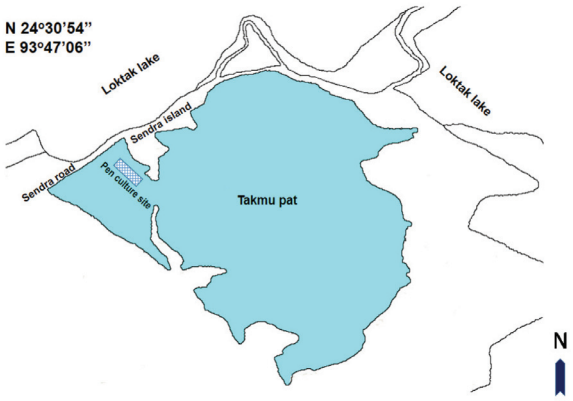

Fig. 1 Map showing the pen culture site at Takmu pat, Bishnupur district, Manipur

Pen construction and preparation

A square-shaped pen of approx. 0.1 ha area (31.62 m × 31.62 m) was constructed in collaboration with the Directorate of Fisheries, Govt. of Manipur. The pen was constructed using a nylon net (25 mm mesh size) with bamboo supports. Whole bamboo poles were fixed to the bottom of the lake along the pre-marked pen area at every 6 m which were supported by 2 smaller bamboo poles from the front and backside forming the letter 'X'. Horizontal support was given by half-split bamboo strips by tying it horizontally to the bamboo poles, one just above the water level and the other 1.5 m above the first one. Nylon net was then tied to the bamboo framework to form the net-pen. The bottom end of the net was held together using a nylon foot rope tied with sinkers (brick pieces) at regular intervals. The sinkers along with the foot rope were driven into the bottom sediment using pointed bamboo barbs to prevent the entry of undesirable aquatic organisms into the pen as well as escapement of cultured fish from the pen. The upper end of the net was tied to the upper horizontal half-split bamboo using twines.

During and after construction, all the floating and most of the submerged aquatic macrophytes in the pen area were removed manually. Then, unwanted aquatic organisms were removed from the pen by repeated netting using a fine-meshed net. Liming was done @ 500 kgha^{-1}and the pen was left undisturbed for 2-3 days for settling before stocking.

Stocking and feeding of fish

The pen was stocked with yearlings of three Indian major carps, viz., *L. catla* (catla), *L. rohita* (rohu) and *C. mrigala* (mrigal), three exotic carps, viz., *Ctenopharyngodon idella* (grass carp), *Hypophthalmichthys molitrix* (silver carp) and *Cyprinus carpio* (common carp) and the minor carp *Osteobrama belangeri* (pengba) obtained from a local fish farm. The pen was stocked @ 5 fingerlings per m^2 with a species ratio of 40% surface feeders (catla and silver) : 20% column feeder (rohu) : 30% bottom feeders (mrigal and common carp) : 10% macrophyte feeders comprising of grass carp and pengba following the observations of Basudha and Vishwanath (1999) so that all the ecological niches were properly occupied and submerged aquatic macrophytes were controlled. The average length and weight of the fish at the time of stocking were: 16.1 cm/ 39.0 g for catla, 14.8 cm/38.6 g for rohu, 16.2 cm/41.9 g for mrigal, 14.8 cm/55.1 g for common carp, 22.4 cm/115.2 g for grass carp, 14.2 cm/30.3 g for silver carp and 9.4 cm/10.6 g for pengba.

The stocked fish were fed with commercially available pelleted feed containing 23.4% crude protein @ 5% of body weight twice-a-day during the morning and afternoon hours. Important water quality parameters governing fish production were analyzed from inside the pen area using standard protocols (APHA, 1992). The range of water quality parameters in the pen was: 23.8-28°C temperature, 85-95 cm Secchi disc visibility, pH 6.6-6.8, 6.5-7.0 mgl^{-1} dissolved oxygen, an undetectable level of free carbon dioxide and total alkalinity of 25-30 mg $CaCO_3$ l^{-1}.

Growth increment, survival and fish production

Fish in pens were sampled at 30 days intervals to monitor their growth and health and also for adjusting feed rations of the fish. Sampling was done by netting and the length and weight of 30 randomly selected fish of each species were measured. The fishes were reared in the pen for 180 days and released in the lake proper for further growth. Growth was estimated by calculating the specific growth rate (SGR) and weight gain percent (WG%). Various response parameters were calculated as follows:

SGR = 100[{ln(FW) – ln(IW)}/experimental period]
WG% =100 [(FW – IW)/ IW]
Survival (%) = (Number of fish harvested/ number of fish stocked) × 100
Fish production (FP) = S × SD × GI
Where, ln = natural logarithm, FW= final weight, IW=initial weight, S =survival rate, SD = stocking density and GI = growth increment.

Proximate composition of feed and fish muscle

The proximate composition of the pelleted feed and fish muscle tissue was analyzed following standard methodologies (AOAC, 1995). Moisture content was determined by drying the samples to constant weight at 100 ^{o}C, crude protein (CP) by Kel Plus (Distyl-EM) (Pelican Equipments, India), lipid by Soxhlet apparatus (Borosil, India) and ash by incineration in a muffle

Table 1 Growth, survival and feed efficiency of seven fish species cultured in net-pen enclosure in Takmu pat for 180 days

Species	Initial length (cm)	Initial weight (g)	Final length (cm)	Final weight (g)	Survival (%)
Labeo rohita	14.78± 0.15	38.6± 2.97	22.83± 0.86	135.56± 10.97	91
Labeo catla	16.10± 0.88	39.00± 1.16	29.93± 1.04	327.14± 32.39	82
Cirrhinus mrigala	16.24± 0.32	41.86± 2.12	25.50± 1.05	181.00± 13.08	70
Hypophthalmichthys molitrix	14.20± 0.64	30.33± 2.42	19.20± 0.71	67.64± 6.77	90
Ctenopharyngodon idella	22.44± 0.29	115.2± 6.42	45.18± 2.48	1020.00± 100.00	95
Cyprinus carpio	14.77± 0.81	55.14± 3.39	22.70± 0.57	160.50± 6.36	86
Osteobrama belangiri	9.44± 0.26	10.60± 0.55	22.93± 0.67	128.00± 5.29	73

Data are presented as mean±standard error; n = 30 for length and weight measurements.

furnace (Nutronics India, India) at 550°C for 6 h. Total carbohydrate was calculated by difference as 100 – (moisture% + CP% + lipid% + ash%).

Economics of pen culture operation

Economics of the pen culture operation was analyzed taking into consideration the costs involved in the construction of the pen (cost of bamboo, net, coir rope, labour, etc.) and operational costs (cost of fish seed, feed, lime, labour costs). Based on past experiences the durability of the bamboo structure was assumed to be two years and a nylon net to be 5 years. In this analysis, 3 fish rearing cycles in 2 years was considered as the fishes were reared for 6 months in the present study and 2-3 months gap can be given in between the cycles for pen installation/ harvesting/ cleaning/ repairing, etc.

Statistical analysis

Simple arithmetic means and standard error of replicate measurements were calculated using MS-Excel 2010 and data are presented as mean±standard error (S.E.).

Results

Fish growth, survival and production

The initial length and weight of the stocked fish, final length and weight after the experimental period of 180 days and survival % are shown in Table 1. Survival of fish ranged from 70% (mrigal) to 95% (grass carp). The change in body weight of the cultured fish during the experimental period is shown in Fig. 2. The highest weight was gained by grass carp, followed by catla, mrigal, common carp, rohu, pengba and silver carp. The growth responses in terms of weight gain (WG %) and specific growth rate (SGR) are shown in Fig. 3a-b. The highest average WG % was recorded for pengba,

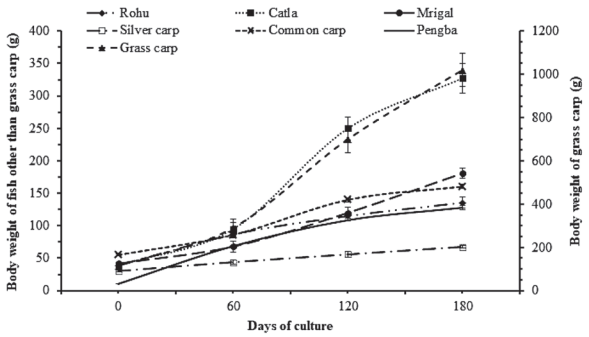

Fig. 2 Change in body weight of the seven fish species cultured in net-pen enclosure in Takmu pat for 180 days

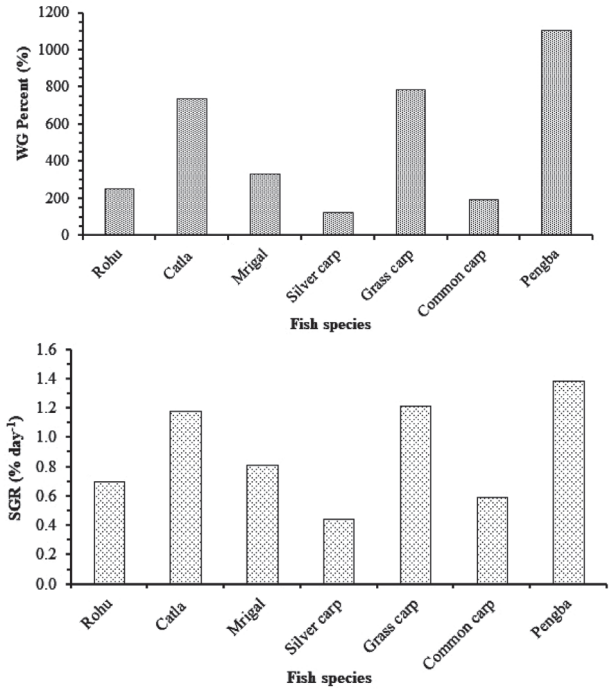

Fig. 3a-b Weight gain percent (WG%) and specific growth rate (SGR) of seven fish species cultured in net-pen enclosure in Takmu pat for 180 days

Table 2 Muscle proximate composition (% wet weight) of seven fish species cultured in net-pen enclosure in Takmu pat at the end of 180 days rearing period

Fish species	Proximate components					
	Moisture	Crude protein	Total fat	Total carbohydrate	Total ash	Digestible energy
Labeo rohita	78.61 ± 0.01	14.15 ± 0.05	2.59 ± 0.01	1.47 ± 0.03	3.38 ± 0.08	85.79 ± 1.64
Labeo catla	78.42 ± 0.54	12.82 ± 0.08	2.70 ± 0.95	2.46 ± 0.08	4.36 ± 0.04	85.42 ± 2.35
Cirrhinus mrigala	77.09 ± 2.29	14.59 ± 0.13	4.56 ± 0.04	1.38 ± 0.11	3.39 ± 0.10	104.92 ± 1.32
Hypophthalmichthysmolitrix	77.73 ± 0.13	15.87 ± 0.04	1.19 ± 0.09	2.65 ± 0.01	1.37 ± 0.05	84.79 ± 2.11
Ctenopharyngodon idella	71.27 ± 1.00	12.96 ± 0.47	2.57 ± 0.28	2.07 ± 0.08	4.41 ± 0.22	83.25 ± 0.98
Cyprinus carpio	79.88 ± 0.13	14.02 ± 0.08	4.09 ± 0.15	2.11 ± 0.08	3.33 ± 0.01	101.33 ± 3.67
Osteobrama belangeri	75.60 ± 1.25	15.15 ± 0.13	3.12 ± 0.26	1.80 ± 0.07	4.33 ± 0.03	95.88 ± 1.95

Data are presented as mean±standard error; n = 3.

Table 3 Economic of culturing of seven fish species in net-pen enclosure in Takmu pat for 180 days

Sl. No.	Particulars	Amount (₹)
1.	Fixed/ Capital costs	
1.1	Cost of bamboo	6,150
1.2	Cost of nylon netting	15,480
1.3	Cost of nylon twines	1,000
1.4	Cost of coir rope	900
1.5	Labour charges for constructing and erecting the pen	11,250
1.6	Total cost for initial construction	34,780
1.7	Cost of repairing the pen for second crop @ 5% of initial construction cost	1,739
1.8	Cost of repairing the pen for third crop @ 10% of initial construction cost	3,478
1.9	Total cost for 2 years (considering life span of bamboo as 2 years and the others as 5 years)	22,819
1.10	Fixed cost per crop	7,606
2.	Recurring cost	
2.1	Cost of fish fingerlings	35,000
2.2	Feed cost	10,400
2.3	Labour charges (for stocking, harvesting, macrophyte control etc.)	6,000
2.4	Charges for watch & ward and feeding for 6 months (@ 2000/ month)	12,000
2.5	Miscellaneous costs (prophylactic agents, boat/ net hiring)	3,170
2.6	Total recurring cost per crop	66,570
3.	Total costs per crop (1.10+2.6)	74,176
4.	Gross revenue	1,01,980
5.	Net Income (4-3)	27,804
6.	Benefit Cost Ratio (BCR)	1.37

followed by grass carp, catla, mrigal, rohu, common carp and lowest weight gain was recorded for silver carp. Similarly, the highest SGR was recorded for pengba (1.38) and the lowest for silver carp (0.45). An estimated fish production of 5713 kg ha^{-1} was obtained after the rearing period of 180 days.

Proximate composition of feed and fish muscle

The proximate composition of the commercial pelleted feed used in the study was: crude protein – 23.4%, total lipid – 6%, total carbohydrate – 37.04%, total ash – 18.4% and moisture – 15.16%. At the end of the rearing period, the muscle proximate composition of the reared fishes was analyzed (Table 2). The moisture content of the fish varied from 71.27 to 79.88%. The highest crude protein content was observed in *H. molitrix* (15.87%), followed by *O. belangeri* (15.15), *C. mrigala* (14.59), *L. rohita* (14.15), *C. carpio* (14.02), *C. idella* (12.96) and *L. catla* (12.82%). Lipid content was measured to be highest in *C. mrigala* (4.56%) and lowest in *H. molitrix* (1.19%). The ash content of the fishes varied from 1.37-4.41%.

Economics of pen culture operation

The economics of pen culture operation was worked out and presented in Table 3. The cost of pen construction was worked out to be ₹34,780. Considering 3 production cycles in 2 years, the cost of pen construction per crop was estimated at ₹7,606. The

total recurring cost per crop was worked out to be ₹ 66,176. Gross income from fish seed rearing in the pen was estimated at ₹1,01,980 year^{-1} with a profit of ₹27,804 year^{-1}. The benefit-cost ratio for a single crop was calculated as 1.37.

Discussion

Breeding and culture of pengba in ponds has been successfully practiced in Manipur during the last few years mainly for its conservation (through ranching) as well as commercial culture of the species (Behera *et al*., 2015). At present, the grow-out culture of pengba is mainly confined to earthen ponds, which caters to the needs of the consumer in Manipur only during the festive season. Hence, pen culture of this fish was demonstrated for the first time in a lake of Manipur. Given the extensive area under floodplain wetlands (*pats*) in the state with low productivity (Behera *et al*. 2009), it is necessary to culture pengba along with other carps in pen enclosures in the *pats* of Manipur with the objective to conserve and reestablish pengba in nature as well as enhancing fish production from these waterbodies. Results of the present study indicated the suitability of polyculture of *O. belangeri* in pen enclosure system. Pengba recorded the highest SGR and WG% and grew from 9.44 g to 128 g in 180 days (Fig. 3a-b). We observed that there was moderate macrophyte infestation (mostly submerged) in the pen area, which must have been effectively utilized by this species and grass carp. This could be associated with improved feed efficiency of pengba and grass carp, both of which are macrophagous in nature. To corroborate the macrophagous nature of the species, dietary incorporation of an aquatic macrophyte, *Azolla* was reported to result in good growth and survival in pengba (Basudha and Vishwanath,1993). However, in pond aquaculture systems, pengba has limitations in terms of poor growth and survival compared to IMCs (Behera *et al*., 2015). The better growth rate of pengba recorded in the present study could be attributed to the natural lake environment as well as the presence of submerged macrophytes in the pen area. The survival rate of 73% observed in the present study was good considering the delicate nature of the fish. Among the IMCs, catla showed better growth performance followed by mrigal and rohu. Silver carp was observed to gain the lowest weight as well as feed efficiency as opposed to our previous study in a beel of Assam, India where this species attained the highest growth in a pen culture demonstration (Bhattacharjya *et al*., 2015). The abundance of the phytoplankton *Microcystis aeroginosa* in the pen area in addition to daily feed supplementation could be one of the reasons for the better growth of silver carp in Assam. Though phytoplankton counts were not done in the present study, earlier studies on the ecology of wetlands of Manipur showed low phytoplankton population in Takmu pat because of luxurious growth of submerged macrophytes (Bhattacharjya *et al*., 2014), which is corroborated by high Secchi disc visibility (0.90-1.1 m) compared to wetlands in Assam where Secchi disc visibility is about 0.5 m.

In the present experiment, an estimated fish production of 5713 kg ha^{-1} was obtained after the rearing period of 180 days. Earlier reports on fish production in pen aquaculture in beels of Assam showed a production level of 1529 kg ha^{-1} (Bhattacharjya *et al*., 2015) and 1943 kg ha^{-1} (Gorai *et al*., 2006) during a rearing period of 70 and 145 days, respectively. Rai and Singh (1990) reported a fish yield of 3362-3962 kg ha^{-1} in six months by rearing advanced fingerlings of IMCs from pens in ox-bow lakes of Bihar, India. Higher fish production recorded in Takmu pat may be due to the use of pelleted feed having more balanced nutrition than a simple mixture of rice bran and mustard oil cake used in other studies. It can also be attributed to the presence of natural food for herbivorous fish in the pen area, stocking of advanced fingerlings as well as longer rearing periods in the present experiment.

The biochemical composition of the stocked fishes at the end of the rearing period was assessed to compare major nutrient contents across the species. The nutritional composition ought to change with species and size of fish, hence showing differences in these qualities is not warranted in the present study. However, it could be stated that no aberration in the nutritional quality of pen-reared fishes was observed if we compare it with pond-reared fishes.

The economics of pen culture operation was calculated and the benefit-cost ratio (BCR) for a single crop was estimated to be 1.37 indicating that the pen culture was

a profitable one. The BCR for rearing IMC fingerlings in pens in wetlands of Assam generally vary from 1.4 to 1.8 (Gorai *et al*., 2006; Bhattacharjya *et al*., 2015; Das *et al*., 2017a) indicating relatively higher profitability of pen culture than other entrepreneurship. In conclusion, *O. belangeri* can be included as a potential candidate species for carp polyculture in net-pen enclosures in wetlands of Manipur considering its good growth performance in the pen as well as high local demand/value of the fish. The study also showed that net-pen aquaculture in wetlands of Manipur was technically feasible as well as economically viable, which could also be used for culturing other fish species having local demand either for rearing them up to advanced fingerling size for their subsequent release into wetland-proper or table fish for market.

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