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Multi-species farming of major and minor carps for enhancing fish production in freshwater aquaculture

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ABSTRACT

An year long experimental multi-species farming of Indian major carps (IMC) and minor carps was conducted with varied stocking densities in 15 earthen ponds (0.08 ha) to develop a suitable farming model. The IMC group included *Catla catla, Labeo rohita* and *Cirrhinus mrigala* at 35:40:25 ratio while minor carp and barb (MCB) group included *Puntius gonionotus, Labeo fimbriatus* and *Puntius sarana* at 40:35:25 ratio. Fingerlings were stocked in five density combinations (treatments) as: T1 - IMC at 8000 ha^{-1}, T2 - IMC at 8000 ha^{-1} + MCB at 4000 ha^{-1}, T3 - IMC at 4000 ha^{-1} + MCB at 4000 ha^{-1}, T4 - IMC at 4000 ha^{-1} + MCB at 8000 ha^{-1} and T5 - MCB at 16000 ha^{-1}. Survival of all species in both groups showed inverse relation with their stocked densities. T4 with IMC and MCB at 4,000 and 8,000 fingerlings ha^{-1}, respectively, formed the ideal density with 28.8 and 76.0% higher yield realisation compared to T1 with only IMC and T5 with only MCB group, respectively. All multispecies treatments having MCB group as major component yielded higher fish biomass than those with IMC group. Such results indicated potential of multispecies farming system to increase production in seasonal ponds and water bodies retaining lower water level.

Keywords: Barb, Grow-out, Major carp, Minor carp, Species diversification

Introduction

Farming of the three Indian major carps (IMC), *viz*., catla (*Catla catla* Hamilton), rohu (*Labeo rohita* Hamilton), mrigal (*Cirrhinus mrigala* Hamilton) and the three exotic carps *viz.,* silver carp (*Hypophthalmichthys molitrix* Valenciennes), grass carp (*Ctenopharyngodon idella* Valenciennes) and common carp (*Cyprinus carpio* Linnaeus) under composite culture system is in vogue in the south Asian countries. Such farming system produces more biomass compared to monoculture of any of these species. In India, above mentioned carp species contribute more than 80% of the annual aquaculture production. Production level as high as 17.5 t ha^{-1} has been reported from composite culture of these species (Tripathi *et al.,* 2000). Increasing the species spectrum in carp farming has shown to enhance fish productivity of the system in other Asian countries including China, Vietnam and Bangladesh. However, apart from the three exotic carps, inclusion of other species into the IMC based composite culture system has been limited to only few, such as magur (*Clarius batrachus* Linnaeus), Asian catfish (*Pangasionodon hypophthalmus* Sauvage), freshwater prawn (*Macrobrachium rosenbergii* De Man; *Macrobrachium malcolmsonii* Milne-Edwards) and small indigenous fish species, often resulting in yield enhancement (New, 2002; Kohinoor *et al.*, 2005; Hossain and Islam 2006; Jana *et al.,* 2007; Jasmine *et al.,* 2011).

In India, necessity of inclusion of more promising species into the freshwater aquaculture systems has been emphasised long ago. There are many minor carp species available in the natural waters of India which have culture potential and regional importance which command high consumer preference. Being categorised as local fish by the consumers, these minor carps also command 20-30% higher market price than the Indian major carps depending on the regional demand. Attempts are made to diversify the major carp based composite culture systems by changing the composition incorporating minor carps. Minor carps such as kalbasu (*Labeo calbasu* Hamilton), fringe-lipped carp (*Labeo fimbriatus* Bloch), kuria labeo (*Labeo gonius* Hamilton), bata (*Labeo bata* Hamilton), reba (*Cirrhinus reba* Hamilton) and barbs such as silver barb (*Puntius gonionotus* Bleeker) and olive barb (*Puntius sarana* Hamilton) have shown promising results in terms of compatibility with major carps and possibility of increasing the biomass yield (Haque *et al.,*1998; Sahu *et al.,* 2007; Jena *et al.,* 2007, 2008; Jena and Das, 2011). Most of the studies, however, have been restricted to inclusion of one or two of these species in the major carp system at a time. Based on the assumption that fish yield is likely to increase in the multi-species production system with inclusion of more number of species, an attempt was made in the present study to culture two groups, *i.e.,* the Indian major carps (IMC) group and the minor carps-barbs

(MCB) group, together at varied stocking densities to identify a suitable multi-species carps and barbs farming model based on the evaluation of their yield potential.

Materials and methods

The multi-species grow-out trial was conducted for a period of one year in 15 earthen ponds of 0.08 ha^{-1} area each, in the farm of the ICAR-Central Institute of Freshwater Aquaculture (ICAR-CIFA), Bhubaneswar. The IMC group included catla, rohu and mrigal at 35:40:25 species ratio while the minor carp and barb (MCB) group included silver barb, fringe-lipped carp and olive barb at at 40:35:25 ratio. Fingerlings of these two groups were stocked in five density combinations (treatments) as: T1- IMC at 8000 ha^{-1}, T2 - IMC at 8000 ha^{-1} + MCB at 4000 ha^{-1}, T3 - IMC at 4000 ha^{-1} + MCB at 4000 ha^{-1}, T4 - IMC at 4000 ha^{-1} + MCB at 8000 ha^{-1} and T5 - MCB at 16000 ha^{-1}. Each treatment had three replications. Ponds were filled up to 1.2 m water depth. After the pre-stocking pond preparation as per Jena *et al*. (2009), fingerlings of all these species, raised in the ICAR-CIFA farm, were stocked in the ponds as per the required species ratio and stocking density. Commercial extruded floating feed pellets (28% protein, ABIS Gold 28-3, IB Group, India) were fed to the fish during morning hours at 6 and 4% of the estimated biomass per day during first and second month, respectively, followed by 2-1 % in the subsequent months.

Water quality in the ponds was monitored at monthly intervals. Sampling was done during 08.00 - 09.00 hrs. Temperature, pH (Orion 2 star pH Bench top) and dissolved oxygen (DO) (Orion 5 star DO portable, Thermo Electronic Corporation, USA) of water were measured *in situ*. Total alkalinity, total hardness and inorganic nutrients, *viz*., total ammonical nitrogen (TAN), nitrite-nitrogen (NO_2-N) and phosphate-phosphorus (PO_4-P) of water samples were estimated following standard methods (APHA, 1998) using a UV-VIS spectrophotometer (UV1 Spectrophotometer, Thermo-Electronic model). Liming and fertilizations were carried out in ponds as per requirement based on the observed water quality. Fish sampling was carried out at monthly intervals to assess growth and health condition. The water depth in the ponds varied between 1.0-1.2 m during most part of culture excepting brief period (1.5 m) during rainy season.

The data on water quality parameters and fish yield parameters such as growth, survival and biomass production were statistically analysed using PC-SAS program for Windows, release v6.12 (SAS Institute, Cary, NC, USA). Duncan's multiple range tests was used to compare the value of parameters among the treatments.

Results and discussion

The water quality parameters such as DO, pH, alkalinity and hardness did not show much variations in the treatments or experimental ponds irrespective of the season (Fig. 1 a-g), which could be attributed to the periodic liming and fertilization measures adopted during the experimental culture as per standardised protocol of carps pond management. Although there were seasonal variations of the nutrients, the levels of TAN, nitrite and phosphorus were low and were mostly within the tolerable limits as reported for carps (Tripathi *et al.* 2000; Jena *et al.,* 2002; Sahu *et al.,* 2007). Such values of the parameters indicated prevalence of suitable growing environment for the species during the study period.

The survival of catla, rohu and mrigal remained higher in T3 and T4 when the IMC density was 4000 ha^{-1}, but the same reduced in T1 and T2, obviously due to the higher stocking density (8000 ha^{-1}) (Table 1). Similarly in the MCB group, survival of fringe-lipped carp and olive barb were affected with increased density in T4 and T5 as compared to T2 and T3. In contrast, silver barb showed a consistent higher survival of 71.6-78.9% irrespective of the varying stocking density in treatments. Further, average body weight of silver barb during the culture period was not only higher among the MCB species in all treatments, but also was comparable to that of catla in all the multi-species treatments (Fig. 2 a-e) indicating greater potential of this species for inclusion in the multi-species farming.

All the three major carps *viz*., catla, rohu and mrigal recorded highest harvested mean body weight (HBW) in T1 (Table 1), which could be attributed to efficient utilisation of respective niche (surface, column and bottom respectively). But in presence of MCB group in T2, T3 and T4, catla showed lower HBW indicating probable interference from silver barb, the other surface feeder in the system. Though Jena *et al.* (2007) have reported compatibility of silver barb with catla, probably the observed aggressive feeding behaviour of the former towards floating pellet ensured its primary access to supplementary feed, there by affecting growth of the later in these treatments. In fact, silver barb exhibited almost comparable growth as that of catla in T2 and T3. However, HBW of this species in T4 and T5 were much lower which could be attributed to the increased intra-specific competition owing to higher stocking densities (>2 - 4 times) in all these treatments.

The HBW of all the coloumn/bottom dwellers, *viz.*, rohu, mrigal, fringe-lipped carp and olive barb in T2 and T4 were lower than those of T3, with the only exception of olive barb having higher HBW in T2

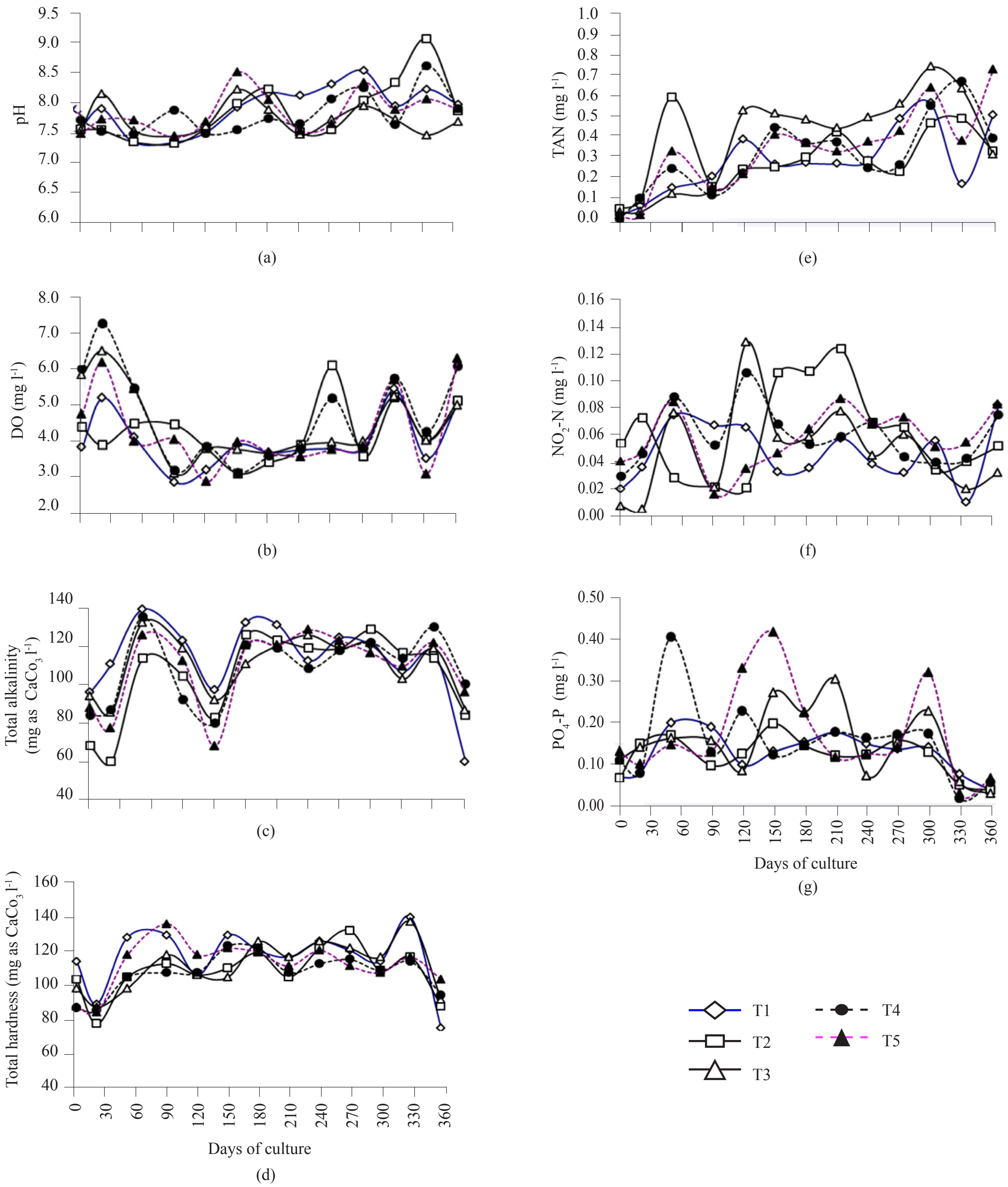

Fig. 1. Water quality parameters during the multi-species farming of major and minor carps. (a) p^H, (b) Dissolved oxygen (DO), (c) Total alkalinity, (d) Total hardness, (e) Total ammoniacal nitrogen (TAN)

(Table 1). The results indicate that increase in stocking density (2 times) of rohu and mrigal in T2 and of fringe-lipped carp and olive barb in T4 led to increase in intra-specific competition, which in turn affected the growth of all these coloumn/bottom dwellers. Further, HBW was found to be more in fringe-lipped carp and olive barb in T4 than that of rohu and mrigal in T2 indicating greater intra-specific competition arising out of the higher (2 times) stocking density in the respective treatments.

In polyculture systems, rohu generally shows better growth than mrigal. In contrast, in the present study, mrigal registered higher growth than rohu in all the treatments. Presence of mrigal in fewer numbers (25% of IMC) compared to rohu (40% of IMC) could be a valid explanation for higher HBW of the former. Non-availability of a good water coloumn (little above 1 m in most part of the year except in the rainy season) (Jhingran 1991; Rahman *et al.,* 2008) and inter-specific competition from silver barb (Haque *et al.,* 1998, Jena *et al.,* 2007) might have also affected performance of the latter. Iinfluence of olive barb on growth of rohu could be put to a lower level, since the inter-specific competition between them does not affect former's growth significantly (Jena *et al.,* 2008). Growth of fringe-lipped carp was the lowest in all species treatments and was severely affected in T5. Fringe-lipped carp is reported to be compatible with catla and rohu with certain level of competition from mrigal (Jena *et al.,* 2015) and significant ($p<0.05$) reduction in its growth in T5 may be attributed to higher density, and strong inter-specific competition for supplementary feed, from silver barb.

The net biomass production differed significantly among the treatments ($p<0.05$) (Table 1). Treatment T4 having MCB group as the major component (8000 fingerlings ha^{-1}) registered the highest biomass followed by T3, T2 and T1, while T5 with only MCB group yielded the lowest (Fig. 3). Despite having same density (8000 fingerlings ha^{-1}), the total yield of IMC group in T2 was 38% lower than T1, which could be attributed to their inter-specific competition from additional stock of MCB

Table 1. Stocking and harvesting details of the major carps and minor carp/barbs in the multi-species model

Treatment	Species	Survival (%)	Harvest body weight (g)	Net weight gain (g)	Net production (kg ha^{-1})	FCR
T1	Catla	67.6±4.2	710.7±62.4	639.7±60.5	*1141.0±51.3*	
*IMC at 8000 ha^{-1}	Rohu	46.9±5.4	475.1±20.5	441.8±19.5	603.9±55.1	
	Mrigal	54.4±5.0	577.6±12.8	558.3±12.8	588.8±44.1	
	Average	*56.3±2.7^d*	*587.8±23.5^a*	*546.6±23.0^a*	*2333.7±38.2^c*	*2.61±0.18*
T2	Catla	49.6±2.4	670.7±17.7	584.5±4.3	688.4±59.1	
*IMC at 8000 ha^{-1}	Rohu	40.1±2.3	347.3±31.3	312.8±29.4	333.9±30.4	
+	Mrigal	55.0±2.3	420.8±15.3	401.5±15.3	424.3±23.1	
# MCB at 4000 ha^{-1}	Silver barb	71.6±3.2	645.4±9.4	588.5±18.5	648.7±36.6	
	Fringe-lipped carp	71.1±5.8	171.2±11.8	147.1±12.5	136.1±3.1	
	Olive barb	74.6±5.6	272.2±10.7	252.5±10.7	183.5±21.7	
	Average	*60.3±0.6^c*	*421.3±11.0^c*	*381.1±10.9^c*	*2414.8±123.7^c*	*2.65±0.43*
T-3	Catla	78.9±4.6	674.6±26.3	631.5±26.3	683.6±21.9	
*IMC at 4000 ha^{-1}	Rohu	87.2±4.7	429.5±1.6	411.5±1.5	570.7±30.4	
+	Mrigal	63.3±5.1	541.6±21.9	522.3±21.9	323.1±16.2	
# MCB at 4000 ha^{-1}	Silver barb	70.3±5.5	651.6±7.9	611.1±18.4	667.8±35.3	
	Fringe-lipped carp	86.9±4.6	232.1±11.5	216.9±13.0	261.3±23.3	
	Olive barb	70.4±6.3	205.7±12.6	186.0±12.6	124.6±4.9	
	Average	*76.2±0.1^a*	*455.8±9.0^b*	*429.9±9.8^b*	*2631.1±44.8^b*	*2.44±0.21*
T-4	Catla	73.8±2.2	665.4±21.5	618.3±16.6	621.9±34.0	
*IMC at 4000 ha^{-1}	Rohu	80.7±3.2	367.5±21.3	349.5±21.4	446.5±45.1	
+	Mrigal	91.3±5.0	358.3±18.5	339.0±18.5	307.9±28.3	
# MCB at 8000 ha^{-1}	Silver barb	81.9±4.1	543.1±35.1	506.0±39.2	1301.7±45.0	
	Fringe-lipped carp	45.1±3.4	159.3±5.6	144.3±4.0	159.1±20.3	
	Olive barb	56.0±4.4	186.0±16.6	166.3±16.6	168.1±6.4	
	Average	*71.5±2.5^b*	*379.9±5.1^d*	*353.9±4.6^d*	*3005.3±59.7^a*	*2.34±0.26*
T-5	Silver barb	75.3±1.8	364.2±13.8	315.6±6.6	1444.2±54.4	
# MCB at 16000 h^{-1}	Fringe-lipped carp	52.2±1.6	73.2±6.5	61.2±7.3	146.1±18.1	
	Olive barb	38.6±2.5	127.2±8.1	107.5±8.1	117.4±11.7	
	Average	*55.4±0.7^d*	*188.2±6.6^e*	*161.4±3.8^e*	*1707.7±45.6^d*	*2.86±0.14*

Values (Mean ±SD) in a coloumn having different superscripts differ significantly ($p<0.05$, n=3)
*Species composition of IMC group - catla -35%, rohu - 40%, mrigal -25% ; # Composition of MCB group - Silver barb - 40%, fringe-lipped carp - 35%, Olive barb - 25%

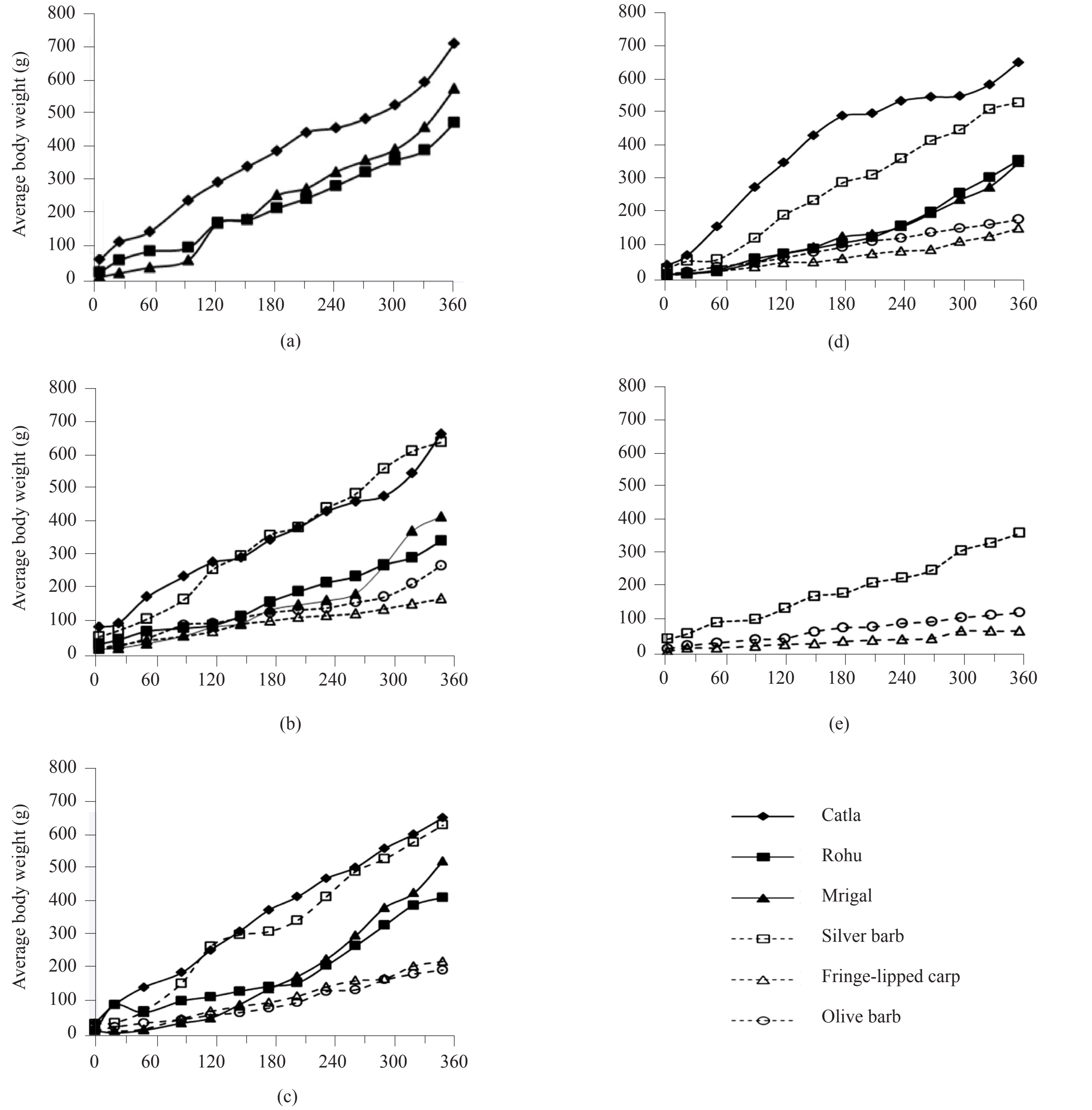

Fig. 2. Growth curve of different species during the multi-species grow-out culture in different treatments (a) Treatment 1, (b) Treatment 2, (c) Treatment 3, (d) Treatment 4, (e) Treatment 5

group. But when density of IMC was reduced to half (4000 no. ha^{-1}) and MCB group kept unchanged in T3, the reduced intra-specific competition led to 9% increase in IMC yield than T2. Further, there was only 13% reduction in IMC yield in T4 compared to T3, despite greater inter-specific competition from MCB group stocked in T4. Such results of insignificant variations of IMC yield among T2 to T4, irrespective of variation in the MCB density, indicated that 4000 no. ha^{-1} was the ideal density for IMC group in such multi-species carp farming systems. In case of MCB group, both T2 and T3 were stocked at 4000 no. ha^{-1}, but the latter showed 8.7% higher yield of the group, again indicating the reduced inter-specific competition due to reduced density (half density) of IMC group. However, unlike the IMC group which showed yield reduction with increased density in T2 compared to T3, the MCB group showed 68.2 and 54.6% enhanced yield with doubling of their density in T4 compared to the respective yields of the group in T2 and T3. Though production of the MCB group further increased in T5 with increased density

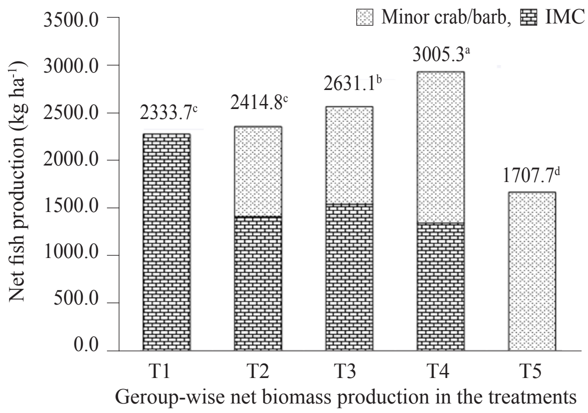

Fig. 3. Net biomass production of IMC and MCB in grow-out culture

(16000 no. ha^{-1}), the total yield was significantly lower among the treatments which proves that this density is not ideal for recommendation. The above results indicate that stocking at 8000 no. ha^{-1} is more ideal for the MCB group in the multi-species carp farming system. In the present study, T4 yielded the highest total production ($p<0.05$) among the treatments, indicating, stocking densities @ 4000 and 8000 fingerlings ha^{-1} for IMC and MCB groups respectively, as ideal for recommendation in multi-species carp farming system.

Fig. 4 represents the relative variation in net biomass production in various treatments compared to the treatments having only major carps (T1) or only minor carp-barbs (T5). Treatments stocked with both the groups registered 3.5-28.8% and 41.4-76.0% higher production respectively, compared to those having only the IMC or the MCB groups. This results clearly indicated that fish production can be enhanced through increasing the species spectrum in multi-species culture systems. Further, the production went on increasing as the density of IMC group decreased (T2<T3<T4) and that of MCB group increased. In other words, the multi-species carp-barb system with minor carp and barbs as the major component

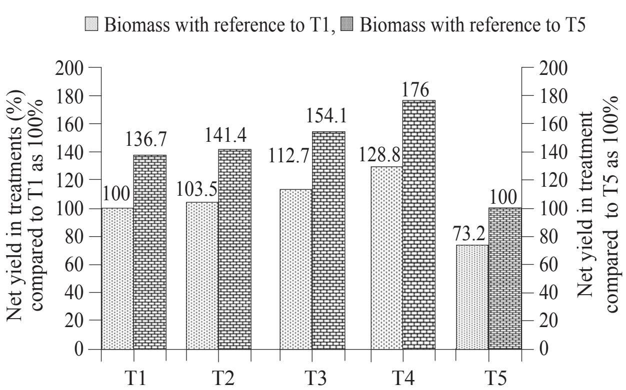

Fig. 4. Relative fish biomass production with varied density and species composition under multi-species farming (n=3)

yielded higher fish production compared to the system with major carps alone/or as the major component. Minor carps and barbs can thrive and grow better compared to the major carps in pond with low water level. Thus, the multi-species model with minor carp and barb as major component can ensure more effective utilisation of such water bodies with low water levels, thereby increasing productivity. Further, the density and species composition as used in T4 can be taken up as model for short term crop in the seasonal ponds which form considerable part of our culture resources.

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