Indian Journal of Animal Sciences **91** (2): 159–164, February 2021/Article
https://doi.org/10.56093/ijans.v91i2.113834

Evaluation of stocking density for pond aquaculture with special reference to survival and production in Tiruchirapalli, Tamil Nadu

PAWAN KUMAR SHARMA[1✉], J STEPHEN SAMPATH KUMAR[2] and D MANIKANDAVELU[3]

Tamil Nadu Dr J. Jayalalithaa Fisheries University, Thanjavur, Tamil Nadu 614 904 India

Received: 23 May 2021; Accepted: 12 July 2021

ABSTRACT

The present study was conducted to optimize the stocking density for pond fish culture. For this purpose, two different stoking densities, i.e. 18000 (T1) and 7600 per hectare (T2) were tested using earthen ponds of 0.25 ha size. Both ponds were stocked uniformly with 4 carp species, viz. *Catla catla, Labeo rohita, Cirrhinus mrigala,* and *Cyprinus carpio* in equal proportions and fed on commercial pellet feed (20% crude protein). The estimated gross production was found higher in pond T2 (4166 kg/ha) than that of T1 (4000 kg/ha). The T2 pond showed a net estimated additional yield of 187.76 kg/ha, which was 4.74% higher than that of T1 pond. A higher survival rate was observed in T2 (59.17%) than that of T1 (27.68%), which was statically significant. Further, the ADG (average daily growth) rate of fishes in T2 was 0.70 kg/ha/day higher than that of T1. The study revealed that there is an inverse relation between the stocking density of fishes and production rate. Considering the growth/production rate and survival in present study, a seed stocking density of 7600 per ha is recommended for farm pond aquaculture.

Keywords: Farm ponds, Gross biomass production, Stocking density, Survival rate

The fish production has steadily increased over last few decades and contribution from aquaculture to total fish production has risen to more than 35%. Inland sector contributes biggest part of the production. It is again dominated by inland aquaculture. The rapid growth and higher productivity from inland aquaculture sector is an outcome of quality inputs and more importantly the advancement in polyculture techniques. In aquaculture, increasing stocking density is one of the solutions for increasing per unit higher production. Variation in stocking density of fish may change growth and survival rates. Fish have a slow growth and low survival rates at high density. Several studies have investigated the effects of stocking density on different farmed species growth (Hasan *et al.* 2010, M'balaka *et al.* 2012, Ramadan and Ahmed 2012, Apu *et al.* 2012). Fish survival, growth rate, feeding behaviour, health, water quality, and total production are directly influenced by the stocking density (Oliveira *et al.* 2012). Both positive and negative relationships between stocking density and growth have been reported and the pattern of this interaction is species specific (Rahman and Marimuthu 2010). A number of factors affect the optimal stocking rate in a culture system such as the size of fish, type and level of nutrient inputs, culture period, rate of water exchange, and possibility of aeration. Stocking rate directly affects the final production from a culture system (Holliday *et al.* 1993, Tidwell and Webster 1993, Tidwell *et al.* 1994, Brown *et al.* 1995, Mgaya and Mercer 1995). Therefore attention and care are needed while adopting the technology.

The rate of rearing density is further decided based on the expected growth increment of individual fish and survival level in production systems. Rearing at higher densities not only results in higher production but also minimises the total land requirement and water usage. The high rearing density, however, may exert adverse effects on growth and survival. Therefore, it is necessary to predetermine and standardise the optimum rearing density for each farming system in order to obtain the best possible output. In view of this, the present study was conducted to standardize the stocking density for pond fish culture in Tamil Nadu state of India. The main aim of this study was to understand the growth and survival fish, at different rearing densities.

MATERIALS AND METHODS

To assess the impact of stoking density on fish growth and survival, an experiment was conducted during 5 December 2018 to 5 September 2019. This experiment was conducted in two earthen farm ponds in delta district Tiruchirappalli (Latitude 10.775632 N and Longitude 78.692360 E) of Tamil Nadu, India. Both the ponds were of uniform size (0.25 ha), and feature-wise similar in every respect like shape (rectangle – 42 m × 60 m), water depth

Present address: [1]Ministry of Fisheries, Animal Husbandry and Dairying, Govt. of India, New Delhi; [2]Directorate of Sustainable Aquaculture, Thanjavur, Tamil Nadu; [3]Fisheries College and Research Institute, Ponneri, Tamil Nadu. ✉Corresponding author email: pawan@tnfu.ac.in

(1.5 m) and pond topography. These ponds were stocked uniformly with four carp species, viz. *Catla catla, Labeo rohita, Cirrhinus mrigala* and *Cyprinus carpio* of uniform seed size (5–6 cm) in equal proportions. Stocking density in one pond was kept at a level of 18,000/ha (T1) while in another it was 7,600/ha (T2). Thus the stocked seed/fish were fed on commercial pellet feeding having 20% CP (crude protein). The feeding rate was 5–6% of total biomass for the 1st month and 3–4% for the subsequent months at fixed time every day (10:00 AM and 05:00 PM). One week before stocking, the selected ponds were treated with lime @ 60 kg/0.25 ha, kerosene @ 38 litre/0.25 ha, and cow dung @ 2,500 kg/0.25 ha.

Before stocking, the initial length and initial weight of each fingerling were recorded. In the experimental systems, selected water quality parameter (i.e. temperature, TDS, pH, alkalinity, dissolved oxygen, total nitrogen, total phosphorus, total potassium and gross primary productivity) were monitored on the initial day and subsequently at an interval of one month following APHA (2005). At the end of experimental period, the weight of fish from each experimental pond was recorded using an electronic weighing balance. On the basis of initial and final weight and survival data, the fish growth performance parameters (i.e. survival percentage, net weight gain, net biomass production, etc.) were generated, which were calculated following standard methods of Biswas (1992). The harvested weight of individual species was recorded along with their survival rate and total biomass. The recorded data were statistically analysed using the Graphpad prism software (Version 6.1).

RESULTS AND DISCUSSION

The data recorded for selected water quality parameters and fish growth/production survial rate are presented in Tables 1–5. In the present study, the stocking level had not affected the water quality parameters. As such the levels of selected water quality parameters such as water temperature, pH, dissolved oxygen, etc. remained more or less same except alkalinity and TDS (Table 1). In T1 pond, the mean values of water quality parameters like temperature, TDS, pH, alkalinity and dissolved oxygen were 31.63±3.37°C, 0.825±0.08 ppt, 8.013±0.19, 191.58±10.86 mg/l and 4.36±0.47 mg/l, respectively. In T2, these values were 31.87±3.22°C, 0.680±0.06 ppt, 8.136±0.20 mg/l, 221.68±15.76 mg/l, 4.21±0.51 mg/l, respectively (Table 1).

The mean values of pond water fertility factors like total nitrogen, phosphorus, potassium and GPP (Gross Primary Productivity) were 1.80±0.04 mg/l, 0.29±0.02 mg/l, 1.36±0.02 mg/l and 0.61±0.01 g C/m^3/h, respectively in T1; while in T2 these were 1.53±0.06 mg/l, 0.29±0.04 mg/l, 1.17±0.035 mg/l and 0.59±0.02 g C/m^3/h (Table 1). It could be observed that there was dissimilarity in the total nitrogen and potassium between the two treatments, which are statistically significant (P<0.05) (Table 5). The statistical analysis revealed no significant difference between water temperature, *p*H, dissolved oxygen, total phosphorus and GPP during the culture period while TDS and alkalinity were found significantly different (P<0.05) (Table 5).

The data related to species wise contribution and the difference in net biomass production are depicted in Table 3. Initial mean biomass in T1 and T2 were 10.24 kg and 4.32 kg respectively (Table 3). After a culture period of 270 days, 999.98 (T1) and 1041 (T2) biomass was harvested. As such, a net surplus production of 41.02 kg in T2 as compared to T1. It is worth mentioning here that the highest (1,041 kg) gross biomass produced was in T2 pond where the stocking density was lower (7,600/ha) than that of T1 (18,000 ha).

The growth of rohu and catla was higher in T1 pond as compared to T2. In net biomass were 7.07% higher for rohu and 4.24% higher for catla than that of T2. The growth of mrigal and common carp was higher in T2 as compared to T1. As such, the net biomass of mrigal was 7.64% higher than common carp (3.68%) in T2 as compared to T1 (Table 3). In total biomass production, the highest contribution was from mrigal in T2 (364.18 kg) which accounted 35.02% of total biomass production. In T1, rohu accounted for 29.71% (296.59 kg) in total net biomass (Table 3). The maximum mean body weight was gained (1.296±0.135 kg-T2) by the *C. mrigala*, while the minimum mean body weight was gained by the *C. catla* (0.627±0.059 kg) in T2 (Table 2).

The estimated net biomass production of the fishes was 187.76 kg/ha higher in T2 than that of T1. The net production level was estimated to be 4.74% higher in T2 than that of T1 (Table 4). The average daily growth rate was 4.77% (0.70 kg/ha/day) higher in T2 than that of T1 (Table 4). In the case of production parameters species wise mean initial biomass of the fishes (kg), mean survived fishes (numbers) and mean survival rate of fishes (%) were found significantly different (P<0.05) (Table 5).

The results of the present investigation (Tables 1–5) have revealed a significant impact of stocking density on fish survival and growth. However, no significant impact on water quality was visible. On comparing the values of

Table 1. Average values of selected physico-chemical parameters and fertility factors

Treatment	Physico-chemical parameters (Mean±SD)					Fertility factors (Mean±SD)			
	Temperature (°C)	TDS (PPT)	pH	Alkalinity (mg/l)	DO (mg/l)	Total nitrogen (mg/l)	Total phosphorus (mg/l)	Total potassium (mg/l)	GPP (g C/m^3/h)
T1	31.63±3.37	0.825±0.08	8.103±0.19	191.58±10.86	4.36±0.47	1.80±0.04	0.29±0.02	1.36±0.02	0.61±0.01
T2	31.87±3.22	0.680±0.06	8.136±0.20	221.68±15.76	4.21±0.51	1.53±0.06	0.29±0.04	1.17±0.035	0.59±0.02

Table 2. Species wise growth and biomass harvested from the experimental farm ponds

Species stocked	Mean final body weight of fishes (kg)		Harvested weight of fishes (kg)	
	T1	T2	T1	T2
L. rohita	0.907±0.177	0.839±0.099	296.589	235.759
C. catla	0.692±0.123	0.627±0.059	208.292	172.425
C. mrigala	0.827±0.096	1.296±0.135	273.737	364.176
C. carpio	0.733±0.159	0.956±0.090	221.366	268.636

different water quality parameters in both the treatments, obviously the levels of dissolved oxygen, *p*H, and temperature remained more or less the same. On the other hand, alkalinity and TDS showed significantly different levels in both the ponds (Table 1). Still the observed water quality parameters in both the treatments remained within the congenial levels for good aquaculture (Keshavanath and Radhakrishnan 1990). The variations in fish growth and survival could be due to rearing densities and not the water quality.

The effect of stocking density on survival and growth of early life stages of different fish species has been the focus of research for many years. The relationship between stocking density, survival, growth and FCR has been reported to be positive (Papst *et al*. 1992), negative (Hengsawat *et al*. 1997), density independent (Fairchild and Howell, 2001) or dependent on different experimental density ranges. Rearing density might vary as a function of behavioural adjustments, food availability and water quality. However, the mechanisms linking rearing density and growth are not fully understood, but it is generally accepted that when water quality is not affected by the increased number of fish per cubic meter and sufficient food is provided, differences in growth performances could be attributed to the onset of hierarchies and dominant relationship (Bolasina *et al*. 2006).

During the course of the experiment, the TDS (total dissolved solids) ranging from 0.680±0.06 to 0.825±0.08 ppt. (Table 1), was found suitable as per the recommendation of Ehiagbon and Ogunrinde (2010), where the suggested suitable range is 22–960 mg/l. The variation in the range of TDS may be due to the use of supplementary feeds (Ogbeibu and Victor 1989). The fertility factors of pond water, like nitrogen ranged from 1.53±0.06 to 1.80±0.04 mg/l, phosphorus ranged from 0.29±0.02 to 0.29±0.04 mg/l, potassium ranged from 1.17±0.035 to 1.36±0.02 mg/l (Table 1). All of these components were found to be suitable and productive for the fish culture pond, as suggested by Adhikari *et al.* (2017) that the level of phosphorus between 0.05 to 0.20 mg/l, and above 0.20 mg/l, may be indicative of medium to high, and highly productive fish ponds respectively. The values of nitrogen and potassium were found to be suitable and well supported by Ayyappan (2013). Gross primary productivity ranging from 0.59±0.02 to 0.61±0.01 g C/m^3/h (Table 1) is also considered suitable, as suggested by Santosh and Singh (2007) that the value of good productivity is between 1000–2500 mg C/m^3/day. There were much variations in TDS and alkalinity (Table 1) which are statistically significant also ($P<0.05$) (Table 5). This variation could be attributed to the variation in the stocking density. Statistical significance could be seen in total nitrogen and total potassium ($P<0.05$) (Table 5). These variations between treatments could not be attributed to any single factor as during the culture process, there might be more than one factor that would intervene and impact the soil water interaction. However, it could be concluded that the stocking density of 7,600/ha did not create any negative situation in the pond, rather it supported the system with higher fertility and conducive condition for the fishes.

In the present experiment, lower stocking density (T2: 7,600/ha) in farm pond aquaculture has led to an additional

Table 3. Fish biomass production parameters in the experimental farm ponds

Species	Initial biomass (kg)		Final biomass (kg)		% In total final biomass		Net biomass produced (kg)		% in total net biomass	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
L. rohita	2.55	1.08	296.59	235.76	29.66	22.64	294.04	234.68	29.71	22.64
C. catla	2.78	1.17	208.29	172.43	20.83	16.56	205.51	171.26	20.76	16.52
C. mrigala	2.76	1.16	273.74	364.18	27.37	34.98	270.98	363.02	27.38	35.02
C. carpio	2.15	0.91	221.37	268.64	22.14	25.81	219.22	267.73	22.15	25.83
Total	10.24	4.32	999.98	1041.00	100.00	100.00	989.74	1036.68	100.00	100.00

Table 4. Estimated production parameters in the experimental farm ponds

Treatment	Stocking density/ha	Mean survival rate (%)	Estimated gross production (kg/ha)	Net biomass produced (kg)	Estimated net biomass production (kg/ha)	Average daily growth rate (kg/ha/day)	Difference in net biomass among treatments	
							kg/ha	%
T1	18000	27.68	4000	989.74	3958.96	14.66	187.76	4.74
T2	7600	59.17	4166	1036.68	4146.72	15.36		

production up to 4.47%. This can be compared to the findings of Glenewinkel (2007) who compared two stocking densities for channel catfish production in earthen ponds and observed that high-density ponds experienced water quality problems compared to the low-density ponds, which could have affected the production in the higher density. There was significant difference (P<0.05) in the survival rate and the number of fishes survived (Table 5). The highest survival was in T2 pond (59.17%) than T1 (27.68%) (Table 4), further confirming the advantage of lower density and the finding of different authors like Uddin *et al.* (2002), Glenewinkel (2007), Cruz and Ridha (1991) and Prithwiraj and Sudip (2005) supported well. The experiment of Akinwole *et al.* (2014) also could be compared with the present finding, where effects of higher stocking density resulted in more competition for food, space and stress, leading to reduced production. Supporting results were earlier found by Oliveira (2012) also, where it was concluded that fish survival, growth rate, feeding behaviour, health, water quality, and total production are directly influenced by the stocking density (Oliveira 2012). The total estimated production of farm pond stocked with 7,600/ha stocking density (4,166 kg/ha) (Table 4), was found in line with the findings of Jhingran and Sharma (1980) and Sin (1980) where a polyculture experimental crop yielded up to 3,600–4,000 kg/ha/year.

The mean survival rate of fishes was higher in T2 pond stocked with 7,600/ha than the T1 pond which is in line with the findings of Narejo *et al.* (2005), who observed higher survival at lower densities and concluded that availability of more space and food for the fishes could have helped in reaching higher survival. The findings of Tibile *et al*. (2016) also could be cited as an evidence of lower survival with increasing stocking density. Lower density favoured suitable water quality and less competition whereas incidence of mortality at higher densities (Cruz and Ridha 1991,Vera and Mair 1994, Barton and Iwama 1991, Akinwole *et al.* 2014 and Ronald *et al.* 2014). The supportive results were earlier found by Prithwiraj and Sudip (2005) where survival rate of koi carps was inversely related to stocking density and experiments with other fish species can also support the reduced survival rate with increased stocking density (Shelton *et al.* 1981, Degani 1993, Stone *et al.* 2003). The findings of Kaiser *et al.* (1995) also could be reason for higher survival at lower density, as low stocking rates could have led to reduced aggression between fish and improve survival rates. The findings of Hasan *et al.* (2010) also supports the results as they studied effects of stocking density on growth and production and concluded that survival rate was found to be negatively influenced by different stocking densities due to high competition for food and space among the fishes.

Faster growth (1.296±0.135 kg) and more production of *C. mrigala* (364.18 kg) (Tables 2 and 3) are similar to the findings of Verma (2018) who recorded the highest growth for *C. mrigala* (172.42% higher) in a semi intensive carp production. Although no specific reasons could be attributed for the higher growth of *C. mrigala* and poor growth of *C. catla* (0.627±0.059), there can be further research in this line to investigate the interaction of the species ratio, selection, combination and other pond water quality parameters.

Generally in farm pond aquaculture, the stocking density recommended by Ayyappan (2013) had been followed with 5,000–10,000 fingerlings of 100 mm size per hectare. Accordingly in the present trial, the stocking density had been choosen to be 7,600/ha and this was found safe with a stocking ratio of 1:1:1:1 while the enhanced stocking density 18000/ha was found unsuitable due to the lower

Table 5. Statistical analysis of fish growth and water quality parameters

Parameter	Treatment		
	T1	T2	P value
Temperature	2.28±0.26^a	2.28±0.26^a	0.5000
Mean initial biomass of the fishes species wise (kg)	2.56±0.29^a	1.08±0.12^b	<0.0001
Mean final body weight of individual fish at harvest (kg)	0.789±0.10^a	0.929±0.279^a	0.191
Mean body weight of fishes at harvest (kg)	250±42.01^a	260.24±79.97^a	0.414
Mean survived fishes (Nos)	315±15.97^a	279±3.5^b	0.0023
Mean survival rate (%)	27.68±1.42^a	59.17±0.63^b	<0.0001
Average net growth rate of the individual species (kg/ha/day)	3.67±0.62^a	3.84±1.18^a	0.4018
Temp. (°C)	31.63±3.37^a	31.87±3.22^a	0.4409
TDS (PPT)	0.825±0.08^a	0.680±0.06^b	0.0016
pH	8.103±0.19^a	8.136±0.20^a	0.4089
Alkalinity (mg/l)	191.58±10.86^a	221.68±15.76^b	0.0003
D.O. (mg/l)	4.36±0.47^a	4.21±0.51^a	0.2710
Total nitrogen (mg/l)	1.80±0.04^a	1.53±0.06^b	0.0196
Total phosphorus (mg/l)	0.29±0.02^a	0.29±0.04^a	0.500
Total potassium (mg/l)	1.36±0.02^a	1.17±0.035^b	0.0103
GPP (g C/m^3/h)	0.61±0.01^a	0.59±0.02^a	0.2031

Note: The treatment values with different superscripts indicate significant differences (P<0.05) determined by unpaired one tailed t test.

survival rate of the fishes which may be due to lower size of fishes stocked (5–6 cm), but stocking with advanced fingerling size seed (10 cm to 15 cm) may be useful for the enhanced stocking density as higher mortality noticed with the lower size seed stocking.

The findings of the present study indicated that the four species (*C. catla, L. rohita, C. mrigala,* and *C. carpio*) combination with 7,600/ha stocking density in equal proportions are better than the 18,000/ha. As during the experiment *C. mrigala* and *C. carpio* has shown the higher growth, further trials are recommended with higher stocking ratio of bottom feeders to achieve the enhanced yield. However, some more trials with different stocking densities between 7,600/ha and 18,000/ha are recommended with advanced fingerling size seed (10 cm to 15 cm). The study concluded that the stocking of advanced fingerling size seed @ 7,600 Nos/ha and better management practices can be useful to enhance the production level with higher stocking density.

ACKNOWLEDGEMENTS

We are grateful to all the farmers of Tiruchirappalli district for providing their farm ponds for the purpose of this experiment. We are thankful to Mr. Senthil Kumar, Assistant Director; Mr. Palani, Fisheries Inspector and other supporting staff of Fisheries Department, Tiruchirappalli, for their assistance and collaboration during the entire course of this experiment. We are also thankful to the Administration of Tamil Nadu Dr J. Jayalalithaa Fisheries University for providing the Systematic Research Fund of the Tamil Nadu- Irrigated Agricultural Modernization Project (financed by World Bank), laboratories and technical support.

REFERENCES

Adhikari S, Chakrabarti P P, Paul B N and Sundaray J K. 2017. Training manual on "Nutrient management in fish culture with emphasis on soil health and carbon budget management" (11–15 December, 2017). ICAR- Central Institute of Freshwater Aquaculture, RRC, Rahara, Kolkata, West Bengal, India. pp. 1–140.

Akinwole A O, Bankole A F, Dauda A B and Saliu O E. 2014. Growth and survival of *Clarias gariepinus* (*Burchell 1822*) fingerlings cultured at different stocking densities in Igboora, Oyo State, Nigeria. *Journal of Agriculture and Biodiversity Research* **3**(4): 58–60.

APHA. 2005. Standard Methods for the Examination of Water and Wastewater. 21st Edition, American Public Health Association/American Water Works Association/Water Environment Federation, Washington DC.

Apu J K, Rahman M S and Rashid H. 2012. Effects of fish population densities on growth and production of fishes. *Progressive Agriculture* **23**(1 and 2): 63–73.

Ayyappan S. 2013. Management of soil and water quality, Carp culture. Handbook of Aquaculture, Directorate of Knowledge Management in Agriculture, Indian Council of Agricultural Research, New Delhi. chapter 16, 396 p.

Barton B A and Iwama G K. 1991. Physiological changes in fish from stress in aquaculture with emphasis on the response and effects of corticosteroids. *Annual Review of Fish Diseases* **10**: 3–26.

Biswas S P. 1992. *Manual of Methods in Fish Biology*. South Asian Publishers, Delhi, 157 pp.

Bolasina S N, Masatomo T, Yamashita Y and Tanaka M. 2006. Effect of stocking density on growth, digestive enzyme activity and cortisol level in larvae and juveniles of Japanese flounder, *Paralichthys olivaceus*. *Aquaculture* **259**(1): 432–43.

Brown P B, Wilson K A and Wetzel J E and Hoene B. 1995. Increased densities result in reduced weight gain of crayfish *Orconetes virilis*. *Journal of the World Aquaculture Society* **26**: 165–71.

Cruz E and Ridha M. 1991. Production of the tilapia, *Oreochromiss pilurus* (Gunther) stocked at different densities in sea cages. *Aquaculture* **99**: 95–103.

De Oliveira E G, Pinheiro A B, de Oliveira V Q, da Silva A R M, de Moraes M G, Rocha Í R C B, de Sousa R R and Costa F H F. 2012. Effects of stocking density on the performance of juvenile pirarucu (*Arapaima gigas*) in cages. *Aquaculture* **370–371**: 96–101.

Degani G. 1993. Growth and body composition of juveniles of *Pterophyllum scalare* (*Liechtenstein*) (Pisces: Cichlidae) at different densities and diets. *Aquaculture and Fisheries Management* **24**: 725–30.

Ehiagbon J E and Ogunrinde Y O. 2010. Physico-chemical analysis of fish pond water in Okada and its environs Nigeria. *African Journal of Biotechnology* **9**(36): 5922–28.

Fairchild E A and Howell W H. 2001. Optimal stocking density for juvenile winter flounder (*Pseudopleuronectes americanus*). *Journal of World Aquaculture Society* **32**(3): 300–308.

Glenewinkel H. 2007. Comparison of two stocking densities for channel catfish production in earthen ponds, management data series no. 245, 2007, Texas Parks and Wildlife Department Inland Fisheries Division 4200 Smith School Road Austin, Texas 78744.

GraphPad Prism version 6.04 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com.

Hasan S J, Mian S, Rashid A H A and Rahmatullah S M. 2010. Effects of stocking density on growth and production of GIFT (*Oreochromis niloticus*) *Bangladesh. Journal of Fisheries Research* **14**(1–2): 45–53.

Hengsawat K, Ward F J and Jaruartjamorn P. 1997. The effect of stocking density on yield, growth and mortality of African catfish (*Clarias gariepinus* Burchell, 1822) cultured in cages. *Aquaculture* **152**(1–4): 67–76.

Holliday J E, Allan G L and Nell J A. 1993. Effects of stocking density on juvenile Sydney rock oysters, *Saccostrea commercialis* (Iredale and Roughley), in cylinders. *Aquaculture* **109**: 13–26.

Jhingran V G and Sharma B K. 1980. Integrated livestock fish farming in India. *Integrated Agriculture Aquaculture Farming Systems*. (Eds) R S V Pullin and Z H Shehadeh. ICLARM Conf. Proc. 4, pp. 225–38.

Kaiser H, Weyl O and Thomas H. 1995. The effect of stocking density on growth, survival and agonistic behaviour of African catfish. *Aquaculture International* **3**: 217–25.

Keshavanath P and Radhakrishnan K V. 1990. Carp seed production technology. Asian Fisheries Society, Indian Branch, Special, 94.

M'balaka M, Kassam D A and Rusuwa B. 2012. The effect of stocking density on the growth and survival of improved and unimproved strains of *Oreochromiss hiranus*. *Egyptian*

Journal of Aquatic Research, National Institute of Oceanography and Fisheries, http://ees.elsevier.com/ejar.

Mgaya Y D and Mercer J P. 1995. The effects of size grading and stocking density on growth performance of juvenile abalone, *Haliotis tuberculata* Linnaeus. *Aquaculture* **136**: 297–312.

Narejo N T, Salam M A, Sabur M A and Rahmatullah S M. 2005. Effect of stocking density on growth and survival of indigenous catfish, *Heteropneustes fossilis* (*Bloch*) reared in cemented cisterns fed on formulated feed. *Pakistan Journal of Zoology* **37**(1): 49–52.

Ogbeibu A E and Victor R. 1989. The effects of road and bridge construction on the bank root marcroin vertebrates of a Southern Nigerian stream. *Environmental Pollution* **56**: 85–100.

Papst M H, Dick T A, Arnason A N and Engel C E. 1992. Effect of rearing density on the early growth and variation in growth of juvenile Arctic charr, *Salvelinusal pinus* (L.). *Aquaculture Research* **23**(1): 41–47.

Prithwiraj J and Sudip B. 2005. The effect of stocking density on growth, survival rate, and number of marketable fish produced of Koi carps, *Cyprinus carpiovr. koi* in concrete tanks. *Journal of Applied Aquaculture* **17**: 89–102.

Rahman A M and Marimuthu K. 2010. Effect of different stocking density on growth, survival and production of endangered native fish climbing perch (*Anabas testudineus*, Bloch) fingerlings in nursery ponds. *Advances in Environmental Biology* **4**(2): 178–86.

Ramadan M, Abou-Zied Ahmed and A A Ali. 2012. Effect of stocking density in intensive fish culture system on growth performance, feed utilization and economic productivity of nile tilapia (*Oreochromis niloticus L.*) Reared in hapas, *Abbassa. Int. J. Aqua.* **5**(1): 487–99.

Ronald N, Gladys B and Gasper E. 2014. The effects of stocking density on the growth and survival of Nile tilapia (*Oreochromis niloticus*) fry at Son fish farm, Uganda. *Aquaculture Research and Development* **5**(2): 1–7.

Santosh B and Singh N P. 2007. Guidelines for water quality management for fish culture in Tripura, ICAR Research Complex for NEH Region Tripura Center, Lembucherra 799 210 Tripura west.

Shelton W L, Smitherman R O and Jensen G L. 1981. Density related growth of grass carp, *Ctenopharyngodon idella* (*Val.*) in managed small impoundments in Alabama. *Journal of Fish Biology* **18**: 45–51.

Sin A W. 1980. Integrated animal fish husbandry systems in Hong Kong, with case studies on duck-fish and goose-fish systems. (Eds) R S V Pullin and Z H Shehadeh. Integrated Agriculture-Aquaculture Farming Systems. ICLARM Conf. Proc., 4, pp. 113–123.

Stone N E, McNulty and Park E. 2003. The effect of stocking and feeding rates on growth and production of feeder goldfish in pools. *North American Journal of Aquaculture* **65**: 82–90.

Tibile R M, Sawant P M, Chadha N K, Lakra W S, Chandra P, Swain S and Kaustubh B. 2016. Effect of stocking density on growth, size variation, condition index and survival of discus, *Symphysodon aequifasciatus Pellegrin,* 1904. *Turkish Journal of Fisheries and Aquatic Sciences* **16**: 453–60.

Tidwell J H and C D Webster. 1993. Effect of stocking density and dietary protein on green sunfish (*Lepomis cyanellus*) × bluegill (*L. macrochirus*) hybrids overwintered in ponds. *Aquaculture* **113**: 83–89.

Tidwell J H, Webster C D, Clark J A and Brunson M W. 1994. Pond culture of female green sunfish (*Lepomis cyanellus*) × male bluegill (*L. macrochirus*) hybrids stocked at two sizes and densities. *Aquaculture* **126**: 305–13.

Vera C E M and Mair G C. 1994. Conditions for effective androgen sex reversal in *Oreochromis niloticus* (*L.*). *Aquaculture* **112**: 137–248.

Verma R. 2018. Study of average growth performance and condition factor of fish (Indian Major Carps) in the sub pond of the Gawala Talab, Maheshwar, Khargone (MP), *International Journal of Zoology Studies* **3**(2): 342–46.