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REVIEW PAPER OPEN ACCESS

Effect of stocking density on fish growth and feed conversion ratio: A review

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Abstract

Stocking density is defined as the weight of fish per unit volume of water. Large number of species in any limited space can cause stress or another change in fish physiology. Stress caused by high stocking density would ultimately affects rate of growth, survival, behavior, yield, reproduction and water quality. It is concluded that high stocking density decreased the fish biomass as well as fish length and weight. As the fish stocking density is higher than their specific limit it will automatically cause disturbance in relation to the water quality parameters due to less space and no removal of waste materials has been held which causes diseases or mortality. High stocking density not only affect the growth of fish it also has bad impact on the feed conversion ratio (FCR). FCR also decreased by increasing the stocking density and it also depends on the different type of feed given to the fish. Low stocking density show better FCR. Fish grow properly at optimum stocking density. As stocking density vary from species to species, before stocking any species one must figure out the optimum stocking density to obtain beneficial results. High stocking density is an efficient way to get the high yield if properly controlled. High yield will be obtained at the optimum range.

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Introduction

Stocking density

The total number of the fishes initially stocked per unit area is called as "Stocking density" (El-Sayed, 2006). Stocking density is an efficient way to find out the yield of a pond or any area where fish is being stocked (El-Sayed, 2006). Along with many others factors stocking density is also cause of stress in fish which is harmful for fish health. One of the pivotal factor affecting fish welfare is stocking density, particularly when there is a high density in a restricted space to aim for high productivity. Even though hardly defined, stocking density is the term normally used to refer to the weight of fish per unit volume or per unit volume in unit time of water flow (Ellis, 2002).

At the fingerlings or juveniles stage of fish, production was maximum at high stocking density (HSD). While in case of adult fish, yield was low at high stocking density. High production is attained at optimum stocking which vary from species to species. Stocking density has major influence on fish such as their growth, survival and production (Herrera, 2014).

Inappropriate stocking density have negative impact on fish health so to attain better yield stocking density must be at optimum level (Ellis, 2002). Stocking density is maintained at high level to obtain maximum commercial output. HSD causes conquest of growth due to competitive consumption of feed, bad water quality and altered hematology and metabolic conditions (Papoutsoglou *et al.*, 2006; Zhang *et al*, 2008; Lupatsch *et al.*, 2010; Tolussi *et al*, 2010; Faggio *et al*, 2014; Fazio *et al.*, 2014). High stocking density is a major cause of stress in fishes as it directly affects the energy demands causing reduction in size, growth and food consumption (Rahman *et al.*, 2008; Rahman and Verdegem, 2010).

Effect of stocking density

Growth

For best aquaculture practice, stocking density should be optimum for each species. This optimum density is calculated for each species by considering environmental and economic gains (Holm *et al.,* 1990; Kuipers and Summerfelt, 1994; Szkudlarek and Zakes, 2002). Optimum stocking density values vary from species to species as some are adapted to high density conditions but few species cannot adjust to it.

Table 1. Optimum stocking density for different fish species.

Species	Optimum stocking density	Reference
Pterophyllumscalare	0.4 fish/L	Degani, 1993
Xiphophorushelleri	0.4 fish/L	Mondal *et al.*, 2004
Trichogastertrichopterus	0.5 fish/L	Cole *et al.*, 1997
Cyprinus carpio	0.25 fish/L	Asano *et al.*, 2003

Different species have different ways to respond stress and high stocking density. In a study, Thai Climbing perch (*Anabas testudineus*) shows higher growth rate when the stocking density is low in a pond but not efficient growth was noticed on high stocking density (Rahman *et al.*, 2012). While Nile Tilapia (*Oreochromis niloticus*) shows low growth rate in high stocking density and high growth rate at optimum density (El-Sayed, 2002). Effect of population can be either density dependent or density independent. Experiment on Nile tilapia showed the negative correlation between stocking density and fish growth (Ronald *et al.,* 2014). Stocking density have negative impact on fish growth in density dependent method. Not only growth but fish length and weight is also effected by High stocking density (HSD). Reduced growth of*Bryconcephalus*larvae and fingerling was observed by increasing the stocking density as space is reduced which cause stress (Gomes *et al.*, 2000). Study on *O. niloticus* and *Oreochromis aureus* also showed the similar results that fish growth reduced in case of HSD (Table 2) that coincides with the previous findings (Al- Harbi and Siddique, 2000).

Table 2. Effect of different stocking density on different species.

Serial No.	Species	Stocking density	Results	Conclusion	Reference
1	*Sander lucioperca*	25 and 100 larvae L^{-1}	2.7-1.9 mg day^{-1}	Negative	Szkudlarek and Zakęś, 2007
2	*Sander lucioperca*	6 and 15 larvae L^{-1}	28.8 to 23.1 mg day−1	Positive	Szkudlarek and Zakęś, 2007
3	Oncorhynchus mykiss	10 kg m^{-3}	Increase in size	positive	North *et al.*, 2006
4	Oncorhynchus mykiss	80 kg m^{-3}	Fin erosion	Negative	North *et al.*, 2006
5	*Clariasbatrachus*	1000 m^{-2}	High growth	Positive	Sahoo *et al.*, 2004
6	*Clariasbatrachus*	5000 m^{-2}	Low growth	Negative	Sahoo *et al.*, 2004
7	*Oreochromis niloticus*	1000	93	Positive	Ronald *et al.*, 2014
8	*Oreochromis niloticus*	1330	95	Positive	Ronald *et al.*, 2014
9	*Oreochromis niloticus*	2000	92.1	Positive	Ronald *et al.*, 2014
10	*Oreochromis niloticus*	2670	96.9	Negative	Ronald *et al.*, 2014
11	*Oreochromis niloticus*	4000	87	Negative	Ronald *et al.*, 2014
12	*Oreochromis niloticus*	5330	82.8	Negative	Ronald *et al.*, 2014
13	*Oreochromis niloticus*	125 kg/decimal	87	Positive	Rahman *et al.*, 2016
14	*Oreochromis niloticus*	250 kg/decimal	76	Positive	Rahman *et al.*, 2016
15	*Oreochromis niloticus*	375 kg/decimal	69	Negative	Rahman *et al.*, 2016
16	*Scophthalmus maximus*	0.7 kg/m^2	-	Positive	Irwin *et al.*, 1999
17	*Scophthalmus maximus*	1.1 kg/m^2	-	Positive	Irwin *et al.*, 1999
18	*Scophthalmus maximus*	1.5 kg/m^2	-	Negative	Irwin *et al.*, 1999
19	*Scophthalmus maximus*	1.8 kg/m^2	-	Negative	Irwin *et al.*, 1999
20	*Oreochromis aureus*	1 kg m^{-3}	-	Positive	Al-Harbi and Siddiqui, 2000
21	*Oreochromis aureus*	5 kg m^{-3}	-	Positive	Al-Harbi and Siddiqui, 2000
22	*Oreochromis aureus*	10 kg m^{-3}	-	Negative	Al-Harbi and Siddiqui, 2000
23	*Oreochromis aureus*	15 kg m^{-3}	-	Negative	Al-Harbi and Siddiqui, 2000

(Szkudlarek and Zakes, 2007) analyzed the effect of stocking density at very initial stage of Pikeperch *Sander lucioperca*. He concluded that the rate of survival and growth increased by increasing initial stocking density. North *et al.* (2006) worked on the welfare of farmed fish by keeping three stocking density 10, 40 and 80 kg m^{-3} for nine months. Among all three stocking densities the best results were obtained at stocking density of 10 kg m^{-3}. While HSD causes disease which includes fin erosion. Major studies carried on rainbow trout has negative impact of high stocking density on fish growth (Ellis, 2002). Sahoo*et al.* (2004) explained the effect of high stocking density on *Clariasbatrachus* on their growth and survival. By increasing stocking density, weight and specific growth rate was decreased. Best results were obtained at the stocking density of 1000 m^{-2} as compared to 5000m^{-2}.

Table 3. Data of koi carps, *Cyprinus carpio* reared in concrete tanks at different stocking densities after 90 days trial period.

??	LSD	HSD	Difference	Result	Conclusion
Harvest weight (g)	7.42±0.05	3.48±0.05	3.94	-	Decrease in harvest weight due to HSD
Weight gain (g)	7.28±0.05	3.34±0.05	3.94	-	Decrease in weight gain due to HSD
SGR (%/day)	4.38±0.03	3.54±0.03	0.84	-	Decrease in SGR due to HSD
Survival rate (%)	93.36±0.89	62.43±0.15	30.93	-	Mortality rate increases in HSD
Feed conversion ratio	1.82±0.02	2.88±0.03	-1.06	+	FCR increases in HSD
pH	7.05±0.04	6.33±0.09	0.72	-	Medium becomes acidic due to ions
Dissolved oxygen (DO) (mg/L)	6.57±0.15	4.82±0.26	1.75	-	DO decreased in HSD
Free CO_2 (mg/L)	5.03±0.18	6.81±0.31	-1.78	+	Value increased in HSD
HCO_3_ alkalinity (mg/L)	35.14±0.77	53.69±3.02	-18.55	+	Sharp increase in HCO_3
NO_3^- - N (mg/L)	0.105±0.006	0.263±0.020	-0.158	+	Nitrate ions increased in HSD
NO_2^- - N	0.019±0.001	0.034±0.003	-0.015	+	Nitrite ions increased
NH_4^+ - N (mg/L)	0.145±0.005	0.432±0.037	-0.287	+	Ammonium ions increased in HSD
PO_4^{-3} - P (mg/L)	0.152±0.011	0.342±0.024	-0.19	+	Phosphates increased in HSD
Specific conductance (mmhos/cm)	0.22±0.002	0.37±0.018	-0.15	+	Value increased

A study was conducted by Jha and Barat (2005) in order to examine the effect of HSD on various parameters by conducting a 90-day trial on Common Carp, *Cyprinus carpio* in concrete tanks. These fishes were divided into 5 group which were formed on the basis of stocking density varying from high stocking density (HSD) to low stocking density (LSD). This variation in stocking density influenced several other parameters, in most cases negatively while in some cases it does not have any effect.

Table 4. Feed conversion ratio at different feeding level in different species.

Species	Feeding level	Survival rate	FCR	References
Oreochromis niloticus	10	61	1.27	El-Sayed, 2002
Oreochromis niloticus	20	86	1.98	El-Sayed, 2002
Oreochromis niloticus	25	85	2.13	El-Sayed, 2002
Oreochromis niloticus	30	87	2.20	El-Sayed, 2002
Oreochromis niloticus	35	82	2.98	El-Sayed, 2002
Himribarbel fry	2.5	97	1.41	Jokcek and Tepe, 2009
Himribarbel fry	5.0	100	1.43	Jokcek and Tepe, 2009
Himribarbel fry	7.5	95	2.48	Jokcek and Tepe, 2009
Himribarbel fry	10.5	88	3.20	Jokcek and Tepe, 2009

So, it can be concluded that increasing the stocking density have both positive and negative impact on different parameters. Considering the main outputs such as harvest weight, weight gain, specific growth rate, dissolved oxygen (DO) and survival rate, HSD has negative impact on them as their values decline as compared to LSD. While in some cases HSD is also the reason in increase of some factors such as feed conversion ratio, free CO_2, HCO_3, NO_3^-, NO_2^-, NH_4^+, PO_4^{3-} and specific conductance. Increase in the nitrogenous compounds and ions is due to the increase in metabolic waste as fish density is increased which simultaneously decrease DO that is not beneficial for fish.

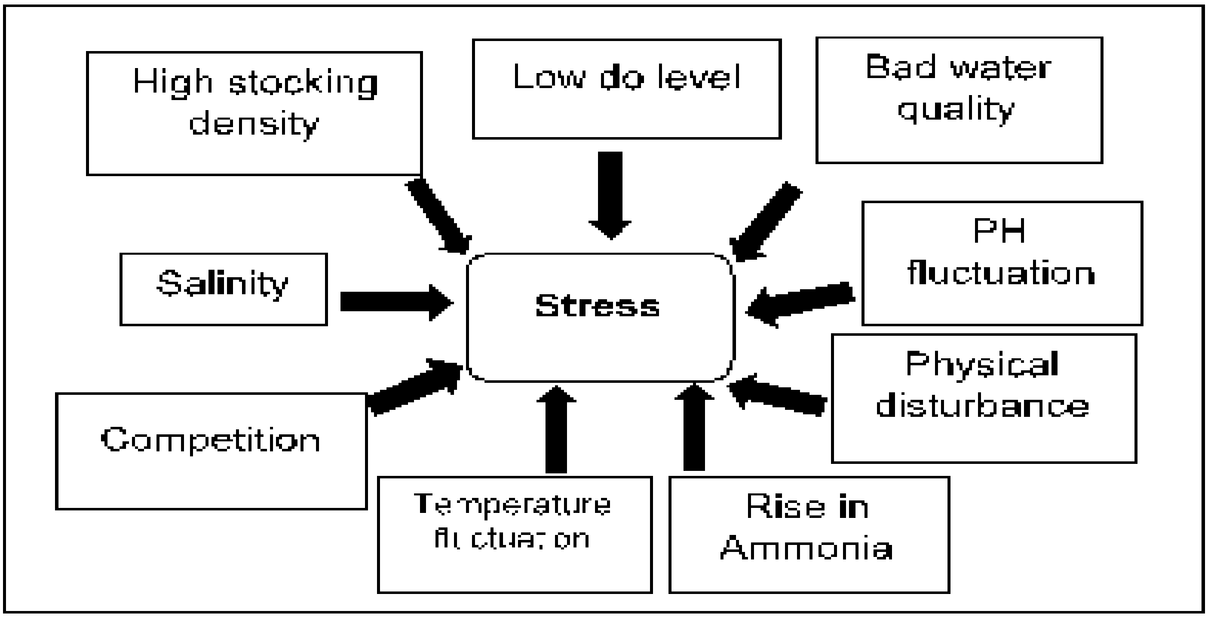

Fig. 1. Factors which induced stress in fish.

Schram *et al.* (2006) worked on Dover sole, *Soleasolea* to examine its growth that depends on stocking density by conducting experimental trial of 55 days. This species is well adapted to low stocking density as it relatively grows slow. The results from the study indicates that increasing stocking density reduces specific growth rate which ultimately decreases productivity. Mortality rate was also high but that rate was seen in fishes having below average size. Work of (Montero *et al.,* 1999; Fairchild and Howell, 2001; Iguchi *et al*., 2003) on Winter flounder (*Pseudopleuronectus americanus*), ayu (*Plecoglossus altivelis*) and seabream (*Sparusauratus*) respectively supports the work of (Schram *et al*., 2006) that mortality rate is high at high stocking density. While, study on turbot (*Scopthalmus maximus*) suggested higher survival rate at higher stocking density (Martinez-Tapia and Fernandez-Pato, 1991). Increasing stocking density produces both positive and negative response that vary from species to species. It can be inductor of stress response in fish according to work of (WendelaarBonga, 1997; Ruane*et al*., 2002). However, work of (Procarione *et al.,* 1999) contradicts this finding as low stocking density of rainbow trout (*Oncorhynchus mykiss*) produces stress and ultimately effects growth.

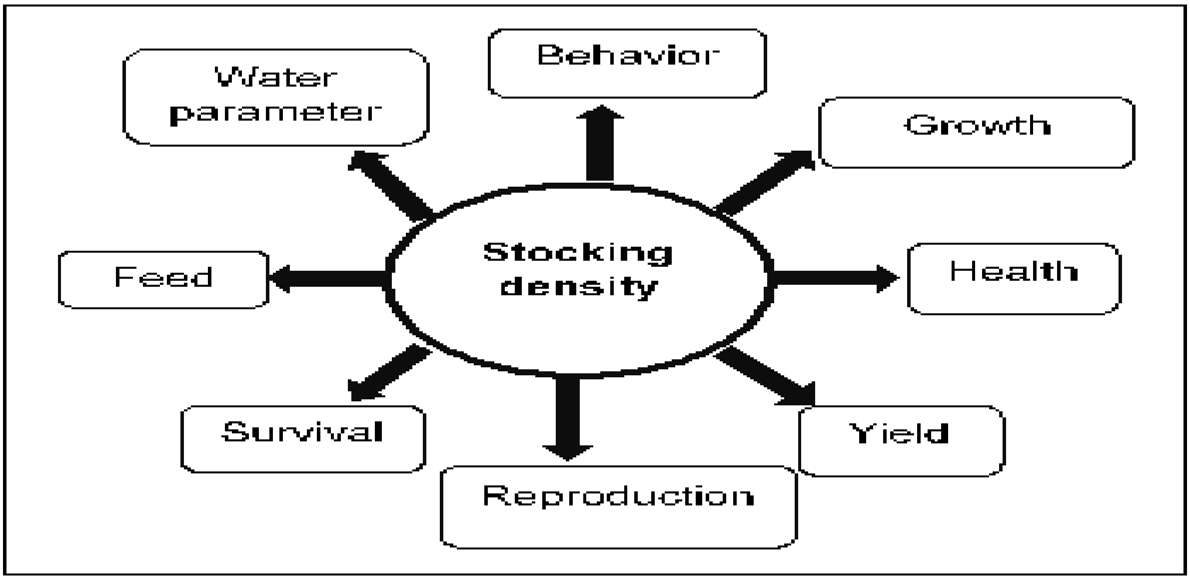

Fig. 2. Effect of stocking density on fish profile.

Toko *et al.* (2006) examined African catfish (*Clarias gariepinus*) and vundu catfish (*Heterobranchus longifilis*) to determine effect of HSD on various parameters. Experimental trial of 70 days was conducted by using 3 stocking densities low, middle and high. The results indicated that high stocking density was more feasible for African catfish as it becomes aggressive and stressed at low stocking density.

Food conversion ratio

Like growth, stocking density also affect the food conversion ratio. When fish is stocked at different densities feed consumption varies. Food conversion ratio is increased by increasing the stocking density (Ronald *et al.,* 2014). In contrast, (Osofero, 2009) explained that there was no effect of stocking density on food conversion ratio when fish were given same type of feed in same environment. (Guimareaes *et al*., 2008) reported that utilization of feed varies from species to species and as well as within a species. Environmental factors also affect the FCR. (Kheyrabadi*et al*., 2014) concluded that fish that was given extruded feed grow better and gain weight.

Their FCR was better as compare to the fish fed on pelleted feed as feed intake ratio was more efficient as compare to the other. Feed was given according to the fish body weight. (D'Silva and Maughan, 1995) examined that FCR was better in low stocking density as there was no competition for the food. He did this experiment on *Oreochromis mossambicus* and *Oreochromis urolepishornorum*. Jarboe and Grant (1997) also concluded that in Channel cat fish FCR was more at low stocking density.

Kheyrabadi *et al*., 2014 concluded a result that fish feed on extruded fed grow better and also gain weight.

Their FCR was better as compare to the fish feed on pelleted feed. Their feed intake ratio was better as compare to the other. Feed was given according the fish body weight.

Conclusion

High Stocking density is a major cause for the induction of stress in a fish body by which there will be change in fish physiology, increase in mortality rate and decreased in feed conversion ratio. But by providing suitable environment such as DO, Temperature and pH farmers can get high yield.

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