Importance of carrying capacity for sustainable trout culture: the case of "bagci balik"

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Abstract

Trout is a fish species that is produced widely all over the world and it has an important place in the aquaculture industry. For the sustainable development of the trout culture, it is need to determine how much fish can be stocked per unit volume (carrying capacity). Over-stocking could threaten fish welfare and sustainable use of environmental resources. Estimating of carrying capacity is necessary both to minimize these adverse impacts on fish and environment, and in terms of sustainable use of water resources. In this study, carrying capacity of a commercial land based trout farm in Koycegiz (Mugla/TURKEY) was investigated. Two methods were used to calculate carrying capacity and compared with each other: "Oxygen requirement based carrying capacity" and "Metabolic waste based carrying capacity". The mean values of studied water quality parameters that used in calculations were measured as; 14.12 ± 0.72 °C for temperature, 7.78 ±0.20 for pH, 10.1 ± 0.93 mg/l for oxygen, 3,05 ± 0,84 m3 s-1 for flow rate. The annual production capacity was calculated with these measured parameters. By the observed data, the carrying capacities of the farm were found respectively with based on oxygen requirement as 538.42 ± 196.22 tonnes; and based on metabolic waste as 1113.4 ± 463.7 tonnes per years. According to the results that obtained from the study, there was significant difference between two carrying capacity estimation methods. However when the oxygen levels of the water were examined, in some months the negative values, that could adversely affect the life and growth of the trouts, were observed. Fort this reason, to reduce the limiting effect of the oxygen and reach maximum carrying capacity; it is needed to be integrated oxygenation or aeration systems into the production ponds. On the other hand, for the sustainable use of the environmental sources in the facilities engaged in production according to the metabolic waste based carrying capacity, it is important to use advanced water filtration systems.

Keywords: Carrying capacity, land-based trout culture, water quality.

1.INTRODUCTION

Aquaculture is a farming method of aquatic animals and plants for nutrition, stocks enrichment, making ornaments, hobby activities, and for scientific studies in a controlled or semi-controlled manner, by human (Çelikkale, et al., 1999). Today, it is a rapidly growing industry especially in terms of animal food. The combined result of development in aquaculture worldwide and the expansion in global population is that the average annual per capita supply of food fish from aquaculture for human consumption has increased by ten times, from 0.7 kg in 1970 to 7.8 kg in 2008, at an average rate of 6.6 percent per year(FAO, 2010). According to data obtained from the FAO, in 2010, total global aquaculture production (quantity) is 73 million tonnes. The value of the world aquaculture harvest, excluding aquatic plants, is estimated at US$110.1 billion in 2009 (FAO, 2010). Turkey's total fisheries production is 653 thousand tons and 167 thousand tons of total production comes from aquaculture. More than half of the amount of aquaculture (51%) is due to the trout culture, and the value of production is around US$ 207 million (TUIK, 2010).

Sustainability has great importance for the aquculture industry as in all sectors. At this point, the condition of the water is one of the vital criteria for aquaculture enterprises that are at the top level of the production cycle. Aquaculture can be made depending on the the physical, chemical and biological properties of water. These criteria should be in optimum standards fort he sustainable aquaculture. Rate of flow and quality of incoming water are the first parameters to be dealt with in establishing suitable living conditions for fish. (Penneli and Mclean, 1996). Because, the water that is used for aquaculture, both brings oxygen to the aquaculture environment and also provides removal of the accumulated wastes (Balık, et al., 2002). On the other hand, estimating the carrying capacity of the farm, is an important criteria to be considered. Carrying capacity is usually expressed in terms of quantity of fish per unit of water flow (loading rate) or per cubic meter of rearing space (density) (Hinshaw, 2000). Carrying capacity has an important influence on the success of aquaculture operations. The appropriate stocking level is ascertained in carrying capacity studies (Frechette, 2005). Many studies have demonstrated an effect of stocking density on various aspects of the welfare of farmed fish (Wedemeyer, 1997). In intensive aquaculture fishes are usually reared at high densities, which has led to concerns about welfare of the fish, so there is a need for the development of reliable stocking density guidelines (Adams, et al., 2007; Ashley, 2007; Ellis, et al., 2002; Huntingford, et al., 2006). Several causative mechanisms have been proposed to explain why high densities negatively affect growth and feed utilization. The biochemical, behavioural, and physiological changes induced by high stress levels are presumed to be energetically costly, affecting the amount of energy available for growth (Barton and Iwama, 1991; Pickering, 1992; Vijayan and Leatherland, 1998; Wendelaar, 1997). High rearing density in itself may further reduce access to feed, thereby reducing feed intake and directly affecting growth (Alanara and Brannas, 1996; Boujard et al., 2002; Marchand and Boisclair, 1998). Incorrect Carrying capacity aplications both affect negatively to fish welfare and cause environmental issues. This is the biggest obstacle in front of the goal of sustainable aquaculture. Therefore, it is necessary to estimate the carrying capacity so good to reflect the facts.

In this study, carrying capacity of a commercial land based trout farm in Koycegiz (Mugla/TURKEY) was investigated. For the sustainable use of Yuvarlak Çay, the optimum capacity and the maximum capacity had been calculated with both formulas.

2.Materials and methods

2.1.Experimental area

The study was conducted in a commercial trout farm that was located on Yuvarlakçay Stream in Fethiye/Koycegiz. The commercial farm aimed to produce 900 tons trout per year in its project. For the sustainable trout farming on this stream continuously, optimum and maximum amount of fish, that could be stocked in the farm, was estimated.

2.2.Fish material

The farmed fish species in the trout enterprise, was rainbow trout (Oncorhynchus mykiss) (Walbaum, 1792), and the production period that was used in the farm, from egg to market size.

Method

A number of different formulas have been devised to calculate carrying capacities, taking into account oxygen consumption, growth rate of fish, feeding rates, water volume and temperature, and other factors. Dissolved oxygen and ammonia (un-ionized) concentrations are the primary limiting factors in the culture systems, with oxygen normally the more critical (Hinshaw, 2000). Therefore carrying capacity (stock density) of the fish farms, can be estimated with the amount of oxygen consumed by fish or methabolic wastes of the fish. To be able to make this calculation, it is important to know amount of the feed given to fish. Because, the single artificial input is the feed to the fish that grown in the farm and to the natural environment (Balık, et al., 2002). In the calculations; two criteria are taken into consideration: The oxygen rate that fish need to metabolize the feed and the amount of ammonia released by digestion of feed the environment. In this study the approach of Brannon, (1991), calculating carrying capacity of trout farming with oxygen and metabolic wastes based methods.

2.3.Oxygen-Based Carrying Capacity Estimation

The optimum carrying capacity according to water flow rate and the dissolved oxygen in the water was calculated by the following formula:

$$N = (0{,}25) / (0{,}00143 \times Of)$$

$$p = R / N$$

*N : L /min required/kg of fish feed

*0,25 : kg O_2 to metabolize 1 kg of fish feed

*0,00143 : conversion constant

*Of : inlet oxygen minus outflow oxygen (Oa - Ob)

*p : kg of food fed

*R : total rate of flow in L / min.

Mechabolic waste-Based Carrying capacity Estimation

The maximum amount of fish that could be produced by increasing the amount of oxygen in the water, was calculated with this method.

Table 1. NH3 percentage of Total Ammonia Relationship to pH and Temperature

Temp (°C)	pH					
	6.0	6.5	7.0	7.5	8.0	8.5
4	0.01	0.03	0.12	0.37	1.10	3.39
8	0.02	0.05	0.16	0.50	1.58	4.82
12	0.02	0.07	0.21	0.68	2.12	6.40
16	0.03	0.09	0.29	0.92	2.86	8.52
20	0.04	0.13	0.40	1.24	3.83	11.18

N = (0,032 x r) / (0,00143 x 0,02)

p = R / N

*N : L / min. required/kg of food fed

*0,032 : kg NH3 + NH4+ produced/kg of food fed

*r : % NH3 of total ammonia present (Table 1. NH3 percentage of Total Ammonia Relationship to pH and Temperature(Brannon, 1991).

*0,00143 : conversion constant

*0,02 : ppm max. NH3

*p : kg of food fed

*R : total rate of flow in L/min

To use in the calculations, temperature(°C), flow rate (L/s), oxygen (mg/L) and the other chemical water parameters were measured regularly every month.

Table 2. Monthly measured water parameters used in the calculations

Parameters	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Flow Rate (m3/s)	2,88	2,38	2,34	1,94	1,98	2,74	2,91	3,09	4,13	4,09	4,05	4,04
Temperature (°C)	14,7	15,3	14,8	14,3	14,5	14	13,7	13,5	12,5	13,7	14,2	14,2

pH	8,1	7,9	8,1	7,6	7,4	7,6	7,8	7,8	7,7	7,8	7,8	7,8
NH3 (%)	3,20	2,09	3,23	0,98	0,65	0,98	1,49	1,55	1,15	1,55	1,94	1,94
Oxygen (mg/l)	9,3	9,3	8,9	9,9	10,0	11,7	10,3	10,4	11,0	9,5	9,3	11,6
Oxygen (mg/l) (discharged from ponds)	4,0	4,2	5,7	5,12	3,85	4,97	4,97	6,35	8,01	6,3	6,51	7,77

3.Results and Discussion

3.1.Carrying Capacity

According to “Oxygen-Based Carrying Capacity Estimation” method, it was calculated between May to April with the varying flow rate in the ongrowing ponds, respectively; 212.5 , 175.6 , 156.6 , 163.1 , 169.8, 315.0 , 264.7 , 295.3 , 406.0, 315.8 , 298.8 , 457.7 tons trout could be farmed in the months (Table 3. The total amount of fish produced by month (tons) The sample enterprise could make two production in a year. When the carrying capacity was calculated; 198,77± 24,58 tons trout could be farmed in the one production period and in the second period; 339,72 ± 30,64 tons. It was estimated that totally 538,49±55,22 tons of trout could be produced per year.

According to the calculation of “Mechabolic waste-Based Carrying Capacity Estimation” method, that is taken into consideration the percentage of toxic NH3 in the total ammonia; respectively; 241.3, 305.3, 194.2, 529.5, 816.8, 747.9, 520.5, 534.6, 966.3, 707.6, 559.1, 557.7 tons fish could be farmed (Table 3. The total amount of fish produced by month (tons). 472,50 ± 109,01 tons trout could be farmed in the one production period and 640,97 ± 70,65 tons in the second period. It was estimated that totally 1113,47 ± 179,98 tons of trout could be produced per year.

Table 3. The total amount of fish produced by month (tons)

Capacity (tonnes/year)	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.

Based on oxygen	212,5	175,6	156,6	163,1	169,8	315	264,7	295,3	406	315,8	298,8	457,7
Based on ammonia	241,3	305,3	194,2	529,5	816,8	747,9	520,5	534,6	966,3	707,6	559,1	557,7

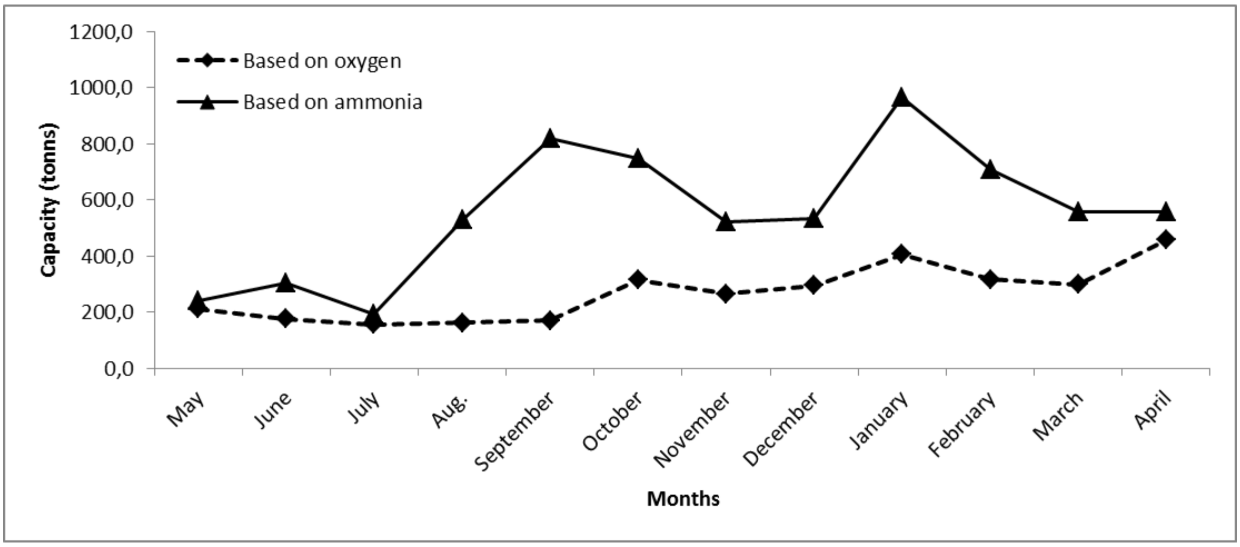

Figure 1. Estimated carrying capacities calculated with oxygen based and ammonia based methods between May to April.

4.CONCLUSION

One of the most important issues is to measure water properties. While doing this the physical and chemical parameters should be known. Beveridge (2004), previously reported that any increase in temperature affected the metabolism, oxygen consumption and also increased activity of fish. Optimal on-growing temperature level was reported between 10-15 °C by Sedgwick, (1985) , and in addition to this between 12-18 °C by Çelikkale, (1988). In this study, the water temperature ranged between 12,5-15,3 °C and the average temperature level in the ponds was 14,12 ± 0,21 °C (Table 2). The temperature level did not adversely affect the development of the fish.

Çelikkale, 1988 reported that 100 – 150 kg rainbow trout could be farmed with 1 L.s-1 . In this study the avarage flow rate was measured 3.05 ± 0.24 m3.s-1. Additionally, water flow rate was reduced during the experimental period due to very low rainfall in that season.

The dissolved oxygen (DO) level in the water is another important criteria in the estimating of carrying capacity of the trout farm. Çelikkale, (1988); Edwards, (1987); and Stevenson, (1984); reported that the DO level had to be more than 6 mg.L-1 for the rainbow trout farming. The levels of DO varied between 8,9 and 11.7 mg.L-1 at farm inlet during the study and the lowest DO at the pond outlet was observed in September (3.85 mg.L-1) (Table 2).

This value was found to be below the limit of DO concentration for rainbow trout farming (5 mg.L-1) as recommended by Belaud, (1995). Additional oxygenation systems were used to solve lower DO problem, in the farm.

The present study showed that carrying capacity (stock density) of a trout farm was related with water parameters. Although, the presence of suitable water temperature for trout farming, the water parameters limited production. In the first method, oxygen was the significant limited parameters for carrying capacity. Especially between May and September, the oxygen levels decreased due to reduced water flow and as a result of this, amounts of the production in those months were minimum. Although this farm was allowed to produce 900 tons of trout, maximum 538,49±55,22 tons of rainbow trout could be farmed due to the low oxygene levels. The problem of low oxygen levels for carrying capacity can be solved with by adding alternative oxygenation systems. Aerators were used in this farm but it was observed that the aerators were not sufficient and suitable capacity. Toxicity of total ammonia in water, was the most important parameter that limiting carrying capacity. By using additional oxygenation systems, the carrying capacities were increased between May and September. But maximum carrying capacity was determinated by using the second method. By using the second calculation method, the maximum production and carrying capacity was observed 1113,47 ± 179,98 tons per year.

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