Pakistan J. Zool., vol. 49(6), pp 2257-2261, 2017. DOI: http://dx.doi.org/10.17582/journal.pjz/2017.49.6.2257.2261

Comparison of Rainbow Trout (*Oncorhynchus mykiss*) and Brown Trout (*Salmo trutta ssp*) Dual Culture in Different Ratios and Growth Performances

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ABSTRACT

The objective of the present study is to analyze the growth performance of rainbow trout (*Oncorhynchus mykiss)* (G) and brown trout (*Salmo trutta* ssp) (K) monoculture and polyculture in 75-25%, 66-34% and 50-50% stocking rates and its effects on food utilization and to determine the results with respect to aquaculture. Stocking was conducted in 5 different ratios in the study and each different stocking ratio was considered as a group and 24 fish were used in each group. Study groups were named based on stocking ratio percentages as G, K, G75K25, G66K34 and G50K50 and the study lasted 80 days. When the growth parameters in polycultures of rainbow trout and brown trout are considered, it was determined that the growth rates were not statistically different between rainbow trout monoculture and rainbow trout G75K25 and G50K50 groups, however rainbow trout in G66K34 experienced statistically significantly less growth when compared to others ($p<0.05$). Growth parameters of brown trout in polycultures demonstrated that the best growth was observed in G66K34 polyculture group ($p<0.05$). Study results showed that there was no significant difference between the groups based on food conversion coefficients and survival rates ($p>0.05$). As a result, it was determined that brown trout monoculture was the most advantegous group followed by G50K50 polyculture group, and when ecological and environmental parameters are concerned, G75K25 group, which consumed statistically significantly less food and demonstrated a lower food conversion ratio, would be more beneficial, and for fish breeders, who would like to increase the growth rate of the trout, G66K34 polyculture group would be more useful when compared to brown trout monoculture.

Article Information
Received 19 September 2016
Revised 12 March 2017
Accepted 01 April 2017
Available online 05 December 2017

Authors' Contribution
BK and MA designed the experiments, BK evaluated the results. TA results and OS created graphics. AM and OS wrote the manuscript.

Key words
Rainbow trout, Brown trout, Monoculture, Polyculture, Growth performances.

INTRODUCTION

Polyculture breeding aims to obtain maximum productivity in the whole environment and to increase production per unit area or volume by enabling utilization of a volume, area or food that could not be utilized by one species by another (Sırtkaya, 2013). Within the context of aquaculture, a cold water fish, the trout is bred in extensive environmental conditions around the world. Rainbow trout aquaculture is preferred due to good adaptation of rainbow trout to environmental conditions, its resistance against diseases, active food intake, high food utilization ability and good growth performance. In contrast, although brown trout culture developed recently, it started to be preferred by farmers during recent years due to its high market prices and new studies are being conducted on brown trout concurrently.

Certain fish farmers consider polyculture of rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta* ssp) useful, while others find it useless and consider that polyculture affects growth negatively. Fish farmers who consider the polyculture of these two species useful reported a shorter market length, higher food utilization ratio and minimum food waste. The reason behind the contradictory results reported by fish farmers was the different stocking ratios they utilized. Especially in small and medium sized businesses, if a capacity is reserved for brown trout culture, sustainable profitability of these businesses would increase due to polycultural breeding applications, since the market price of brown trout is generally higher.

Thus, the objective of the present study is to determine the results of the monoculture and polyculture of two cultured carnivore species, rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta* ssp) in 75-25%, 66-34% and 50-50% stocking rates.

MATERIALS AND METHODS

Animals and study setup

The study was conducted for 80 days between August 1, 2014 and October 20, 2014 in Yüzüncü Yıl University,

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0030-9923/2017/0006-2257 $ 9.00/0

Aquaculture Research and Application Facility using 10 500 L PVC tanks (Aktaş Ltd. Şti.). Five different ratios of stocking were used in the study. Each different stocking ratio was considered as a study group and the groups were planned as two-repeat. Each group included 24 fish (Table I). The water utilized in the study was filtered through a sand filter (STF Faber) before use. Semi-closed aquaculture systems were created using one external filter (LifeTech 835), one UV filter (Jebo UV-H9) and three air stones for each tank.

Table I.- Group names used in the study and related stocking ratios.

Groups	Stocking ratios (Species and number of fish in the groups)
G	100% rainbow trout (24)
K	100% brown trout (24)
G50K50	50% rainbow trout (12) + 50% brown trout (12)
G66K34	66,6% rainbow trout (16) + 33,3% brown trout (8)
G75K25	75% rainbow trout (18) + 25% brown trout (6)

Aeration of the tanks used in the study were performed by a 750 W blower (Resun GF_750). The flow rate of the water influent to the tanks was set at 2 L/min. During the study, water temperature and dissolved oxygen were measured every morning and evening, hence twice a day.

Food utilization

During the study, fish were fed with 2 mm and 3 mm trout grower feed produced by a private company (Skretting) twice every day; once in the morning and once in the evening. To determine the exact environmental and food consumption effects of polyculture, "over nutrition" method was used as nutritional regime. To prevent the feed to affect the behavior of the fish and to be ever present in the environment whenever they needed, the feed was delivered more than the amount required by the fish. Unconsumed feed was gathered 90 min after feeding with siphoning method and was dried (at 105°C for 3 – 5 h (Kutlu, 2008)) and the weight was determined in grams. By adding the moisture rate of the dry feed to the measured weight, the real weight of the feed was calculated.

Economic analysis

Current prices were used in determination of the highest yielding group at the harvest for trout bred with monoculture and polyculture (Tekelioğlu and Sarıhan, 1985). In economic analyses, it was accepted that the tank volumes were 1000 liters, wholesale price for portion rainbow trout was 8 TL/kg, for fingerlings it was 0.18 TL/piece, wholesale price for portion brown trout was 13 TL/kg and 0.25 TL/piece for fingerlings, and the feed price was 5 TL/kg.

Table II.- Results obtained on growth performance at the end of the study.

Groups	G	K	G50K50		G66K34		G75K25	
Fish species	**G**	**K**	**G50**	**K50**	**G66**	**K34**	**G75**	**K25**
Initial weight (g)	24.70	42.96	24.44	41.43	24.93	41.99	24.86	41.08
Final weight (g)	124.17	112.35	117.19	122.68	92.85	125.77	122.85	111.05
MLWI	99.47±10.1^{a}	69.39±19.6^{b}	92.75±12.07^{a}	81.25±0.6^{ab}	67.92±2.6^{b}	83.78±2.4^{ab}	97.99±0.2^{a}	69.97±2.3^{b}
SGR	2.02±0.09^{a}	1.20±0.21^{c}	1.96±0.14^{a}	1.36±0.007^{c}	1.65±0.007^{b}	1.37±0.04^{c}	2.0±0.04^{a}	1.25±0.02^{c}
DLWI	1.24±0.09^{a}	0.87±0.24^{b}	1.16±0.15^{a}	1.01±0.007^{ab}	0.85±0.02^{b}	1.05±0.02^{ab}	1.23±0.007^{a}	0.88±0.03^{b}
CGT	0.0015± 0.00009^{a}	0.0009± 0.0002^{b}	0.0014± 0.0001^{a}	0.0010± 0.000007^{b}	0.0012± 0.00001^{b}	0.0011± 0.00003^{b}	0.0015± 0.00001^{a}	0.0009± 0.00002^{b}
RWI	4.03±0.34^{a}	1.62±0.45^{c}	3.8±0.57^{a}	1.96±0.02^{c}	2.73±0.02^{b}	2±0.10^{c}	3.95±0.17^{a}	1.7±0.04^{c}
MR	0	6.63±2.9	4.55±4.5	0	0	8.33±8.8	0	8.33±11.7
TB	2387±244.78^{a}	1666±472.07^{b}	2087±152.55^{ab}		1756±61.56^{ab}		2183±8.76^{ab}	
FCC	1.1±0.11	1.33±0.31	1.16±0.007		1.25±0.006		1.08±0.006	
FCA	2617±2.20^{a}	2148±110.08^{c}	2432±161.30^{ab}		2214±88.96^{bc}		2365±0.95^{abc}	

$^{a,\ ab,\ b,\ c}$, different letters on the same line identify that the difference between the means is statistically significant (p<0.05); MLWI, mean live weight ıncrease = End of the experiment mean weight (g) – Initial mean weight (g) (Atay, 1989); SGR, specific growth rate = (ln end of the experiment mean weight (g) – ln ınitial mean weight (g) / day) x 100 (Bagenal and Tesch, 1978); DLWI, daily live weight ıncrease = (End of the experiment mean weight (g)- Initial mean weight (g) / day) (Clark *et al*., 1990); CGT, coefficient of growth due to temperature = (End of the experiment mean weight (g) $^{(1/3)}$ – Initial mean weight (g) $^{(1/3)}$ / Day x Water Temperature) (Iwama, 1996); RWI, relative weight ıncrease = ((End of the experiment mean weight (g) – Initial mean weight (g))/ Initialmeanweight (g)) x 100 (Atay, 1989); MR, mortality rate = (Final individual count / Initial individual count) x 100 (Pickering and Pottinger, 1987; Atay, 1989); TB, total biomass = (End of theexperiment mean weight (g) – Initial mean weight (g)) x fishcount (Bagenal and Tesch, 1978); FCC, feed conversion coefficient = Feed consumed in oneperiod (kg) / (Total live weight increase in one period (kg) + Total weight of the fish died (kg)) (Watanabe *et al*., 1990); FCA, feed consumption amount = (Feed amount given per period (g))- (Feed left at the end of the period (g)) (Atay, 1989).

Statistical analyses

For each property indicated in the study, significance test for group averages and one-way analysis of variance test were conducted. Data was analyzed using SPSS software package Duncan Multiple Comparison Test at 5% significance level (Hayran and Özdemir, 1995).

RESULTS

During the study, mean dissolved oxygen was measured as 6.55 ± 0.8 mg/l, water temperature as 17.2 ± 0.5 ˚C, and water pH was measured as 8.1 ± 0.7. Considering the rainbow trout and brown trout polyculture growth parameters, it was determined that rainbow trout demonstrated a statistically indifferent growth when compared to trout grew in monoculture, however, the rainbow trout in G66K34 group experienced a statistically significantly lower growth when compared to others ($p<0.05$) (Table II).

There was no statistical difference between specific growth, growth due to temperature, and relative growth performances of brown trout in brown trout and rainbow trout polycultures ($p>0.05$). However, brown trout in all polyculture groups demonstrated better growth rates when compared to monoculture group. In fact, G50K50 and G66K34 polyculture groups demonstrated a statistically significant increase in growth when compared to K an G75K25 groups based on mean live weight increase and daily live weight increase ($p<0.05$) (Table II).

In the study, the highest biomass was obtained in rainbow trout monoculture (G) among the groups and it was observed that the difference was statistically significant ($p<0.05$). It was also observed in the study that there was no statistically significant difference between the groups based on feed conversion coefficients and survival rates ($p>0.05$). However, when all groups were assessed based on consumed feed, it was determined that there were statistically significant differences between all groups ($p<0.05$) (Table II).

DISCUSSION

Findings of the study with respect to growth performance demonstrated that polyculture displayed a case favoring growth in brown trout, it did not have a negative effect on growth in rainbow trout with the only exception of G66K34 group. Previous studies similarly reported that polyculture provided advantages for the growth of this species. For instance, this culture displayed a better growth performance in brook trout (*Salvelinus fontinalis*) and rainbow trout (*Oncorhynchus mykiss*) polycultures (Okumuş *et al*., 1999); lake trout, Atlantic salmon and rainbow trout polycultures (Bong-Joo *et al*., 2010), and albino and normal pigmented rainbow trout polycultures (Yıldırım *et al*., 2002). In fact, certain previous studies reported that polyculture could positively affect the growth of both species or could negatively affect the growth of both species. For example, it was reported that the polycultures of Siberian sturgeon (*Acipenser baeri)* and rainbow trout (*Onchorhynchus mykiss*) (Ak, 2013), Nile tilapia (*Oreochromis niloticus)* and African sharptooth catfish (*Clarius gariepinus*) (Ibrahim and El-Naggar, 2010), brook trout (*Salvelinus fontinalis*) and Black Sea salmon (*Salmo trutta labrax*) (Başçınar *et al*., 2010), gilt-head bream (*Sparus aurata*) and Senegalese sole (*Solea senegalensis*) (Ferreira *et al*., 2010) demonstrated better growth performance when compared to monoculture. On the contrary, certain researchers stated that fish bred in monoculture had better growth performance than those bred in polyculture. Negative effects of polyculture was reported by Çakıcı (2010) with rainbow trout and brown trout polyculture, Aksoy (2007) with albino and normal pigmented rainbow trout (*Onchorhynchus mykiss*) polyculture, Başçınar (2011) with brown trout (*Salmo trutta ssp*) and turbot (*Psetta maxima*) polyculture, Sırtkaya (2013) with rainbow trout (*Oncorhynchus mykiss*) and turbot (*Psetta maxima*) polyculture. When previous reports and the results of the present study are considered together, it could be stated that polyculture growth performances differ based on the selected species.

Study findings related to feed utilization performance demonstrated that polyculture group brown trout consumed more feed when compared to brown trout in monoculture, while polyculture group rainbow trout consumed less feed than rainbow trout in monoculture. The increase in brown trout in polyculture feed consumption could be explained with behavior change. Better fed brown trout in polyculture displayed better growth performance.

Different results were observed when findings of the polyculture breeding study were analyzed. In fact, previous studies reported statistically significant feed conversion coefficients in brook trout (*Salvelinus fontinalis*) and Black Sea salmon (*Salmo trutta labrax*) polyculture (Başçınar *et al*., 2010), albino and normal pigmented rainbow trout (*Onchorhynchus mykiss*) polyculture (Aksoy, 2007), brown trout (*Salmo trutta ssp*) and turbot (*Psetta maxima*) polyculture (Başçınar, 2011), Siberian sturgeon (*Acipenser baeri)* and rainbow trout (*Onchorhynchus mykiss*) polyculture (Ak, 2013). However, there are reports that were similar to the findings of the present study. Several studies reported that, similar to the results of this study, there were no statistically significant differences among the groups based on feed conversion ratio in albino and normal pigmented rainbow trout (*Oncorhynchus mykiss*) polyculture (Değirmenci, 1998), brook (*Salvelinus fontinalis*) and rainbow trout (*Oncorhynchus mykiss*) polyculture (Okumuş *et al*., 1999), rainbow trout (*Oncorhynchus mykiss*) and turbot (*Psetta maxima*) polyculture (Sırtkaya, 2013), and albino and normal pigmented rainbow trout (*Oncorhynchus mykiss*) polyculture (Yıldırım *et al*., 2002).

A combined evaluation of feed consumption and feed conversion coefficient in the present study would demonstrate that the most advantageous group was polyculture G75K25 group, and thus, it could be stated that polyculture had ecological and environmental advantages. One of the criteria that would determine the most preferable groups used in this study, no doubt, would be to evaluate economic productivity. In the conducted economical analysis, the difference between the revenues and variable expenses was compared. It was determined that the difference between the revenues and expenses was the highest in brown trout monoculture (K). The analysis of polyculture groups demonstrated that a farmer who stocks G50K50 group would make 49.30% more profit than the farmer who stocked G66K34 group, and 40.41% more profit than the farmer who stocked G75K25 group. These findings showed that when capacity is reserved for brown trout farming in especially small and mid-size businesses, a contribution to the sustainable profitability of small and mid-size businesses that provide employment opportunities in rural regions is possible.

In general, when evaluated together, ecologic and economic findings demonstrated that, although G75K25 group was behind in feed consumption, the same group was the second best group in biomass following rainbow trout group. Albeit not statistically significant, it was the group that utilized feed the best among all groups based on feed conversion coefficient. This group could be recommended for fish farmers based on ecologically and environmentally. However, economic-wise, since unit price per kg was high in this group, the fish in group K were more profitable. Among the polyculture groups, the most profitable fish were in G50K50 group. When the price differences are ignored, the most advantageous group was the group G, which displayed the highest biomass.

On the other hand, among polyculture groups, the best group based on average live weight increase, specific growth rate, growth ratio due to temperature, relative growth, daily live weight increase of brown trout was the G66K34 group. However, since the rainbow trout in this group displayed the worst growth results among the polyculture groups, end of the study total biomass values obtained in this group were low. This culture ratio could be used to facilitate growth in brown trout in fish farming. Observed behavior throughout the study demonstrated that G66K34 group brown trout displayed the most relaxed behavior among all brown trout. This could have been affected the growth of brown trout positively. This relaxed behavior was not observed in other groups that included brown trout. As a result, G66K34 rainbow trout and brown trout polyculture could be recommended to fish farmers to facilitate the growth of brown trout under circumstances where economic or business targets require rainbow trout growth programming or late marketing of rainbow trout is more feasible for the business. This condition does not result in a significant increase in feed expenditures as well. Because, G66K34 group had the lowest feed consumption amount among polyculture groups, and the difference was significant ($p<0.05$).

Finally, it could be argued that, when all criteria scrutinized in the present study are considered, G50K50 polyculture was advantageous and only second to brown trout monoculture, G75K25 polyculture group, which consumed statistically significantly less feed based on ecological and environmental criteria and demonstrated statistically significantly lower feed conversion rate, was the most useful group, and for fish farmers who aim to increase the growth rate of brown trout, G66K34 polyculture group would be more useful than brown trout monoculture.

ACKNOWLEDGEMENT

The present study was produced from Yüzüncü Yıl Üniversitesi, Science Institute, thesis No: 2015/6-XI.

Statement of conflict of interest

Authors have declared no conflict of interest.

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