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RESEARCH ARTICLE

Effect of Duo-Culture on Growth Performance of Brook Trout (*Salvelinus fontinalis* Mitchill, 1814) and Black Sea Trout (*Salmo trutta labrax* Pallas, 1811) in Tank Reared Condition

Nadir BAŞÇINAR * Şebnem ATASARAL ŞAHİN * Mehmet KOCABAŞ **

* Karadeniz Technical University, Faculty of Marine Sciences, Department of Fisheries Technology, TR-61530 Trabzon - TURKEY
** Tunceli University, Faculty of Fisheries, TR-62000 Tunceli - TURKEY

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Summary

The objectives of the present study were to compare growth performance and feed conversion ratios of brook trout *(Salvelinus fontinalis)* and Black Sea trout *(Salmo trutta labrax)* in monoculture and duo-culture tank reared conditions. The fish were about 9-month-old hatchery reared brook trout and Black Sea trout with initial weights of 24.18±0.64 (n=60) and 23.87±1.11 (n=60) g, respectively. Fish were kept in 0.2 m^3 fiberglass tanks. Nine tanks were used and the fish were equally allotted to 3 groups with tree replicates and fed for 240 days. Each tank contained 20 fish from each species for monoculture and 10+10 fish from each species for duo-culture. At the end of the study, mean live weights of brook trout and Black Sea trout increased to 265.47±17.25 g and 206.18±2.95 g in monoculture, 235.53±10.25 g and 222.47±14.29 g in duo-culture, respectively, and significant differences were found among the groups (P<0.01). The highest and lowest specific growth rates were found in brook trout and Black Sea trout in monoculture (P<0.01), respectively. The highest and lowest final condition factors were calculated in duo-culture for brook trout and in monoculture for Black Sea trout (P<0.01), respectively. The feed conversion ratio (FCR) for Black Sea trout was higher than it was for the other groups (P < 0.01).

Keywords: *Brook trout, Black Sea trout, Duo-culture, Growth performance, Feed conversion ratio*

Tank Koşullarında İkili Yetiştiriciliğin Kaynak Alabalığı (*Salvelinus fontinalis* Mitchill, 1814) ve Karadeniz Alabalığı (*Salmo trutta labrax* Pallas, 1811)'nın Büyüme Performansı Üzerine Etkisi

Özet

Bu çalışmanın amacı, tank koşullarında tekli ve ikili yetiştirilen kaynak alabalığı *(Salvelinus fontinalis)* ve Karadeniz alabalığı *(Salmo trutta labrax)*'nın büyüme performansı ve yem değerlendirme oranını karşılaştırmaktır. Kuluçkahane kökenli yaklaşık dokuz aylık kaynak ve Karadeniz alabalıklarının başlangıç ağırlıkları sırasıyla, 24.18±0.64 (n=60) and 23.87±1.11 (n=60) gramdır. Balıklar 0,2 m^3 hacimli fiberglas tanklarda stoklanmıştır. Balıklar dokuz tanka üç tekerrürlü, eşit sayı ve ağırlıkta, tekli grupta 20 balık/tank, ikili grupta ise sayıları 10+10 balık/tank olacak şeklide yerleştirilmiştir ve çalışma 240 gün sürmüştür. Çalışmanın sonunda, kaynak ve Karadeniz alabalıklarının ortalama canlı ağırlıkları tekli grupta sırasıyla 265.47±17.25 g ve 206.18±2.95 g, ikili grupta ise 235.53±10.25 g ve 222.47±14.29 g olarak hesaplanmış ve gruplar arası farklılıklar istatistiksel açıdan önemli bulunmuştur (P<0.01). En yüksek ve en düşük spesifik büyüme oranı değerleri sırasıyla, tekli yetiştirilen kaynak ve Karadeniz alabalığında hesaplanmıştır (P<0.01). En yüksek ve en düşük kondisyon faktörü değerleri sırasıyla, ikili yetiştirilen kaynak alabalığı ve tekli yetiştirilen Karadeniz alabalığında hesaplanmıştır (P<0.01). Tekli yetiştirilen Karadeniz alabalığı grubunda yem değerlendirme oranı diğer gruplara göre yüksek bulunmuştur (P<0.01).

Anahtar sözcükler: *Kaynak alabalığı, Karadeniz alabalığı, İkili yetiştiricilik, Büyüme performansı, Yem değerlendirme oranı*

İletişim (Correspondence)
☎ +90 462 7522805
✉ nbascinar@gmail.com

INTRODUCTION

Aquaculture is rapidly gaining importance in Turkey as in many countries of the world. It started with the culture of rainbow trout in the 1970s, but it did not considerable gain a commercial status until the 1990s. The development of a sustainable industry requires species diversification and application of appropriate management procedures. Culturing more than one salmonid species in farms may provide one viable alternative. In this respect, species of genus *Salvelinus* and *Salmo* have drawn considerable attention in recent years [1,2]. Brook trout *(Salvelinus fontinalis)* introduced from Europe to Turkey has been farmed in small quantities in rainbow trout farms in the last two decade. Culture possibilities of native Black Sea trout *(Salmo trutta labrax)* were evaluated by the Department of Fisheries Technology at the Faculty of Marine Sciences at Karadeniz Technical University [3], the Ministry of Agriculture and Rural Affairs and the Central Fisheries Research Institute [4,5]. Studies of these institutions revealed that the growth performance of Black Sea trout was not at a more desired level than rainbow and brook trout.

Polyculture is the way of simultaneously producing more than one fish species in the same rearing space [6,7]. The principle of polyculture is based on the fact that cultured fish species feed on different levels of food chain and environment [8], but wild species can be stocked with domesticated species to get them used to artificial feed. In this case, increasing food intake due to competition and social hierarchy can affect fish growth positively. At the same time, uneaten feed by wild species consumed by domesticated fish, and feed efficiency is maintained [9].

Between Black Sea trout, a new finfish species for aquaculture [4], and domesticated brook trout may occur competition for food in same culture medium. Whether the increase in feed consumption, and growth performance depending on feed consumption of Black Sea trout, dueculture of these species may be practiced by fish farmers. The objectives of the present study are to compare growth performance and feed conversion ratios of brook trout and Black Sea trout in monoculture and duo-culture tank reared conditions.

MATERIAL and METHODS

The growth trial, which lasted 224 days, was carried out between November-June at the Prof. Dr. İbrahim OKUMUŞ Aquaculture Research and Production Unit at Karadeniz Technical University. The fish were about 9-month-old hatchery reared brook trout and Black Sea trout with initial weights of 24.18±0.64 (n=60) and 23.87±1.11 (n=60) g, respectively. Fish were kept in 0.2 m^3 fiberglass tanks. Nine tanks were used and the fish were equally allotted to 3 groups with tree replicates and fed for 240 days. Each tank contained 20 fish from each species for monoculture and 10+10 fish from each species for duo-culture. Rearing tanks were supplied with freshwater at flow rates of 2 to 12 l/min depending on the fish size, temperature and oxygen content of water and the fish were exposed to natural photoperiod (latitude = 41°N) and temperature regimes.

Fish were fed to apparent satiation with commercial dry extruded pellets of 3 and 4 mm containing 48% crude protein and 18.0% crude lipid. Feed was manually given three times a day (at 8:30, 12:30 and 16:30 h). Pellet size and daily feeding frequency were changed according to recommendations of the feed manufacturer. Growth was followed by bulk-weighing the fish in each tank (within 0.1 g accuracy limit) at two weekly intervals, and total lengths (±1 mm) and individual live weights (±0.1 g) were noted down to determine condition factors.

The following parameters were calculated from the data collected: Specific Growth Rate (SGR, %/day) = $[(\ln W_t - \ln W_0)/t] \times 100$; Condition Factor (CF) = $(W / L^3) \times 100$; Feed Conversion Ratio (FCR) = Feed consumed/ Biomass increment; where W_0 and W_t are live weights (g) of the fish at the beginning and a successive weighing, respectively; t is number of days and L is total length of the fish (cm).

The mean and standard deviation (±sd) were calculated for all parameters in each group and one-way analysis of variance (ANOVA) [10] and Tukey were used to test for differences among the groups. All data analysis and statistical testing were carried out using the Minitab (13.0) statistical software.

RESULTS

Daily water temperatures ranged from 6.5 to 16.5°C, and dissolved oxygen content of incoming water was the highest (over 10 mg/l) in winter, but dropped to a minimum value of 8.7 mg/l in June. At the end of study, mean live weight of brook trout and Black Sea trout increased 265.47±17.25 g and 206.18±2.95 g in monoculture, and 235.53±10.25 g and 222.47±14.29 g duo-culture, respectively *(Fig. 1)*, and significant differences were found among the groups ($P<0.01$) *(Table 1)*. The highest and lowest specific growth rates *(Fig. 2)* were found in brook trout and Black Sea trout in monoculture ($P<0.01$), respectively. The highest and

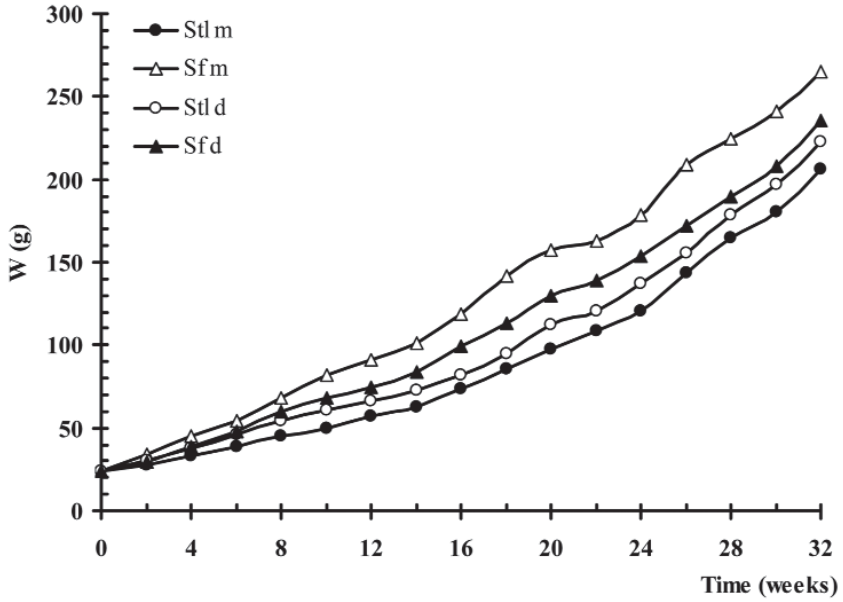

Fig 1. Increments in live weight (W; g) of the experimental fish during the trial period

Şekil 1. Çalışma süresince balıklarda canlı ağırlık (W; g) artışı

Table 1. *Mean (±SD) growth (Wi: initial and Wf: final weights; SGR: specific growth rate; CF: condition factor; D: stocking density) and, feed conversion ratio (FCR) parameters (m: monoculture; d: duo-culture)*

Tablo 1. *Ortalama (±SD), büyüme (Wi: ilk ve Wf: son ağırlık; SGR: spesifik büyüme oranı; CF: kondisyon faktörü; D: stoklama yoğunluğu) ve yem değerlendirme oranı (FCR) parametreleri (m: tekli kültür; d: ikili kültür)*

Parameter	Sf m	Stl m	Sf d	Stl d	F	P
Wi (g)	24.10±0.34	24.25±0.77	23.91±1.11	23.83±1.12	0.11	>0.05
Wf (g)	265.47±17.25 [a]	206.18±2.95 [d]	235.53±10.25 [b]	222.47±14.29 [c]	12.66	<0.01
SGR	1.071±0.026 [a]	0.955±0.015 [c]	1.021±0.017 [b]	0.996±0.018 [b]	18.59	<0.01
CFi	1.079±0.015	1.068±0.007	1.092±0.011	1.088±0.035	1.32	>0.05
CFf	1.400±0.051 [b]	1.288±0.002 [c]	1.578±0.081 [a]	1.352±0.04 [b]	17.04	<0.01
FCR	0.909±0.020 [a]	1.019±0.014 [b]	0.925±0.023 [a] *		28.35	<0.01
Di (kg/m3)	2.39±0.003	2.38±0.006	2.38±0.002 *		1.39	>0.05
Df (kg/m3)	26.54±1.725 [a]	20.62±0.295 [b]	22.90±0.853 [b] *		22.38	<0.01

*: duo-culture value of Sf and Stl

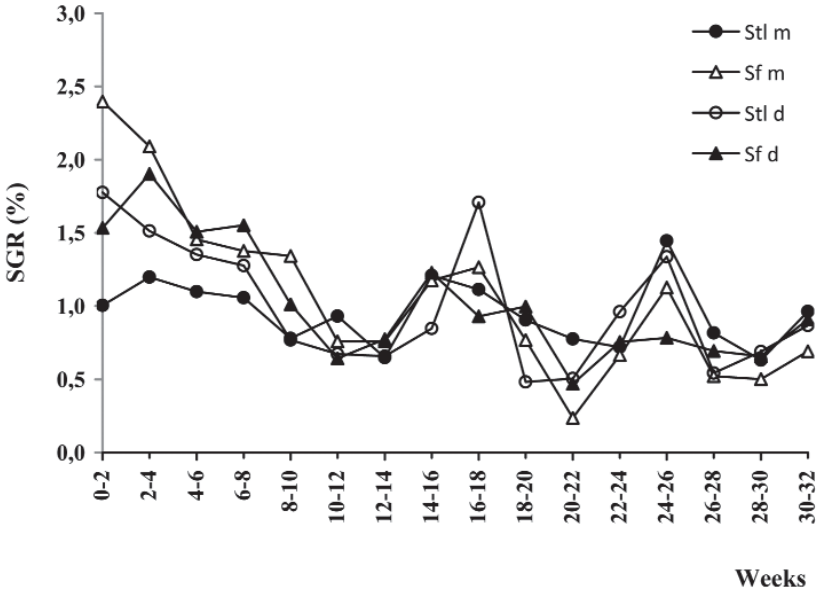

Fig 2. Variations of specific growth rates (SGR; %) of the experimental fish during the trial period

Şekil 2. Çalışma süresince balıklarda spesifik büyüme oranı (SGR; %) değişimleri

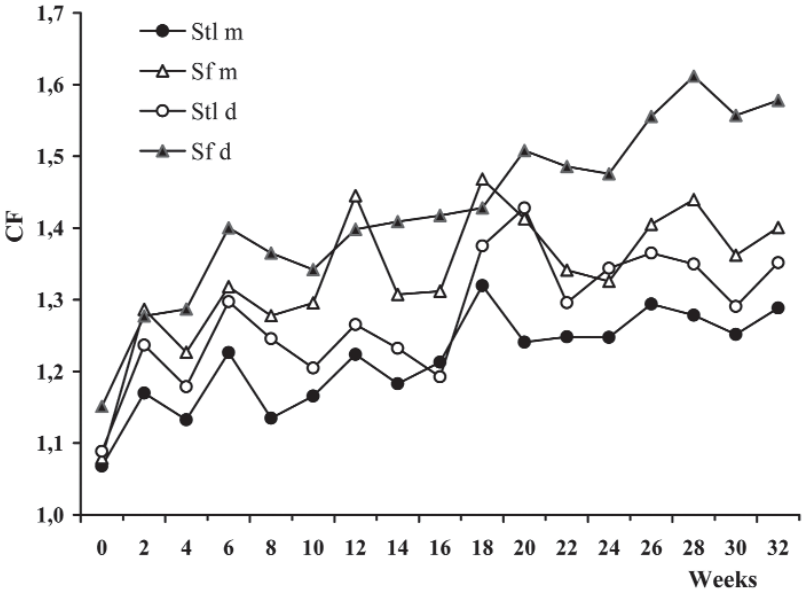

Fig 3. Variations of condition factors (CF) of the experimental fish during the trial period

Şekil 3. Çalışma süresince balıklarda kondisyon faktörü (CF) değişimleri

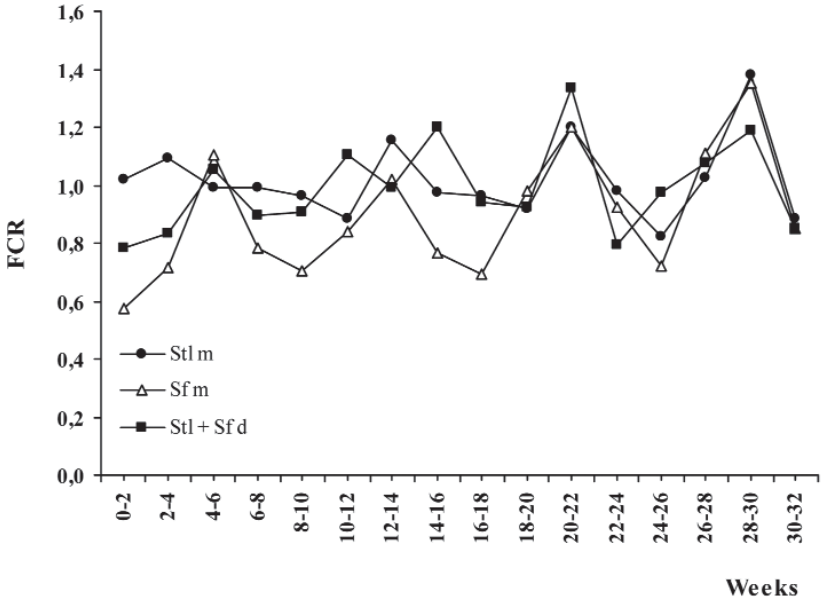

Fig 4. Variations of feed conversion ratios (FCR) of the experimental fish during the trial period

Şekil 4. Çalışma süresince balıklarda yem değerlendirme oranı (FCR) değişimleri

lowest final condition factors were calculated as 1.578±0.081 in duo-cultured brook trout and as 1.288±0.002 in monocultured Black Sea trout (P<0.01), respectively, and the others were similar *(Fig. 3)*. The feed conversion ratio (FCR) *(Fig. 4)* for Black Sea trout was higher than it was for the other groups (P<0.01) *(Table 1)*. No fish died during the trial.

DISCUSSION

The fact that mortality is not seen at stocking densities which are not high (20-26 kg/m^3) shows that feed consumption, food conversion rates (FCR) and growth ratios and the properties of research environment are acceptable and for this reason, the performance of the fish under the trial conditions is highly satisfying.

Rapid growth, FCR, keeping feed loss at a minimum and the optimal use of stocking container are the most commercially important criteria in fish breeding. The feed which meets qualitative needs of growth in fish must be shared equally among fish in order to secure a rapid and uniform growth. Enequal consumption of feed among individuals may be originating from excessive competitive behaviour because of limited supplies of feed and dominant hierarchy in the group and this results

in a discrepancy in the sizes of individuals [1] and a decrease in the biomass. According to some researchers [1,11], zone defence and a dominant hierarchy is inevitable when Salmonidae family individuals are bred in small groups. In such cases, the bigger and more active individuals occupy higher ranks of the hierarchy and they need more feed and this leads to an unequality in feed consumption [12]. For this reason, competition among individuals and differences in fish size increase in circumstances where it is not always possible to get feed and where fish are given feed 1 to 3 three times a day for short periods [1] and competition for feed becomes a significant factor that hinders growth in juveniles. So, dominant hierarchy and unequal feed consumption are inevitable, as it is in this study, in an environment where two species with different behavioural characteristics are cultured. It is certain in this study that brook trout which adapt to culture conditions more easily and are more active is in a more advantageous position than Black Sea trout in terms of feed consumption and growth. Therefore, the growth differences between brook trout and Black Sea trout in the polyculture group *(Table 1, Fig. 1)* can be attributed to the fact that brook trout formed a dominant hierarchy and got a bigger share of the feed.

It is known that the most suitable temperature for brook trout and Black Sea trout growth is 13 to 15°C [3,9]. In our study, water temperature was at optimum levels only from April to June but, it never dropped below 4°C [13] at which growth virtually came to a halt and rose to sublethal levels (>20°C). Results indicate that both Salmonidae species show noticeable seasonal variations in feed consumption, growth *(Fig. 1, 2)* and condition factors *(Fig. 3)* Similar tendencies in the individuals of the Salmonidae family were observed by other researchers, too [14]. Generally, growth is rapid in Spring months and slow in Winter months. Although this variation is due to changes in water temperature, it has been proved that some species (e.g. *Salvelinus alpinus*) living at high latitudes show seasonal variations of growth even when water temperature is kept constant [12,15]. It is claimed that this reflects the annual rhythms in endogeny, which is controlled by seasonal photoperiods, and longer daytimes in Spring months stimulate growth and shorter daytimes in Autumn and Winter months slow down growth [15]. Besides, feed consumption and growth are affected by factors other than water temperature. Fish size is one of these factors [16,17]. The fact that feed consumption and growth ratios were considerably high at the beginning of the trial and decreased as the fish grew towards the end of the trial confirms this. Actually, it is proved in this study that the relation between water temperature and feed consumption and growth characteristics is not a significant one. Feed consumption and growth ratios decreased in the second month of the trial and this was because water temperature dropped rapidly. Although, water temperature was relatively lower in the next month, an increase in growth ratio was observed because water temperature did not vary much.

Feed quality, feeding activities of a species, stock density, oxygen content of water and genetic line of fish can be cited among other factors that influence growth [18]. It is reported that, generally, daily specific growth rate varied from 0.2% to 1.0% and sometimes reached 4.0% of live weight [19] in brook trout and it varied from 0.17% to 2.04% in Black Sea trout [5]. In the present study, the average daily growth rates were found to be between 0.23% and 2.39% in brook trout and 0.63% and 1.44% in Black Sea trout *(Fig. 2)*. That polyculture Black Sea trout grew more rapidly than monoculture Black Sea trout *(Table 1, Fig. 3)* is because they wanted to get the upper hand in their competition with brook trout for feed. So, it can be suggested that differences between groups are largely because of feed consumption.

Condition factor increased progressively although it varied in all the groups *(Fig. 3)*. This increase is a direct indicator of feed consumption, rapid weight increase and energy accumulation [14]. Although the increasing condition factor is partly due to the fact that stomach and entrails of the fish were filled, it is largely due to tissue growth in the fish since they were deprived of feed before they were weighted [17]. Generally, average condition factor values in brook trout were found to be high. This is because brook trout has a relatively deeper body and it consumes more feed and grows rapidly.

In this study, it was found out that both species had good FCR if the conditions are suitable. Feed conversion ratio, which fell below 1.1, in all three groups proves this *(Table 1)*. Since feed conversion ratio is affected by various such factors as biological value of feed, the ratio of main constituents of feed, stock density, genetic line of fish, fish size, basal metabolic rate, water temperature, feeding method and frequency [16-19], comparing results of different trials may not have a practical value. The estimated feed use values during the study shows that there is no need to overfeed. Similar findings in rainbow trout with weights varying between 0.5 and 1.0 kg were obtained by Storebakken and Austreng [20]. Jobling et al.[16] claims that this is because the maximum feed consumption of the rainbow trout, optimum growth and FCR temperatures showed differences of as much as a few degrees. So, optimum FCR temperature <optimal growth temperature <maximum feed consumption and metabolism rate.

As a result, this study has shown that duo-culture of brook trout and Black Sea trout is disadvantageous for brook trout, which is the more rapidly growing and dominant species, in terms of growth and feed use and it has also shown that polyculture provides a more rapid growth for Black Sea trout compared to monoculture. In the culture mediums, brook trout may be used for increasing growth performance of Black Sea trout, therefore food conversion ratio can be effected possitively.

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