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Short Communication

Effects of Mono- and Duoculture on the Survival and Growth Rate of Juvenile Abant Trout (*Salmo trutta abanticus*) and Brook Trout (*Salvelinus fontinalis*)

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ABSTRACT

Abant trout (*Salmo trutta abanticus*) were reared in mono- and duoculture with brook trout (*Salvelinus fontinalis*) for 140 days to assess the effects of culture strategy on its survival and growth rate. Except survival rate, the growth of abant trout was significantly better in monoculture compared to duoculture. The survival rate of abant trout was 10% higher in duoculture. However, the survival rate and growth of brook trout were found similar in both cultures. The length–weight relationship for both species were also determined and could be summarized by the equation $W=0.009L^{3.032}$ ($r^2=0.89$), $W=0.006L^{2.831}$ ($r^2=0.92$) for brook trout in mono- and duoculture, $W=0.007L^{3.161}$ ($r^2=0.95$), $W=0.009L^{3.062}$ ($r^2=0.93$) for abant trout in mono- and duoculture respectively. The feed conversion ratio (*FCR*) was significantly higher in monocultures than duoculture. The duoculture of both species gave the lowest *FCR*.

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MYÖ mainly performed the experimental work and collected the data. UK analyzed the data and wrote the manuscript.

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Abant trout (*Salmo trutta abanticus* T. 1954) is endemic to the Abant Lake in Turkey (Innal and Erk'akan, 2006). It can be discerned from *S. trutta macrostigma* and *S. trutta labrax* with its red spots on the lateral body (Geldiay and Balık, 1988). It is a non-anadromous species (Kocabas *et al*., 2011). The growth rate of abant trout is slower compared to that of other subspecies of the genus *Salmo* (Uysal and Alpbaz, 2002). In this study, it was reared in mono- and in duoculture with brook trout (*Salvelinus fontinalis*, Mitchill) which is an exotic fish introduced from Europe to Turkey in the 1990s (Innal and Erk'akan, 2006). From a couple of decades, it has been farmed in rainbow trout (*Oncorhynchus mykiss*) farms at a small scale and has not yet been included in the aquaculture production figures of Turkey (FAO, 2015).

Polyculture (*e.g.*, duoculture) is the cultivation of more than one species with complementary feeding habits and behavior in a single place (Lazard and Dabbadie, 2002). Polyculture reduces the cost and solves the problems of sourced feed. The feed expenditure which is rising day by day is the most important factor for maintaining a fish farm.

The aim of the present study was to compare the survival and growth performance of abant trout and brook trout in mono- and in duoculture, and to determine their effects of culture strategy.

Materials and methods

Abant trout (4.54 ± 0.27 cm; 1.04 ± 0.20 g, n=135) and brook trout (4.66 ± 0.29 cm; 1.16 ± 0.33 g, n=135) fry were obtained from Sürmene Faculty of Marine Sciences, Trabzon. They were randomly allocated to two monocultures (possessing only abant trout or brook trout) and one duoculture (50% abant trout; 50% brook trout). Moreover, three replicates of each group comprising 45 fishes were setup. In this way total nine aquaria, each with 10-liter water with recirculating aerated water system where the dissolved oxygen saturation was ensured by means of continuous air bubbling, were used. During the study, the water temperature, pH and dissolved oxygen were (mean ± S.D.) 17.1 ± 1.7°C, 8.1 ± 0.3, and 9.7±0.4 mg/l, respectively. Fishes were fed three times a day (08:30, 12:30, 16:30) with commercial pelleted feed. Commercial trout feed 800-1200 µm was obtained from Çamlı feed Co. Ltd, İzmir Turkey, and commercial trout feed 2mm was obtained from Sibal feed Co. Ltd, Sinop, Turkey. For the first two months they were fed on 800-1200 µm pellet size while for the next three months they were fed with 2 mm pellet size.

At every 28th day, the total length and live body weight of all fishes in each aquarium were recorded.

Various calculations were done using the following formulae.

$$\text{Survival rate (\%)} = N_f \times \frac{100}{N_i}$$

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where N_f is no. of fish at the end of experiment, and N_i is number of fish initially stocked.

$$\text{Specific growth rate (SGR)} = 100 \times \frac{(lnW_f - lnW_i)}{t}$$

where lnW_f is the natural logarithm of the final weight, $lnWi$ is the natural logarithm of the initial weight, t is time (days) between $lnWf$ and $lnWi$.

$$\text{Thermal growth coefficient } (TGC) = \frac{(W_f^{1/3} - W_i^{1/3})}{\sum T}$$

where W_f *is* final weight, W_i is initial weight, $\sum T$ is sum day-degrees °C.

$$\text{Feed conversion ratio} = \frac{Feed\ fed}{Gain\ weight\ of\ fish}$$

$$\text{Length-Weight relationship: } W = aL^b$$

where W is fish weight (g), L is total length (cm), a is y-intercept, b is regression coefficient.

The parameters a and b were estimated by nonlinear regression using the iterative Marquardt method (NLIN procedure, SAS, 9.04.).

The one-way analysis of variance (ANOVA) was used to estimate any significant differences between the mean values obtained on *SGR*, *TGC*, and *FCR*. The data were analyzed for any significant differences by the Sigma Plot 11.0 (Systat Software, San Jose, CA, USA).

Results

The Table I shows survival rate, SGR and TGR of abant trout and brook trout.

The survival rate of brook trout was found to be similar in both mono- and duoculture. However, the abant trout had lower survival rate in monoculture compared to that of duoculture. Though, the survival rate of brook trout was similar in both cultures, but the highest survival rate was showed by abant trout in duoculture. The differences in mean (± S.D.) total length and weight of abant trout in monoculture and duoculture were significant at 140th-day. Abant trout showed a higher increment in length and weight gain in monoculture than in duoculture. Also, abant trout produced a higher value of *SGR* and *TGC* in monoculture compared to that of duoculture. In brook trout mono- and duoculture, except the parameter *b* and *FCR* value, the mean (± S.D.) total length, weight gain, *SGR* and *TGC* on 140th-day were found to be non-significant and both cultures displayed similar increment in length and weight gain. Similarly, the values of *SGR* and *TGC* for brook trout were also found to be similar in mono- and duoculture.

Table II shows FCR values, on day 56th and 140th of monoculture and duoculture. The lowest *FCR* values were produced by duoculture. The monoculture of each species showed significantly higher *FCR* values compared to duoculture.

Table III shows the values of parameter *b* were observed to be different between different cultures for both species. The *b* values of abant trout in mono- and duoculture did not differ greatly. However, the *b* values of brook trout in mono- and duoculture were significantly different. The lowest *b* value of brook trout was observed in duoculture.

Discussion

The length-weight relationship of abant trout and brook trout were observed to be different between their monoculture and duoculture. In monoculture both species obtained a higher value of parameter *b* than the isometric range *b*= 3.0 (Abant trout *b*=3.161, brook trout *b*= 3.032). According to Froese (2006) if the value of *b* exceeds from 3.0, then there will be a slightly positive-allometric growth that means an increase in relative body thickness or plumpness.

In duoculture, abant trout showed *b* value slightly smaller than that of its value in monoculture, but the brook trout displayed the lowest *b* value in monoculture which was 2.831. When *b* is smaller than the isometric range, then, there will be negative-allometric growth in which the body shape will become more elongated (Frose, 2006).

Except the survival rate (%), the abant trout had a poor growth rate in duoculture and gave better growth in monoculture. The lowest *TGC* value was obtained by abant trout in duoculture. Similarly, the abant trout *SGR* value was also lower in duoculture than in monoculture. No similar variance in brook trout growth parameters was found, only its length-weight relationship influenced by duoculture. The mean (± S.D.) values obtained for length, weight, *SGR*, and *TGC* were significantly similar between brook trout mono- and duoculture. Bascinar *et al*. (2010) reared brook trout and Black Sea trout (*Salmo trutta labrax*) in mono- and in duoculture. They observed the growth of brook trout was slightly better in monoculture compared to duoculture. However, the Black Sea trout had comparatively poor growth rate in duoculture than in monoculture. The *FCR* of brook trout in the present study appeared to be similar with that reported by Bascinar *et al*. (2010). Nortvedt and Holm (1991) made the duoculture of Atlantic salmon (*Saho*

Table-I.- Survival rate, growth performance of abant trout (*Salmo trutta abanticus*) and brook trout (*Salvelinus fontinalis*) in mono- and duoculture (mean ± S.D.)

		Abant trout			Brook trout		
		Monoculture	Duoculture	p	Monoculture	Duoculture	*p*
Survival rate (%)		77.7%	88.8%		83.3%	84.4%	
Length (cm)	Initial	4.5 ± 0.1	4.6 ± 0.0	0.69	4.6 ± 0.1	4.8 ± 0.1	0.05
	After 140 days	9.3 ± 0.2	8.6 ± 0.3	0.03	10.0±0.4	10.0 ± 0.8	0.99
Weight (g)	Initial	1.04 ± 0.04	1.04 ± 0.06	0.86	1.05 ±0.04	1.19 ± 0.03	0.01
	After 140 days	9.30 ± 0.58	7.19 ± 1.18	0.05	11.1 ± 0.45	12.1 ± 2.21	0.54
TGC	After 140 days	0.11 ± 0.01	0.08 ±0.01	0.06	0.14 ± 0.01	0.15 ± 0.03	0.61
SGR	After 140 days	1.55 ± 0.05	1.37 ± 0.16	0.14	1.68 ± 0.02	1.64 ± 0.13	0.57

Table II.- Feed conversion ratio (*FCR*) of abant trout (*Salmo trutta abanticus*) and brook trout (*Salvelinus fontinalis*) in mono- and duoculture (mean ± S.D.).

Day	Monoculture		Duoculture	*p*
	Abant trout	Brook trout		
at 56th	1.12±0.07	1.36±0.07	1.12±0.12	0.019
at 140th	0.97±0.08	0.95±0.03	0.85±0.04	0.081

Table III.- Length-weight relationship of abant trout (*Salmo trutta abanticus*) and brook trout (*Salvelinus fontinalis*) in mono- and duoculture.

Fish species	Monoculture	r^2	Duoculture	r^2
Abant trout	$W=0.007L^{3.161}$	0.952	$W=0.009L^{3.062}$	0.939
Brook trout	$W=0.009L^{3.032}$	0.895	$W=0.006L^{2.831}$	0.923

salar) and Arctic charr (*Salvelinus aipinus*), and found that duoculture did not affect the growth performance of Arctic charr but influenced only the condition factor (condition factor is an expression of the relationship between fish length and weight). In Nortvedt and Holm (1991) study Atlantic salmon showed better growth performance in duoculture compared to monoculture. However, Holm (1989) also made the mono- and duoculture of Atlantic salmon and Arctic charr, and reported that the duoculture fish were significantly larger than the monoculture fish. Using floating cage, Hussain and Khatoon (2000) made the mono- and duoculture of *Lutjanus johni* and *Pomadasys kaakan*, and reported that *P. kaakan* had higher production in monoculture. Jobling *et al*. (1998) reared Baltic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) in monoculture and in duoculture and observed that the growth of brown trout was significantly same in both culture types while Baltic salmon reared in duoculture had a poor growth rate than those reared in monoculture. According to Jobling *et al*. (1998) the Baltic salmon may have been subjected to increased levels of aggression by possibly interaction with the heterospecific brown trout that resulted in the poor growth rate of Baltic salmon in duoculture. However, several published studies suggest the improved growth of salmonids in duoculture due to the reduced levels of aggressive interactions (as cited in Jobling *et al*., 1998).

In conclusion, contrary to expectation the abant trout held in duoculture with brook trout did not display better growth rate than those reared in monoculture. The result suggested that the rearing of abant trout with brook trout is not a good choice as it will result a poor growth rate of abant trout. Therefore, further studies are required on its culture with other fish species especially Salmonidae to obtain its better growth in polyculture. Though the growth of brook trout was significantly similar but its length-weight relationship in duoculture was found to be below the isomeric range (3.0) that indicates the duoculture also has a small negative influence upon the brook trout.

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