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Compensatory Growth in Sea bass (*Dicentrarchus labrax*), Sea bream (*Sparus aurata*) and Rainbow trout (*Oncorhynchus mykiss*)

Temel ŞAHİN, Bilal AKBULUT, Muharrem AKSUNGUR
Central Fisheries Research Institute, Şana, Trabzon-TURKEY

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Abstract: The effects of a period of starvation and subsequent refeeding on the weight and length of sea bass, sea bream and rainbow trout reared at 17‰ salinity and at different temperatures were investigated. The fish were starved for 3 weeks and then fed *ad libitum* by hand for 3 weeks in the 3 periods studied. The study provided evidence of the adaptation of the fish to starvation followed by what may be termed compensatory growth once feeding was resumed. The length changes of the fish indicate that the weight gains were due to grojth rather than increases in gut fat deposits or increased water uptake.

Key Words: Compensatory Growth, Sea bass, *Dicentrarchus labrax,* Sea bream, *Sparus aurata,* Rainbow trout, *Oncorhynchus mykiss*

Levrek (*Dicentrarchus labrax*), Çipura (*Sparus aurata*) ve Gökkuşağı Alabalığı (*Oncorhynchus mykiss*)'nda Açlıktan Kaynaklanan Büyüme Kaybının Dengelenmesi

Özet: Bu çalışmada, bir dönem aç bırakma ve tekrar yemlemenin ‰17 tuzluluk ve farklı sıcaklıklardaki deniz suyunda yetiştirilen levrek, çipura ve gökkuşağı alabalığında boy ve ağırlıkça büyümeye etkileri araştırılmıştır. Üç aşamada gerçekleştirilen çalışmada, balıklar 3 hafta aç bırakılmış ve bu dönem sonunda tekrar el ile günde 3 kez serbest yemleme yöntemiyle yemlenmiştir. Açlık döneminden sonra tekrar yemleme ile büyümenin devam etmesi balıkların açlığa adepte olduğunu ve boy artışları, balıklardaki ağırlık kazancının su yutması veya iç organlarda yağ birikmesinden ziyade balıkların büyüdüğünü göstermiştir.

Anahtar Sözcükler: Levrek, *Dicentrarchus labrax,* Çipura, *Sparus aurata,* Gökkuşağı alabalığı, *Oncorhynchus mykiss,* Büyüme, Açlık

Introduction

Compensatory growth is a term used to describe a period of increased growth rate which occurs following a growth restriction imposed earlier. The mechanisms governing compensatory growth have been studied by a number of workers (1, 2, 3, 4, 5).

Wilson and Osbourn (1) reported that one of the first references on the subject was in 1908 with regard to beef steers. Some years later, Osborn and Mendel (5) described how rats that had been restricted in growth exhibited greater rates of gain once the restriction was removed. Later, Bohman (6) termed faster rate of growth relative to age "compensatory growth".

An animal whose growth has been slowed by nutritional deprivation may exhibit an enhanced rate of growth when realimented. If this exceeds the maximal rate of gain when adequate nutrition has been provided, the animal is said to have undergone compensatory or catch-up growth (7). Some workers (8) feel that catch-up growth is a more precise term because the word compensatory suggests excessive growth of a body part in compensation for loss of part of its function.

Following these earlier experiments of Osbourn and Bohman, other trials have demonstrated compesatory growth in a number of animals, including cattle (9), swine (10, 11), poultry (1, 12, 13), sheep (14) and rainbow trout in fresh water (15).

Agriculturists are aware of the phenomenon of compensatory growth. In essence, this is a phase of rapid growth, greater than normal growth rates associated with adequate refeeding of animals following a period of weight loss caused by undernutrition.

There is little data on this phenomenon in fish, as most studies have been concerned with the effects of temperature, ration size and size of fish on growth rates rather than regimes of feeding after starvation on three firsh species–sea bass, sea bream and rainbow trout–in Black Sea conditions (17‰ salinity).

Material and Method

A total of 180 sea bass (*Dicentrarchus labrax* L., 1758), approximately 19 months old, and 120 sea bream (*Sparus aurata* L., 1758), approximately 19 months old, obtained from Bodrum-Muğla, and 120 rainbow trout (*Oncorhynchus mykiss* Walbaum1792), approximately 9 months old, obtained from Trabzon, were used. The fish were kept in sea cages located in the Yomra fishing shelter on the eastern Black Sea coast. The fish were acclimatised prior to the experiments. Sea bass were divided into 3 experimental period groups. Three experimental periods were studied between 08 October 1997 and 13 February 1998, for a period of 6 weeks. In each experimental period, the fish were divided into 2 subgroups, A (n=30) and B (n=30), and then placed in sea cages (2x2x1.5 m) designed for this study.

Subgroups A were fed for the first 3 weeks (treatment period A1) and then starved for the second 3 weeks (treatment period A2). Subgroups B were starved for the first 3 weeks (treatment period B1) and then fed for the second 3 weeks (treatment period B2).

All fish in the groups received a dry pelleted commercial feed of the following composition: crude protein 47%, crude fat 13%, crude fibre 3%, moisture 11%, ash 13%, calcium 1.35% and phosphate 1.10%. Fish were fed *ad libitium* by hand three times a day. The fish were weighed and measured individually at the beginning and the end of each treatment period. Sea water temperature was measured daily. The Studenk *t*-test was used to test for differences between groups and subgroups, the level of significance beign set at P≤0.05.

Results

Table 1 shows the mean weight of each fish species with subgroups for each 3 experimental periods together with temperature. Except for sea bream in the second period, the fish gained weight when fed and lost weight when starved. Figure 1 shows mean weight change in all fish species in each of the 3 experimental periods, and figure 2 shows comparison of percentage weight change of subgroup A and subgroup B in sea bass.

The results of the comparison of weight gain prior to starvation (feeding, A_1) and weight gain after starvation (feeding after starving, B2) are shown in Table 2. In the first period, there are significant (P<0.01) increases in the weight gain in sea bass and sea bream after feeding, if the feeding is preceded by a period of starvation.

The results of the comparison of the overall (6 weeks) weight gain for subgroup B (starving then feeding) and the weight gain of fish fed during the first 3 weeks for subgroup A (feeding, A1) are shown in Table 3. The mean weight gain for subgroup B (starving and feeding, B1+B2) was greater than the 3-week feeding weight gain of subgroup A (feeding, A1) in the first period in sea bass and sea bream and weight gain was equivalent in rainbow trout in the third period. In the second period, the growth of sea bass and sea bream almost ceased and sea bream lost weight while fish were fed.

The mean percentage length increase associated with each experimental treatments is shown in Table 4. The results show that subgroups A (feeding, A1) and B (feeding after starving, B2) had a greater increase in

Table 1. Mean weight of subgroup A fed then starved and subgroup B starved then fed after each experimental treatment (±standard error).

Periods of study	Fish species	Sub group	Initial weight (g)	Weight after 3 weeks	Weight after 6 weeks	Temperature range (°C)
1st	Sea bass	A	146.6±8.4	158.4±8.7	157.7±9.1	14.5-23.5
08 Oct.-20 Nov. 1997		B	159.0±10.0	146.6±9.1	176.8±11.0	
	Sea bream	A	247.4±7.7	249.3±8.5	247.2±7.7	
		B	234.8±8.3	225.1±7.7	239.5±7.4	
2nd	Sea bass	A	187.6±10.9	189.9±10.7	183.3±10.4	9.0-15.0
20 Nov.-29 Dec. 1997		B	181.3±6.8	169.9±6.4	171.0±7.4	
	Sea bream	A	262.6±11.2	257.7±11.5	251.1±11.0	
		B	261.6±9.0	251.6±13.8	242.7±8.5	
	R. trout	A	158.1±5.8	267.5±8.7	257.0±10.8	
		B	141.7±4.8	131.0±4.6	197.3±6.7	
3rd	Sea bass	A	206.2±9.6	210.2±8.6	204.5±7.8	7.0-10.0
29 Dec.-13 Feb. 1998		B	205.5±10.00	193.6±9.4	194.8±10.1	
	R. trout	A	153.3±5.6	240.2±8.1	205.7±6.9	
		B	147.1±4.2	141.3±4.1	233.8±9.8	

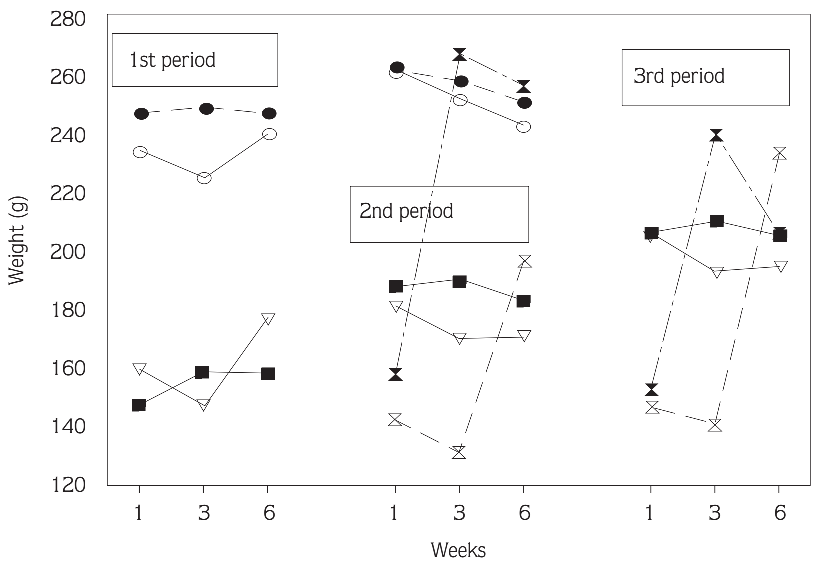

Figure 1. Mean weight change of sea bass, sea bream and rainbow trout

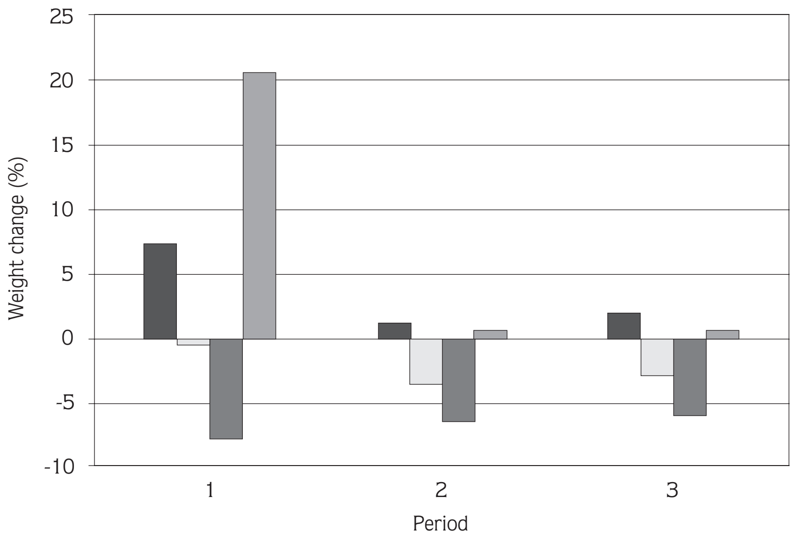

Figure 2. Weight change (%) of sea bass in the 3 experimental periods

Table 2. Comparison of mean weight gain of treatment periods A1 (fish fed for 3 weeks) and B2 (fish fed for 3 weeks after being starved).

Fish species	Periods of study	Mean weight gain (g) A (feeding, A1)	Mean weight gain (g) B (feeding after starving B2)	t-value	d.f.	P
	1	11.8	30.2	-7.1	28	<0.01
Sea bass	2	2.3	1.1	0.01	29	>0.05
	3	4.0	1.2	0.2	29	>0.05
Sea bream	1	1.9	14.4	-7.8	29	<0.01
	2	-4.9	-8.9	3.5	28	<0.05
R. trout	2	109.4	66.3	12.2	29	<0.05
	3	86.9	92.5	1.0	29	>0.01

Fish species	Periods of study	Mean weight gain (g) A (feeding, A1)	Mean weight gain (g) B (starving and feeding, B1+B2)
	1	11.8	17.8
Sea bass	2	2.3	-10.3
	3	4.0	-10.7
Sea bream	1	1.9	4.7
	2	-4.9	-18.9
R. trout	2	109.4	55.6
	3	86.9	86.7

Table 3. Comparison of overall weight gain of subgroup B (fish starved and fed for 3 weeks) with the weight gain of A1 (fish fed for 3 weeks)

		Length changes (%)			
		Subgroups			
Fish species	Periods	A1	A2	B1	B2
Sea bass	1	4.1	1.8	0.4	3.8
	2	1.5	0.0	0.3	1.4
	3	0.2	0.2	0.1	0.6
Sea bream	1	3.0	0.0	0.0	3.3
	2	0.2	0.0	0.0	0.0
R. trout	2	15.2	3.9	1.9	7.1
	3	9.1	3.6	1.6	11.8

Table 4. Mean length change (%) during each period of study and under each experimental treatment

length than did subgroups A (starving after feeding, A2) and subgroup B (starving, B1). This indicates that the weight increase after a period of starvation is associated with an increase in length and can therefore be considered as growth and not merely an increase in gut fat deposits or increased water uptake.

Discussion

In many temperate fish species, growth rates tend to be high in the spring and summer whereas in autumn and winter growth rates are low and many fish may lose weight. If the amount of food is reduced, the fish first lose weight, but then became "adapted" to the new level of feeding, so that they gain weight (15, 16). It was therefore found necessary to reduce the food still further, until there was no further adaptation. When the amount of food was then increased, the fish soon became adapted to the high level of feeding and did not increase in weight proportionally to the extra food given. Thus, the fish showed a maximum efficiency of utilisation of food after a period of food restriction (15, 16, 17).

After the starvation period there is increased efficiency of food utulisation, as shown by the surge of growth following feeding. This growth is termed "compensatory growth" and this phenomenon occurred throughout the year and may be temperature-related. Increase in temperature increases the respiratory metabolism of fish and there is an increase in the maintenance requirement and a more rapid loss of weight during starvation (15, 17, 18).

Tolerable temperatures for sea bass and sea bream range from 5 to 28°C, and the optimal temperature is 22-24°C (19, 20, 21, 22). Tolerate temperature for rainbow trout change from 1 to 25°C and optimal temperature is 12-18°C for best growth. Rainbow trout can be adapted and grow up to high salinity (32‰) values (17).

Some authors reported that growth almost ceased in sea bass (23) and sea bream (24) when temperature dropped below 16˚C and fish lost weight below 12˚C (23, 24, 25). In this study, sea bream lost weight while they were fed, and weight losses were higher in subgroup A (feeding, A1) than in subgroup B (feeding after starving, B2) in the second period. This may be related to low temperature.

Dobson and Holmes (15) have found weight losses in rainbow trout reared between 3-9˚C in experimental conditions and they reported that the phenomenon of compensatory growth occurred in weights above 100 g. It is possible that the fish expended less energy counteracting osmotic forces in this study than in fresh water, although some authors (26) have stated that salinity itself is not a significantly growth promoting factor. However, it was established that food intake was significantly higher when the fish were fed *ad libitum* in sea water than in fresh water (27, 28). In this study, the compensatory growth produced with *ad libitum* refeeding by hand after a 3-week period of starvation may be related to temperature.

In conclusion, a simple change in feeding practice, with a consequent halving of food costs, produces growth rates equivalent to the farm's normal rates. The duration of feeding and starving studied here may not be appropriate to all farm situations and may result in problems with disease, but the phenomenon certainly warrants further investigation.

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