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Growth of rainbow trout (*Oncorhynchus mykiss*) reared in floating cage in the Bay of Kotor

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ABSTRACT

Rainbow trout fingerlings (85 g) were grown out in floating cage in the Kotor Bay. Experiment lasted 84 days (December-February), and fish were fed on a pelleted trout feed distributed manually, in a daily amount to 2% of the fish weight. Fish were measured individually (length, weight) at the approximately 2-weeks intervals. Mortality, water temperature and salinity were monitored daily. The final average weight of fish was 4 times higher than the initial one. The values of all production indicators were within ranges reported for practical production conditions, thus confirming suitability of Bokakotorska area for this type of aquaculture.

Key words: rainbow trout, growth, mariculture, floating cage

INTRODUCTION

At the global scale, aquaculture is rapidly growing industry with significant contribution to global supplies of food products. Since 1970, the sector has grown at average annual compounded rate of 8.9%, while over the same period the capture fisheries and terrestrial farmed meat-production systems have grown at average annual rates of 1.2% and 2.8%, respectively (FAO, 2004; cited by Crab et al., 2007). Marine aquaculture (mariculture) includes production of finfish, molluscs, crustaceans and aquatic plants.

The Montenegrin coast extends in northwest-southeast direction, between 41° 51' N, and 18° 30' E, with a coastline of approximately 294 km of which around 106 km belong to the Bay of Kotor. Despite the relatively small area, along the coast of Montenegro numerous localities are exceptionally suitable for mariculture (Morović, 1974; Kinne & Rosenthal, 1977; Regner et al., 1999; Borović et al., 2000). Moreover, Hegediš (2007) and Mićković (2009) studied potentials of developing ell and mullet culture in the Montenegro. However, the culture of marine organisms is still poorly developed. At present finfish production is practiced on only two farms located in the Boka Kotorska Bay, producing sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata*). On the other hand, authorities at country and local levels adopted several strategies towards development of marine culture in the coastal area. In accordance with officially expressed readiness to support mariculture development a pilot study on the possibilities of rainbow trout production in waters of Bay of Kotor was carried out. The study was conducted as a part of strategic developmental programme "Development of new technologies in marine food and drug industry", aiming to contribute in development of mariculture in the area. In addition, the study is an attempt to promote diversification of cultured fish.

MATERIAL AND METHODS

The pilot experiment was performed at the Institute for Marine Biology in Kotor, and the experiment lasted for 84 days (03. 12. 2001 - 24. 02. 2002). In total 615 rainbow trout (85.36 g average weight, 19.68 average total length, 52.5 kg biomass) were obtained from a commercial farm (Rastovac Fish Farm, Niksic). While transported (2 plastic tanks each

1m^3 volume, aerated with pure oxygen) fish were slightly anesthetised (MS 222). The fish were stocked in floating net cage (3x3 m, 22.5 m^{-3} working volume, temperature varied from 12.60 °C at surface to 19.53 °C at 8 m depth and salinity varied from 7.57 ‰ to 36.26 ‰ for corresponding depth column), deployed over the 15 m depth in the sea cove in front of the institute. Behaviour and survival of the stocked fish were monitored during the following five days, and no mortality was observed. Since absolute survival was recorded during this acclimation period, feeding started and fish were fed on a pelleted trout feed (Biomar, Denmark; 43-45% crude protein, 13-15% crude lipid, granulation 3 and 4), distributed manually, in a daily amount to 2% of the fish weight. Daily feeding rate was distributed in three equal portions (08:30, 11:30 and 14:30). At the approximately 2-weeks intervals (depending on weather conditions) control samples were harvested and number of measured fish varied between 2.6% and 11.1% of total stock. Fish were weighed individually (± 1 g), under light anaesthesia (MS 222), taking at the same time their total length (± 1 mm). The daily food ration (2% of biomass) was re-adjusted to biomass following each measurement.

The growth rate was determined according to the exponentional growth expression:

$$W_t = W_i e^{bt} \text{ or } L_t = L_i e^{bt}$$

where W_t and L_t represent, respectively, body mass (in grams) and total length (in cm) after t days, W_i and L_i stand for the initial body mass and length values, while b is the growth coefficient (Elliot, 1975). Mean rates of change of live weight (G_W) and total length (G_L) were derived from the respective growth coefficients ($G_{W,L}$ = 100b) obtained by regression analysis (*ibid.*). Calculations and statistical analysis were performed using

Statistica 6.0 package (StatSoft). The feed conversion ratio (FCR) was calculated as amount of feed offered per biomass gain. Mortality, water temperature and salinity (both parameters along the 8 m depth gradient) were monitored daily.

RESULTS

The monthly variations of water temperature and salinity along the measured depth gradient are given in Table 1. The stratification of temperature and salinity is distinct throughout the entire rearing period. Both parameters were lowest at the near surface depth (0.5 m), increasing gradually to the deepest measuring points at 8 m depth. Monthly absolute amplitudes were 5.35 °C, 4.16 °C, 2.02 °C, and 18.64 ‰, 14.62 ‰ and 26.24 ‰ for temperature and salinity, respectively. It is evident that salinity varies considerably with brackish conditions prevailing along the upper half of the monitored depth gradient.

Table 1. Average temperatures (°C) and salinity (‰) by depth and month and average overall monthly values.

Parameter	Temperature (°C)			Salinity (‰)		
Depth (m)	Dec.	Jan.	Feb.	Dec.	Jan.	Feb.
0.5	10.25	10.63	11.60	18.16	21.71	8.73
1	12.50	10.60	12.40	24.80	21.53	19.8
2	13.70	13.60	13.02	28.12	31.71	26.22
4	14.45	14.46	13.20	34.25	34.25	28.48
8	15.60	14.79	13.62	37.24	36.33	34.97
Average	13.30	12.85	12.76	28.51	29.10	23.51

Changes in total length of reared fish over rearing time is shown in Figure 1. Growth in length slightly fluctuated up to the 37th rearing day, but from day 37 onwards fish growth exhibited nearly linear pattern. For the entire farming period the gain in length of 9.03 cm was recorded.

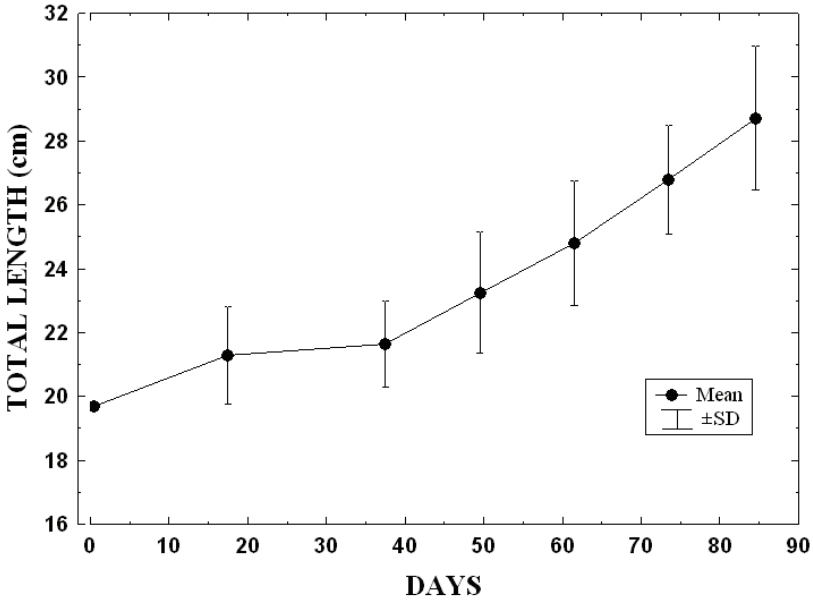

Figure 1. Growth in total length of rainbow trout over 84 rearing days

In Figure 2, the changes in mean weights of reared fish recorded during the experimental trial are depicted. Growth in weight was exponential and final individual mean weight amounted 396.04% of the initial individual mean weight. However, over the rearing period an increasing of heterogeneity in growth within the individuals of the particulate rearing period was noted.

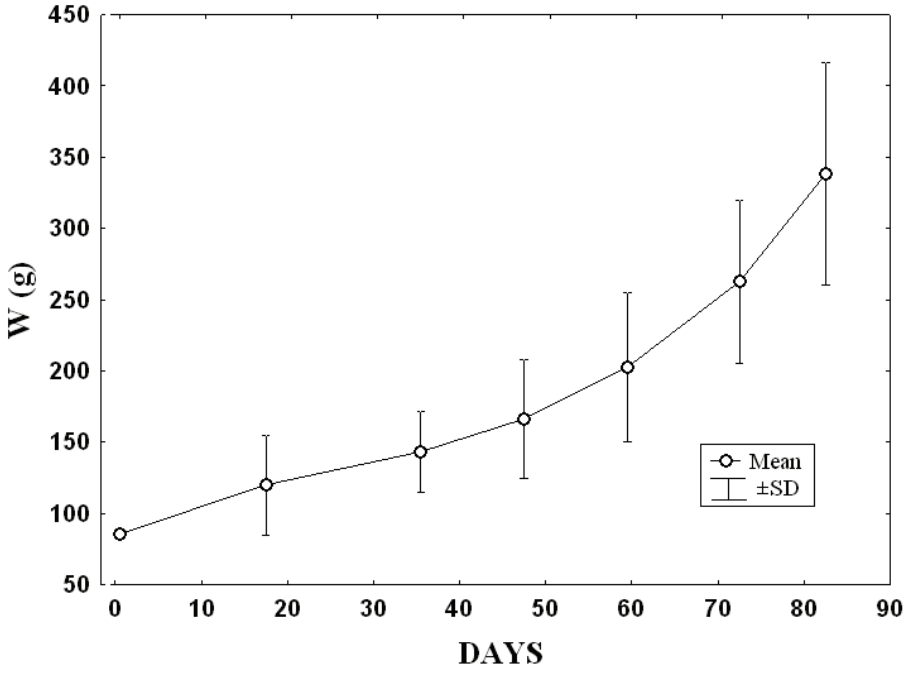

Figure 2. Growth in weight of reared rainbow trout.

Since the growth curves exhibited exponential rates of change, they were linearized and specific growth rates (G_L, G_W) were obtained by regression analysis (Fig. 3). Corresponding equations, mean specific growth rates of increase in length and weight, and correlation coefficients (both highly significant) are presented in the same figure.

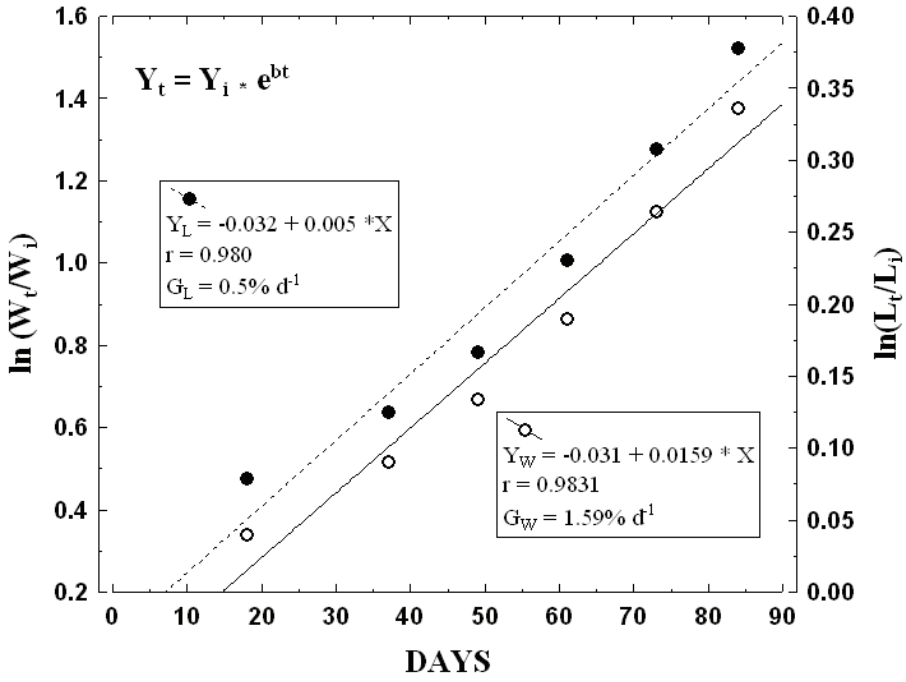

Figure 3. Mean specific growth rate in total length (G_L) and weight (G_w) of reared fish.

Table 2 presents summarized basic production results of the rearing trial. Mortality was low, amounting 2.28% of the initially stocked number of fish. In comparison to the initial values, the final mean weight increased approximately for times, and total biomass reached 203 kilograms. Stocking density in terms of number remained practically identical, while in terms of biomass increased four times. Mean specific growth rates were 0.5% and 1.59% for length and weight, respectively. Feed conversion ratio was lower than one.

Table 2. Summarized results of trout production farmed 84 days in floating cage in the Bay of Kotor: G_L – mean specific growth rate in length; G_W – mean specific growth rate in weight; FCR – feed conversion ratio.

Indicator	Initial	Final
Number of fish	615	601
Average weight (g)	85.36	338.06
Biomass (kg)	52.5	203.2
Stocking density (ind. m^{-1})	27.33	26.71
Stocking density (kg m^{-3})	2.33	9.03
No. of rearing days		84
No. of feeding days		74
G_L (% d^{-1})		0.5
G_W (% d^{-1})		1.59
Offered feed (kg)		138.3
FCR		0.92

DISCUSSION

The rearing of salmonids in seawater was first successfully carried out in Norway around 1955 and since then has increased rapidly spreading in other parts of the world (Huet, 1994). Maricalture of rainbow trout concerns growing-up phase in the production process, and fingerlings when they measure 15-20 cm and weigh > 50 g can be transferred directly from fresh water into the sea (Landless, 1976; Teskeredžić et al., 1989, Huet, 1994). The fish grow better in brackish than in fresh water (Sititonen, 1986; Teskeredžić et al., 1989), however growth declining could be observed in salinities greater than 24 ‰ (McKay & Gjerde, 1985).

Although the Bokakotorska Bays were recognized as a suitable area for marine aquaculture for decades (Morović, 1974; Kinne & Rosenthal, 1977) and particularly for trout production in floating cages (Teskeredžić et al., 1989), no efforts have been made in latter direction. Actually, our experiment on possibility of farming rainbow trout in brackish waters

represents first attempt in introduction of this species in marine aquaculture sector of Montenegro. Obtained physiochemical (temperature and salinity) characteristics were in the ranges that are considered as suitable for growth of rainbow trout under brackish water conditions (McKay & Gjerde, 1985; Austreng et al., 1987; Teskeredžić et al., 1989). At the end of 84-days rearing period, fish were on average approximately four times heavier and reached marketable size. This result gains in importance having in view that feeding of fish was halted during 10 days (11.9% of trial duration), which certainly have had a negative effect on final growth results. Mortality was low, while the recorded feed conversion ratio was within the ranges reported for commercial food by other researchers, under either practical production or experimental conditions (Austreng et al., 1987; Davidson et al., 2009; Teimouri et al., 2013). Moreover, the mean specific growth rate in weight was relatively high and was within the range expected on the ground of literature data for practical production conditions (Austreng et al., 1987).

It is clear from the present results that farming of rainbow trout in floating cages is applicable in the area of Bokakotorska Bay. According to recorded results, by stocking rainbow trout fingerlings > 50 g, it is possible to obtain more than one production cycle of marketable fish (> 300 g) during the late autumn to early spring period. Furthermore, the important result of the present study was that a quite acceptable average body weight of fish was achieved by a feed conversion lower than 1, and that it was accompanied with high survival rate.

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