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Growth and Sex Ratio of Juvenile Olive Flounder (*Paralichthys olivaceus*) at Different Size-ranks

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The aim of this study was to assess whether size-rank at the juvenile stage is associated with growth performance and sex ratio in olive flounder (*Paralichthys olivaceus*). Juveniles (mean body weight, 8.8 ± 0.9 g) were selected from two age groups, with the high size-rank group (HSRG) fish in the upper 19.3-67.3% of 104 days post-hatching (dph) age group and the low size-rank group (LSRG) fish in the lower 9.0-55.7% of 116 dph age group. Triplicate groups of 100 fish were reared over 32 weeks. A heavier final body weight was observed in the HSRG (360 ± 12 g) compared to the LSRG (315 ± 9 g, $P<0.05$), whereas no differences in feed intake, feeding efficiency, and mortality were seen between the experimental groups. The percentage of females was significantly higher in the HSRG (51.7%) than in the LSRG (30.8%, $P<0.05$). In addition, a remarkable increase in growth was recorded in females, indicating that the relative frequency of females increased with a body weight increase. The results suggest that high size-rank juvenile olive flounder have better growth performance and a higher percentage of females, because females start growing faster than males before size grading occurs.

Key words: Growth, Olive flounder, Sex ratio, Size-ranking

Introduction

Growth variation and size-ranks in olive flounder (*Paralichthys olivaceus*) generally start to appear at the early larval stage and become more noticeable as they settle, which could lead to size-dominant social interactions such as aggressive behavior or cannibalism, and consequently cause high mortality of fingerlings (Dou et al., 2000; 2003; Sakakura and Tsukamoto, 2002). Size grading in cultured flounder could be an important and necessary operation to improve the growth and survival of juvenile flounder, because small flounder grow significantly faster and have higher survival in the absence of large flounder (Dou et al., 2004; Kim et al., 2005).

However, it is unknown whether there are differences in growth performance between different size-rank groups after size grading, because most previous studies on size-ranking of fish investigated the effect of size grading on social interactions (Sunde et al., 1998; Saillant et al. 2003). In commercial flounder farms, farmers want to purchase higher size-rank flounder juveniles. However, Kamstra (1993) and Kim et al. (2005) showed that the low size-rank group (LSRG), consisting of small individuals, has a higher specific growth rate, feed intake, and feeding efficiency than the high size-rank group (HSRG). These reports differ from the above-mentioned tendency, but differences in body weight at the start of the experiment could have influenced the variation in individual growth performance because growth rate, feed intake, and feeding efficiency are size-dependent. Consequently, the effect of size-rank on fish growth needs to be determined by using the same size fish to remove the size effect.

Female olive flounder grow faster than males when they are stocked together in tanks (Bang et al., 1996). Morphological sexual differentiation in olive flounder occurs 46 and 80 days post-hatching (dph) for females and males, respectively, although this period can vary with rearing conditions (Lee and Lee, 1990). Therefore, the sex ratio of flounder possibly differs between size-rank groups long before the size grading occurs. Based on this hypothesis, the sex ratio difference due to size-ranking could influence the

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relative growth performance of the HSRG and the LSRG. Thus, estimating the sex ratio of olive flounder is particularly important at different size-ranks.

By selecting juvenile olive flounder of the same size from different age groups and rearing them for 32 weeks, we examined whether the size-rank of juvenile fish is associated with growth, feeding efficiency, mortality, and sex ratio.

Materials and Methods

Juvenile olive flounder were produced twice, at an interval of 12 days, from broodstocks maintained at the Genetics and Breeding Research Center, Geoje, Korea, in April 2005. Rearing and feeding conditions were similar for the two age groups throughout juvenile production. On 4 August 2005, juvenile ages were 104 and 116 dph, and their body weights were 8.3 ± 2.9 and 11.3 ± 3.5 g (mean ± SD), respectively. To collect juveniles of the same size from the two experimental groups, fish (mean body weight of 8.8 g) were selected from the two age groups, with the HSRG fish taken from the upper 19.3-67.3% of the 104 dph age group (Fig. 1a) and the LSRG fish taken from the lower 9.0-55.7% of the 116 dph age group (Fig. 1b). The mean body weight of the experimental fish was 8.8 ± 0.8 and 8.8 ± 1.1 g for the HSRG and the LSRG, respectively.

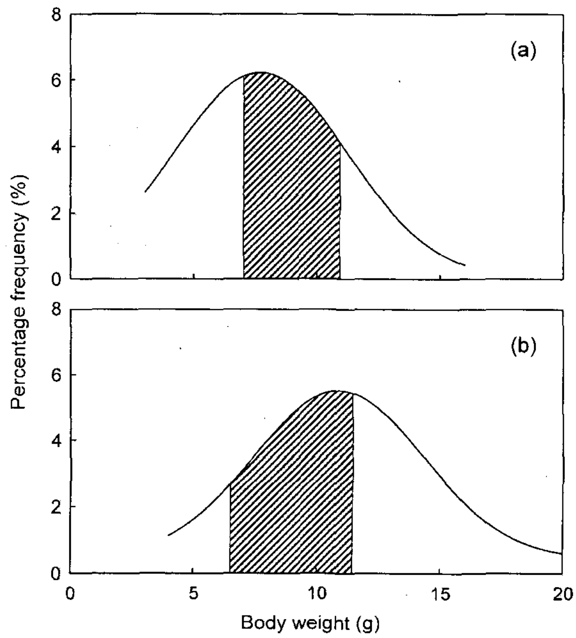

Fig. 1. Selection of the HSRG (a) and the LSRG (b) from 104 and 116 dph age groups of juvenile olive flounder (*Paralichthys olivaceus*), respectively. HSRG and LSRG are represented by diagonal lines.

Triplicate groups of 100 fish were reared over 32 weeks, from 5 August 2005 to 17 March 2006, and held in 2-m^2 green fiberglass tanks (filled with 800 L of seawater) for the first 16 weeks and 6-m^2 green fiberglass tanks (filled with 2,500 L of seawater) for the second 16 weeks, under natural photoperiod and temperature conditions. The water temperature ranged from 10.5 to 25.9°C. The fishes were hand-fed to satiation with commercial extruded diet (Suhyup Feed Co., Korea) twice a day at 09:00 and 17:00.

The fish in each tank were individually weighed at 4-week intervals after being starved for 24 h. Daily feed consumption and mortality were recorded. At the termination of the experiment, all fish were anesthetized by immersion in 400 ppm 2-phenoxy-ethanol (Sigma-Aldrich, St. Louis, USA) and dissected. The phenotypic sex was identified by the ordinary sight of gonads, and the percentage of females was estimated in each tank.

Data are shown as mean ± SE of the triplicates in each group. All data were compared by one-way analysis of variance (ANOVA), followed by Duncan's multiple range test to determine significant differrences between means ($P<0.05$). All statistical analyses were conducted using Statview 8.02, Korean version (SAS Institute, Cary, NC, USA).

Results

Growth performance in body weight was significantly different between the experimental groups of olive flounder from 16 weeks after the start of the experiment ($P<0.05$, Fig. 2). At the end of the experiment, the mean body weight of the HSRG fish (360 ± 12 g) was 14.3% higher than that of the LSRG

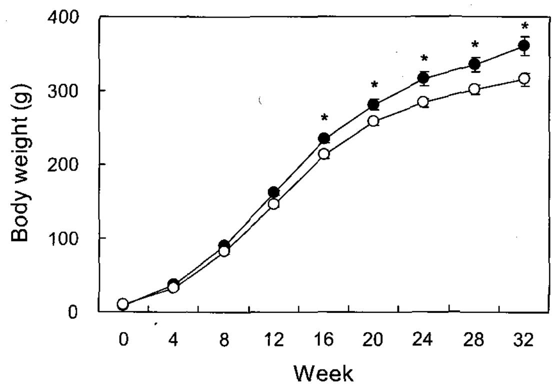

Fig. 2. Mean body weights with standard errors of the HSRG and the LSRG of olive flounder (*Paralichthys olivaceus*) reared over 32 weeks. Symbol ● indicates HSRG, ○ indicates LSRG. Asterisks indicate significant differences between size-ranking groups ($P < 0.05$).

fish (315 ± 9 g, P<0.05). Over the entire experiment, neither daily feed intake nor feeding efficiency differed significantly between the groups (Table 1). No difference in mortality was seen between the groups; only 14 fish died during the experiment. Sex ratio differed between the experimental groups, and the percentage of females was significantly higher in the HSRG than in the LSRG (P<0.05).

Table 1. Feed intake, feeding efficiency, mortality, and sex ratio of the high size-rank group (HSRG) and the low size-rank group (LSRG) of olive flounder (*Paralichthys olivaceus*)

	Daily feed intake (%)	Feeding efficiency	Mortality (%)	Percentage of females
HSRG	0.82±0.01	1.33±0.01	2.0±0.6	51.7±2.5*
LSRG	0.83±0.01	1.31±0.01	2.7±0.3	30.8±3.6

Values are the mean of triplicate groups±SE. An asterisk indicates a signi-ficant difference between size-rank groups (P<0.05). Daily feed intake=feed intake×100/[(initial fish wt+final fish wt+dead fish wt)/2×days fed]. Feeding efficiency=body wet weight gain/feed intake (dry matter)

The distribution of both body weight (133-617 and 142-537 g in HSRG and LSRG, respectively) and the highest body weight class (350 and 300 g in HSRG and LSRG, respectively) differed between the groups (Fig. 3). The relative frequency of females increased with a body weight increase in both experimental groups. Hence, the mean body weight of females (385±92 and 345±86 g in HSRG and LSRG, respectively) was heavier than that of males (334±65 and 301±70 g in HSRG and LSRG, respectively) in both experimental groups.

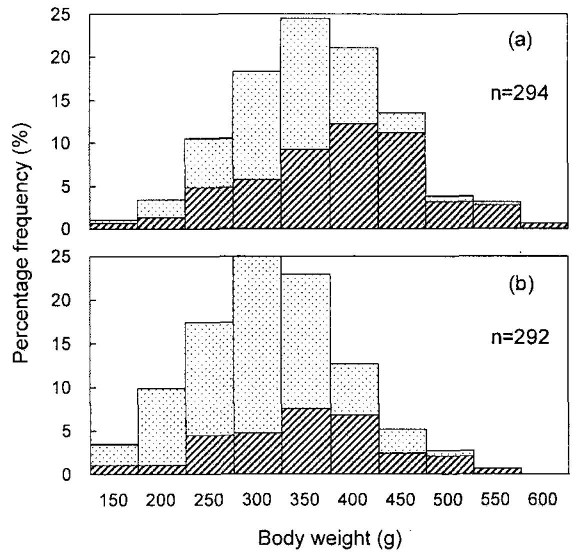

Fig. 3. The final body weight distribution of the HSRG (a) and the LSRG (b) of olive flounder (*Paralichthys olivaceus*). Female and male are re-presented by the hatched and stippled columns, res-pectively. The body weights (mean±SD) of female and male were 385±92 and 334±65 g for the HSRG, and 345±86 and 301±70 g for the LSRG, res-pectively.

Discussion

Juvenile olive flounder of the same size were selected and reared from two age groups. Faster growth was observed in the HSRG fish than in the LSRG fish. As is commonly known by flounder farmers, these findings confirm that higher size-rank fish are associated with better growth performance. In contrast to our findings, recent studies in olive flounder have shown that LSRG fish have a higher growth rate than HSRG fish (Dou et al., 2004; Kim et al., 2005). This discrepancy could be explained by size-specific growth in connection with size variation at the start of the experiment, as has been inferred from a study on size grading in turbot (*Scophthalmus maximus*; Sunde et al., 1998). Feed intake and feeding efficiency are also size-dependent because they decline with a body weight increase (Ogata et al., 2002). In pike (*Esox lucius*), large individuals in the HSRG have lower feeding efficiency than small individuals in the LSRG (Kucska et al., 2005). In our study, the effect of size variation on feed intake and feeding efficiency was removed by using same-size juveniles from different age groups; thus, no di-fferrences in these performance traits were seen between the two experimental groups. Although a fast-growing strain of rainbow trout (*Oncorhynchus mykiss*) had a higher growth rate than a slow-growing strain, a similar trend was observed, with the same feeding efficiency in the two strains (Valente et al., 2001). The approximately 2% mortality observed in our study is in line with an earlier study on juvenile olive flounder, in which we found around 99% survival in the size-graded groups, compared to 93% survival in ungraded group (Kim et al., 2005). The low mortality in the current study indicates that juvenile flounder viability is influenced by size grading. Folkvord and Otterå (1993) suggested that size grading may improve the survival of juvenile Atlantic cod (*Gadus morhua*), with survival of the smallest fish being very poor in the groups with the largest size variation. Similarly, data on juvenile turbot suggest that small fish grading can improve survival, as the smallest individuals in each group usually die (Sunde et al., 1998).

A disproportionate sex ratio for different sizes of fish has been reported for European sea bass (*Dicentrarchus labrax*), in which fast growing populations consist of 96.5% females, while the slow growing populations have only 30.2% females (Papadaki et al., 2005). Saillant et al. (2003) demonstrated that female sea bass start to grow faster than males very early in life, before size grading, since most of the females are isolated in the class consisting of large individuals. Therefore, individual growth trajectories may be fixed before size grading and determine the phenotypic sex. A similar result was documented in parrot fish (*Oplegnathus fasciatus*), with a differing sex ratio among various groups isolated during size grading, and the percentage of males is higher in the graded group consisting of large individuals (75.2%) than in an ungraded group (54.2%) or the graded group of small individuals (31.3%; Kim et al., 2004). In agreement with the results for European sea bass and parrot fish, the sex ratio of olive flounder in the present study was correlated with size-rank, because the percentage of females was significantly higher in the HSRG than in the LSRG. In addition, a remarkable growth increase was recorded in females, indicating that the relative frequency of females increased with a body weight increase. Our study suggests that the very early growth of juvenile flounder, preceding size grading, accounts for the observed differences in growth between the sexes.

Faster growth and a higher percentage of females were seen in HSRG fish compared to LSRG fish. We conclude that higher size-ranks at the juvenile stage of olive flounder lead to better growth of fish, in connection with a higher percentage of females, because females start to grow faster than males before size grading occurs.

Acknowledgments

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