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ORIGINAL PAPER

Effects of stocking density on survival and growth of juvenile tench (*Tinca tinca* L.)

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Abstract In two 120-day experiments, performed in the laboratory at 22°C, the effects of stocking density on the survival and growth of juvenile tench (*Tinca tinca* L.) were evaluated. Fish were kept in fibreglass tanks, supplied throughout with flow of artesian water, and fed a dry diet for salmonids, in excess, supplemented with restricted amounts of *Artemia* nauplii. In the first experiment four-month-old juveniles (0.31 ± 0.04 g and 32.00 ± 1.17 mm TL) were stocked at four densities—0.18, 0.88, 1.05, and 2.10 g l^{-1}. Survival was high (>89%) for all treatments. Final densities ranged between 1.10 g l^{-1} (significantly lowest) and 10.46 g l^{-1} (significantly highest). The density increase was significantly higher (611%) for fish stocked at the lowest initial density (0.18 g l^{-1}) than for fish stocked at 0.88, 1.05, and 2.10 g l^{-1}, for which the density increase averaged 457%. In the second experiment, 4.5-month-old juveniles (0.58 ± 0.17 g and 39.54 ± 0.83 mm TL) were stocked at three densities—1.05, 3.00, and 4.00 g l^{-1}. Survival was high (>96%) for all treatments. Final densities ranged between 4.08 and 16.53 g l^{-1} and were significantly higher for greater initial densities. The density increase was greatest (413%) for fish stocked at the highest density (4 g l^{-1}) and was not significantly different for fish stocked at 1.05 and 3 g l^{-1}. Considering all the densities in the two experiments, for stocking at 4 g l^{-1} the final density was 15 times higher than that reached after stocking at 0.18 g l^{-1}, without harmful effects on survival and growth. This final density (equivalent to 16.53 kg m^{-3}) is in the range recommended for other fish species in this period under intensive conditions.

Keywords Cyprinids · Tench · Intensive culture · Juvenile rearing

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Introduction

Juvenile tench (*Tinca tinca* L.) are usually cultured in extensive or semi-extensive systems in earthen ponds in which fish management is difficult and yield is very dependent on uncontrollable factors. The rate of growth achieved by tench in ponds is, moreover, slow (Steffens 1995). This situation could be improved by intensive rearing under controlled conditions, but little information is available. In intensive aquaculture it is important to pay special attention to stocking density, a decisive factor that directly affects culture production. Comparative studies on effects of density o juvenile tench are not available, however. Because optimum stocking density will depend on culture system and species, we cannot extrapolate data obtained for other systems and fish species to intensive culture of tench, and specific studies should be performed. The objective of this work was to obtain data on survival and growth of juvenile tench fed a dry diet supplemented with *Artemia* nauplii at different stocking densities under controlled conditions.

Materials and methods

Two 120-day experiments were conducted on juvenile tench (*T. tinca*). The experimental fish were obtained in the laboratory by artificial reproduction performed according to Rodríguez et al. (2004). From five days after hatching larvae were maintained in outdoor fibreglass tanks (2500 l) fed with a combination of a dry diet for marine fish and *Artemia* nauplii until the beginning of the experiments. The animals were then stocked in $0.60 \times 0.30 \times 0.33$ m fibreglass tanks containing 25 l water. Tench were randomly grouped to obtain replicates corresponding to the different densities. Fish were anesthetized with MS-222 (Ortoquímica, Barcelona, Spain), bulk weighing (to the nearest 0.01 g) was performed for each tank, and the number of fish was counted.

Each tank had its own water inlet (inflow 250 ml min^{-1}) and outlet (provided with 250 µm mesh filter) and light aeration. Artesian well water was supplied in an open system. The water-quality data were: pH 8.1, hardness 5.2°d (calcium 32.3 mg l^{-1}), total dissolved solids 108.5 mg l^{-1}, and total suspended solids 39.7 mg l^{-1}. Throughout the trials oxygen content ranged between 5.0 and 7.0 mg l^{-1}, ammonia <0.02 mg l^{-1}, and nitrites <0.05 mg l^{-1}. Photoperiod was natural and water temperature was 22 ± 1.5°C. Tank bottoms were cleaned twice a week.

Fish were fed live freshly-hatched *Artemia* nauplii (cysts of INVE Aquaculture Nutrition, High HUFA 430 µm, Hoogveld 91, 9200 Dendermonde, Belgium) and a dry commercial food for salmonids (Nutra, 60% protein, 16% fat, 12% ash, 0.08% cellulose. Skretting Trouw España, Cojobar, 09620 Burgos, Spain). Diameter of pellets was adjusted to fingerling size, 0.6–1.0 mm (Nutra 2.0) during the first 60 days and 0.9–1.5 mm (Nutra 0) from day 60 to day 120. Diet was supplied by hand once a day, starting with 5% of fish biomass of dry food (regarded as excess) plus 1800 nauplii per gram biomass. These quantities were increased monthly by 25%.

At the end of each experiment surviving fish were anesthetized and counted and the biomass of each tank was recorded (bulk weighing to the nearest 0.01 g). From these data, final survival (%), final density (g l^{-1}), and density increase (100 final density/initial density) were calculated. Results were examined by analysis of variance (ANOVA) using the computer software Statistica 4.5 (StatSoft, Tulsa, OK, USA). If ANOVA indicated results from different treatments were significantly different the Newman–Keuls test was used to compare means at the $P < 0.05$ level of significance. Percentages were arcsine-transformed before statistical analysis.

Experiment 1. 1682 4-month-old juvenile tench of mean initial weight of 0.31 ± 0.04 g and total length 32.00 ± 1.17 mm (mean ± SD, $n = 252$) were stocked in sixteen tanks. The initial stocking densities were 0.18, 0.88, 1.05, and 2.10 g l^{-1}. Each treatment was tested in quadruplicate (four tanks per treatment).

Experiment 2. 786 4.5-month-old juvenile tench of mean initial weight of 0.58 ± 0.17 g and total length 39.54 ± 0.83 mm (mean ± SD, $n = 118$) were stocked in nine tanks. The initial stocking densities were 1.05, 3.00, and 4.00 g l^{-1}. Each treatment was tested in triplicate (three tanks per treatment).

Results

Experiment 1

Survival, final density, and density increase after 120 days are presented in Table 1. Mean survival was high, between 89.80 and 99.26%. Biomass increased during the experiment and final densities ranged between 1.10 g l^{-1} (significantly lowest) and 10.46 g l^{-1} (significantly highest), and were higher when the initial density was greater. For fish stocked at the lowest initial density (0.18 g l^{-1}) the density increase was significantly higher (611%) than for fish stocked at 0.88, 1.05, and 210 g l^{-1} (average 457%).

Experiment 2

Survival, final density, and density increase after 120 days are presented in Table 2. Mean survival rates were high, between 96% and 99%. Biomass increased during the experiment and final densities ranged between 4.08 and 16.53 g l^{-1}, being significantly higher when

Table 1 Survival, final density, and density increase in experiment 1 (mean ± mean standard error)

	Initial density (g l^{-1})			
	0.18	0.88	1.05	2.10
Survival (%)	89.88 ± 1.96^{a}	99.26 ± 0.43^{a}	97.56 ± 0.80^{a}	89.90 ± 1.25^{a}
Final density (g l^{-1})	1.10 ± 0.09^{a}	3.93 ± 0.24^{b}	4.49 ± 0.07^{b}	10.46 ± 0.42^{c}
Density increase (%)	611 ± 52^{a}	446 ± 27^{b}	427 ± 70^{b}	498 ± 41^{b}

Data in the same row with different superscripts are significantly different ($P < 0.05$)

Table 2 Survival, final density, and density increase in experiment 2 (mean ± mean standard error)

	Initial density (g l^{-1})		
	1.05	3.00	4.00
Survival (%)	97.67 ± 2.33^{a}	99.28 ± 0.72^{a}	96.38 ± 0.65^{a}
Final density (g l^{-1})	4.08 ± 0.41^{a}	11.82 ± 0.34^{b}	16.53 ± 0.43^{c}
Density increase (%)	388 ± 39^{a}	394 ± 11^{a}	413 ± 11^{a}

Data in the same row with different superscripts are significantly different ($P < 0.05$)

initial densities were greater. For fish stocked at the highest density (4 g l^{-1}) the density increase was greatest (413%) and was not significantly different for fish stocked at 1.05 and 3 g l^{-1}.

Discussion

Until now, trials conducted on juvenile tench have focused on the effects of the diet using dry foods formulated for other aquatic species, because no information is available about nutrition of tench. When commercial dry diets were used as the only food, slow growth (Wolnicki and Myszkowski 1998; Quirós et al. 2003) and a high incidence of external body deformities (Wolnicki et al. 2006; Kamler et al. 2006) were recorded; these were probably a response to unsuitable food. According to Quirós and Alvariño (1998) and Quirós et al. (2003), survival and growth can be improved by adding a supplement of live feed (*Daphnia* sp.), and Wolnicki et al. (2003a) showed that supplementation with frozen insect larvae positively affected growth in fish length and weight. *Artemia* nauplii, which have been successfully used as the sole food for tench larvae (Fleig et al. 2001; Wolnicki et al. 2003b; Celada et al. 2007), have not yet been used to supplement dry diets at the juvenile stage. In this study supplementation with freshly hatched *Artemia* nauplii resulted in high survival with good growth, and deformities were not observed.

For most of the species investigated there is a negative correlation between density and growth. In this study, tench stocked at the lowest density (0.18 g l^{-1}) grew faster than those stocked at higher densities, although no inverse correlation between density and growth was observed from 0.88 to 4 g l^{-1}. Within this range, density increases were not very different and growth seemed to be independent of density. Similar observations have also been reported for turbot (*Scophthalmus maximus*) by Martínez and Fernández (1991) and for halibut (*Hippoglosus hippoglossus*) by Bjørnsson (1994). Surprisingly, positive effects of increased density on growth have also been reported—by Papoutsoglou et al. (1998) for European sea bass (*Dicentrarchus labrax*) and by Jorgensen et al. (1993) for Arctic charr (*Salvelinus alpinus*). For tench, Arlinghaus et al. (2003) have suggested the possibility that food consumption could increase when density exceeds 6 g l^{-1}, leading to the belief this could enable faster growth. During the last two months of the current experiments this density was widely exceeded in three treatments, which concluded with 10.46, 11.82 and 16.53 g l^{-1}, but evidence of faster growth was not obtained.

An initial density of 0.18 g l^{-1} enabled the best growth, and the final density after 120 days was the 611% of the initial density. Because this density seems low for intensive rearing, however, higher densities should be considered to make it possible to enhance production both of the number of fish and total biomass finally collected. After stocking of juvenile tench at 4 g l^{-1} survival after 120 days was 96.38%, the density increase was 413%, and the final density was 15 times higher than that achieved by stocking at 0.18 g l^{-1}.

In this period of intensive fish culture different densities under controlled conditions have been recommended, depending on the species—from 2 to 10 kg m^{-2} for the turbot, *S. maximus*, and the sole, *Solea vulgaris*, (Menu and Person-Le Ruyet 1991); from 5 to 10 kg m^{-3} for the gilt-head seabream, *Sparus aurata*, and the seabass, *D. labrax*, (Barnabé 1991); and from 10 to 15 kg m^{-3} for salmonids (Willoughby 1999). In our study on juvenile tench density increased from 4 to 16.53 g l^{-1} (equivalent to 16.53 kg m^{-3}), values in the range of those recommended for other fish species, without harmful effects on survival and growth. This shows that critical densities, which result in severe mortality and a drastic reduction in growth, were not reached. It also suggests juvenile rearing could be at higher densities, probably with incorporation of techniques to solve consequent problems (oxygen depletion, high concentration of toxic compounds and microorganisms, accumulation of excrement and uneaten food). For example, development of maintenance systems for rainbow trout enabled 79 kg fingerlings m^{-3} to be reared (Steffens 1992). Future research to increase the density of juvenile tench should include improvement of maintenance systems.

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