Culture of Florida Red Tilapia in Marine Cages: The Effect of Stocking Density and Dietary Protein on Growth

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ABSTRACT

Growth, survival, and feed conversion were studied in juvenile, monosex male Florida red tilapia (8.78 g ave. wt.) held in sea cages on Great Exuma, Bahamas. Twenty-four floating cages (1 m^3) were stocked at densities of 100, 200, and 300/m^3 and fed 84 days on diets containing 28 or 32% protein.

Final mean weights were higher for fish fed the diet with 28% protein (ave. = 176.8 g) than those fed at 32% protein (ave. = 166.4 g), under all densities. Survival (avg. = 97.9%) was higher and feed conversion ratio lower (avg. = 1.88) for fish fed the 28% protein diet than for those fed the 32% protein diet. No significant effects of stocking density on these parameters were observed.

Final biomass densities ranged from 16.1 to 52.2 kg/m^3 and were higher for fish fed the 28% protein diet than for those fed the 32% protein diet, under all densities.

Coefficients of variation of final body weights were significantly higher among fish reared at a density of 100/m^3 (avg. = 26.0%) than among those reared at higher densities (avg. = 20.8%), under both dietary protein levels.

INTRODUCTION

While a number of studies have examined growth of various tilapia species under intensive culture in cages (Coche, 1982), little information is available on cage culture in seawater or on the effects of stocking density on growth.

In this study, the effect of stocking density on growth and feed conversion of Florida red tilapia reared in marine cages is assessed. To minimize feed costs, growth response to two levels of dietary protein was also assessed.

MATERIALS AND METHODS

Twenty-four floating cages (1 m^3) were placed in a sheltered sea pass on Great Exuma (Bahamas), where water depth varied from 2 to 4 m with the tidal cycle.

The red tilapia used is a hybrid strain originating in Florida, USA from an *Oreochromis urolepsis hornorum* female x *O. mossambicus* male cross (Behrends *et al.*, 1982). Seawater-acclimated fingerlings (sex-reversed male) were obtained from the Caribbean Marine Research Center hatchery on Lee Stocking Island, approximately 2.4 km NW from the study site.

A 3 x 2 factorial experiment was designed to determine the effects of stocking density on growth under different dietary protein levels. Fish were stocked into cages at densities of 100, 200, and 300/m^3 and growth compared on floating, commercially-prepared diets (3/16", Purina Mills, St. Louis, Missouri) containing 28% and 32% protein. Diets contained similar crude fat (4%) and fiber (6%) levels. Each treatment consisted of 4 replicate cages.

Fish were fed three times daily (0800, 1200, and 1600 h) to satiation: at each feeding, a level of feed was provided that was consumed in 30 minutes. Feeding rate was adjusted according to observed consumption, with cages within a treatment receiving the same daily ration.

At twenty-eight day intervals from 4 June (day 1) to 26 August 1988 (day 84), a sample of 20 fish from each cage was weighed and measured. Water temperature and salinity and ambient as well as in-cage dissolved oxygen (D.O.) were measured daily.

Coefficients of variation (CV) of body weights for each replicate cage were calculated from CV = 100 x SD/$\bar{x}$, where SD = the standard deviation, and $\bar{x}$ = the mean.

Feed consumption during a sampling interval was expressed as a percentage of average biomass during the interval. Feed conversion ratio (FCR) was calculated from FCR = dry weight fed (g)/live weight gain (g).

Two-way Analysis of Variance (ANOVA) was used to determine the effects of stocking density, dietary protein, and their interaction on final body weights, CV of final weights, feed consumption and conversion, and survival.

RESULTS

Initial weights and lengths averaged 8.78 g and 76.9 mm, respectively (Table 1), and did not differ significantly among treatments ($P > 0.05$). Under all stocking densities, final (day 84) mean weights and lengths were higher for fish fed the 28% protein diet (avg. = 176.8 g; 189.2 mm) than for those fed the 32% protein diet (avg. = 166.4 g; 184.4 mm), with a significant ($P < 0.05$) effect of dietary protein on final weights and lengths. No significant ($P > 0.05$) effect of stocking density on final weights and lengths was observed.

Survival was higher for fish fed the 28% protein diet (avg. = 98.6%) than

Table 1. Initial and final weights and lengths, final biomass density, and survival of Florida red tilapia reared for 84 days in floating marine cages at three stocking densities and under two dietary protein levels. Data are presented as means ± SEM (n=4).

Density (number/m³)-protein (%)	INITIAL Wt. (g)	INITIAL Lt. (mm)	FINAL Wt. (g)	FINAL Lt. (mm)	FINAL Biomass density (kg/m³)	FINAL Survival (%)
100-28	8.51 ± 0.32	76.5 ± 0.9	169.9 ± 7.2	186.8 ± 2.3	16.7 ± 0.6	98.5 ± 0.9
100-32	8.79 ± 0.27	77.0 ± 0.9	165.9 ± 6.6	183.8 ± 2.7	16.1 ± 0.6	97.0 ± 0.0
200-28	8.77 ± 0.12	76.8 ± 0.5	184.3 ± 6.0	191.8 ± 2.7	36.3 ± 1.5	98.4 ± 0.8
200-32	8.82 ± 0.22	77.0 ± 0.4	170.4 ± 6.1	187.0 ± 2.9	33.3 ± 1.0	97.8 ± 0.6
300-28	8.81 ± 0.24	76.8 ± 0.6	176.1 ± 2.1	189.0 ± 1.2	52.2 ± 0.7	98.8 ± 0.2
300-32	9.00 ± 0.09	77.3 ± 0.3	162.9 ± 4.2	182.3 ± 2.0	47.3 ± 1.4	96.8 ± 0.8

Table 2. Initial and final coefficients of variation (%) of body weights of Florida red tilapia reared in floating marine cages for 84 days under three stocking densities and two dietary protein levels. Data are presented as means ± SEM (n=4).

Density (number/m^3)-protein (%)	Initial	Final
100-28	24.9 ± 2.2	26.3 ± 0.8
100-32	23.2 ± 2.1	25.6 ± 1.5
200-28	25.8 ± 0.9	21.4 ± 3.5
200-32	25.2 ± 1.3	18.2 ± 1.5
300-28	27.1 ± 1.3	19.7 ± 0.6
300-32	26.8 ± 0.8	23.7 ± 1.9

for those fed the 32% diet (avg. = 97.2%), under all densities (Table 1), with a significant ($P < 0.05$) effect of dietary protein on survival. The effect of stocking density on survival was not significant ($P > 0.05$).

Final biomass densities (range = 16.1 – 52.2 kg/m^3) increased with increasing stocking density and were higher for fish fed the 28% protein diet than for those fed the 32% protein diet, under all densities (Table 1), with a highly significant ($P < 0.005$) effect of dietary protein on biomass density.

Under all treatments, feed consumption declined with growth, from an average of 6.60 to 3.91% body wt./day during the experiment. Feed conversion ratios were lower for fish fed the 28% protein diet (avg. = 1.81) than for those fed the 32% protein diet (avg. = 1.94), under all densities, with a significant ($P < 0.05$) effect of dietary protein on feed conversion. The effect of stocking density on feed conversion was not significant ($P > 0.05$).

Coefficients of variation (CV) of initial weights averaged 25.5%, with no differences among treatments observed ($P > 0.05$) (Table 2). CV of final weights were higher among fish reared at a density of 100/m^3 (avg. = 26.0%) than among those reared at densities of 200 or 300/m^3 (avg. = 20.8%), under both dietary protein levels (Table 2). A significant ($P < 0.05$) effect of stocking density on CV of final weights was observed, while the effect of dietary protein was not significant ($P > 0.05$).

Salinity ranged from 34 to 39 ppt (avg. = 36 ppt) during the experiment, while maximum daily water temperatures ranged from 28.3 to 33.3 C (avg. = 30.9 C) and minimum temperatures ranged from 25.6 to 31.1 C (avg. = 29.2 C). Although ambient D.O. levels as high as 7.5 ppm were recorded (avg. = 4.8 ppm), they fell as low as 3.3 ppm (53% saturation). In-cage D.O. (avg. = 4.4 ppm) generally declined over time due mainly to a trend toward lower ambient levels during the study, which was terminated on day 84 as in-cage D.O. fell below 3 ppm on days 82 and 83.

Mortalities were observed primarily after day 65 in association with heavy rainfall, increased turbidity, and relatively abrupt declines in salinity and temperature. Moribund fish were characterized by clouded eyes and external hemorrhagic areas.

DISCUSSION

Growth and feed conversion of Florida red tilapia fed at two protein levels did not differ at densities ranging from 100 to 300/m^3, suggesting that higher densities are possible. This is similar to what was seen for *O. aureus* fed a 36% protein diet in marine cages, where stocking densities of up to 300/m^3 did not affect growth (McGeachin *et al.*, 1987). In freshwater, Wannigama *et al.* (1985) found no differences in growth or feed conversion of *O. niloticus* reared in cages on 19 – 29% protein diets at densities of 400, 600, and 800/m^3.

Coche (1982) recommended 3.0 ppm as a minimum D.O. level below which adverse affects appear during cage culture of tilapias in freshwater. In this study, in-cage D.O. fell below 3.0 ppm, due mainly to declining ambient levels, likely increasing stress and susceptibility to environmental perturbations such as temperature and salinity. This suggests that considerably higher biomass densities than achieved in this study (*i.e.*, 52.2 kg/m^3) are attainable, given higher ambient D.O.

A small but significant improvement in survival and growth under the 28% protein diet compared to the 32% protein diet suggests that excess dietary protein inhibited growth. Clark *et al.* (in press) recently determined that growth and feed conversion of Florida red tilapia reared from fingerling through large, adult sizes in seawater pools did not differ on diets with protein levels ranging from 20 to 30% demonstrating that maximum growth rates may be supported by diets of relatively low protein content.

Campbell (1985) concluded that a major drawback for producing marketable *O. niloticus* in freshwater cage culture was differential growth rates which required frequent sorting. In this study, a significant effect of stocking density on size variation (*i.e.*, growth depression) (Brett, 1979) was evident, with lower depression observed at the higher densities, possibly resulting from an inhibitory effect of high density on aggression (Balarin and Haller, 1982). This suggests that higher densities are advantageous, not only for increasing production, but for minimizing growth depression.

The results demonstrated that Florida red tilapia fingerlings can be grown in marine cages more economically on a 28% protein than on a 32% protein diet and that, efficiency of production is increased and size variation minimized by stocking at higher densities up to 300/m^3, with higher densities seemingly possible.

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