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Nursing and Production of the Grouper *Epinephelus coioides* at Different Stocking Densities in Tanks and Sea Cages

T.A. AHMAD, C. EL-ZAHAR and T.O. WUAN

Mariculture and Fisheries Department
Kuwait Institute for Scientific Research
P.O. Box 1638 Salmiya
22017 Kuwait

Abstract

Growth, survival, and feed conversion of the brown-spotted grouper *Epinephelus coioides* were determined in a series of four experiments dealing with different size ranges of fish, held at different stocking densities, in tanks and floating net cages. Early fingerlings (2-10 g size range) had higher specific growth rate ($P<0.01$) in cages, but their survival and feed conversion were not different ($P>0.05$) from those in tanks. Growth, survival, and feed conversion of advanced fingerlings (10-40 g) were not different ($P>0.05$) at stocking densities of 250, 500 and 1000 fish•m^{-3} in tanks. Yearlings (200-400 g) did not differ ($P>0.05$) in growth, survival, and feed conversion at different stocking densities (20, 40, and 80 fish•m^{-3}). However, these fish grew faster in cages ($P<0.01$), due to higher water temperature than in tanks, and their survival and feed conversion were not affected by the culture system. For the 400-800 g size range, stocking density (10, 20 and 40 fish•m^{-3}) and culture system had significant effects ($P<0.01$) on growth and feed conversion, where lower densities in cages gave the best results; and the responses to different densities were different in cages and tanks.

Introduction

Research on the mass culture of the brown-spotted grouper *Epinephelus coioides*, (= *tauvina*) have been carried out over several years in Kuwait (Hussain and Higuchi 1980; Akatsu et al. 1983; Abdullah et al. 1987; and Al-Marzouq and Al-Rifae 1994). The hardiness of this fish and its tolerance to culture conditions and crowding, along with its high growth rate and desired quality as food fish, makes it a prime candidate for commercial aquaculture in the region. Members of the same genus have been cultured and studied by other researchers, mainly in the tropical and semitropical Asian countries, including *E. tauvina* (Chua and Teng 1978; Chou and Wong 1985; Chou et al. 1987; Hasma and Kasim 1992) and *E. salmoides* (Chua and Teng 1979, 1980).

Some of the aspects that were examined by these studies included husbandry, breeding and larval rearing, nutrition, and diseases of cultured groupers. It is very likely that all species of groupers studied for various aspects under culture conditions in the tropical and semitropical regions belong to the same species.

The main objective of the present study is to determine the husbandry and production parameters, including growth, survival, and feed conversion ratio of different size ranges of the grouper *E. coioides*, covering nursery and grow-out stages to market size of 800 g, in tanks and sea cages and at different stocking densities. This effort was undertaken to establish base-line production data for the purpose of determining the technical and economic feasibility of commercial mass production of this fish in Kuwait.

Materials and Methods

The fish in the following series of four experiments were obtained from natural spawning of grouper brood stock in 90 m^3 concrete tanks at the Mariculture and Fisheries Department of the Kuwait Institute for Scientific Research. The spawning season normally occurred from April to July of each year. Fertilized eggs were collected and hatched in small nets, then the larvae were reared in 4 m^3 tanks on a diet of rotifers and Artemia nauplii as described earlier by Hussain and Higuchi (1980), with few modifications. The seawater supplied to the tanks was obtained from wells sunk in the sandy beach and had constant temperature year-round ranging from 24-27 °C. Circular fiberglass tanks were used; all tanks were supplied with continuously flowing seawater and aeration through diffusers or airlifts. Floating cages were suspended on pontoons and the cage system was protected with floating breakwater. In all tank and cage experiments, each treatment was replicated three times. The average weight of the fish in each tank or cage was determined initially and at the end of each experiment. The fingerlings were all weaned earlier in the hatchery to accept dry pellets before being used in this study. The fish in all experiments were fed to satiation on a commercial formulated dry-pellet feed with 45% crude protein (Aqualim, France). The following equation was used to calculate the specific growth rate, SGR = 100 x (ln (final mean body weight) – ln (initial mean body weight)) ÷ (number of days). The condition factor was calculated as body weight ÷ (total length)^3 x1000; this was determined by individually weighing and measuring 50 fish at the start of the experiment and from each tank or cage at its end. The data were analyzed with one-way and two-way (with replication) analysis of variance procedures using the statistical package *Statistica* on a PC.

Experiment 1: Nursing of early fingerlings in tanks and cages

In this experiment, performance of early fingerlings (initially weighing about 2 g and ending with about 10 g) in terms of growth, survival, feed conversion, and condition factor was determined in 1 m^3 land-based tanks and floating sea cages at a stocking density of 1000 fish$\cdot m^{-3}$. The purpose is to compare the two culture systems for suitability in nursing early fingerlings coming out of the hatchery. The fish were maintained for 30 days on 2 mm pellets fed twice daily.

Experiment 2: Nursing of advanced fingerlings at different densities in tanks

This experiment compares performance of advanced fingerlings, (10 to 40 g size-range), at three different stocking densities (250, 500 and 1000 fish$\cdot$m^{-3}). The fish were maintained for 42 days in 1 m^3 circular tanks and fed twice daily on 2 and 4.5 mm pellets. It was not possible to repeat this experiment in cages due to shortage of fingerlings.

Experiment 3: Grow-out of early yearlings in tanks and cages at different densities

Performance of yearlings (200-400 g) is compared in 6 m^3 tanks and cages at different stocking densities. The experiment is a 2 x 3 factorial design in which the first factor is the culture system (tanks, cages) and the second factor is density (20, 40 and 80 fish$\cdot$m^{-3}). The effect of interaction between these two factors on growth, survival, and feed conversion is also determined. The experiment was conducted for 70 days during which the fish were fed once daily, 6 days a week, on 6 mm pellets.

Experiment 4: Grow-out of advanced yearlings in tanks and cages at different densities

The size range from 400-800 g is covered in this experiment which was also carried out for 70 days in 6 m^3 tanks and cages. The same experimental design used in the previous experiment (2 x 3 factorial design) is also used here, but the stocking densities were reduced to 10, 20 and 40 fish$\cdot$m^{-3} because of the larger size of fish involved. The fish were fed once daily, 6 days a week, on 6 and 10 mm pellets.

Results

Experiment 1

Daily weight gain ranged from 0.276 to 0.293 g$\cdot$f$^{-1}\cdot$d^{-1} in the tanks and cages but there was no significant difference ($P>0.05$) between these two culture systems (Table 1). However, mean specific growth rate (SGR) was significantly higher ($P<0.01$) in the cages than in the tanks (4.96 and 4.77%, respectively). Survival and feed conversion ratios in tanks and cages were good, but were not significantly different ($P>0.05$), indicating no advantage of either culture system over the other in improving these variables. The condition factor in the tanks averaged 16.21 which was significantly higher ($P<0.01$) than in cages (15.58). Water temperature averaged 26.1 °C (25.3-26.6) in the tanks, and 28.9 °C (27.9-30.2) in the cages. Salinity in the tanks averaged 36 ppt, and 41 ppt in the cages.

Experiment 2

There were no significant differences (P>0.05) among the three stocking densities in any of the measured variables (Table 2), indicating that growth, survival, feed conversion, and condition factor were not affected by holding the fingerlings at densities from 250 to 1000 fish•m^{-3}. This shows that the stocking rate (31.2 kg•m^{-3}) reached at the highest density of 1000 fish•m^{-3} is still

Table 1. Weight gain, specific growth rate (SGR), feed conversion ratio (FCR), survival and condition factor of early grouper, *E. coioides* fingerlings (2-10 g size-range) held for 30 days in tanks and cages at a density of 1000 fish•m^{-3}.

		Mean weight (g)		Weight gain	SGR	FCR	Survival	Condition
	Rep.	Initial	Final	(g•f^{-1}•d^{-1})	(%)		(%)	factor
Tanks	1	2.6	10.8	0.283	4.76	0.95	94.8	16.01
	2	2.6	11.0	0.290	4.79	0.95	93.0	16.28
	3	2.6	10.8	0.284	4.77	0.94	93.5	16.35
	Mean	2.6	10.9	0.286	4.77	0.95	93.8	16.21
Cages	1	2.4	10.4	0.276	4.92	1.17	73.3	15.52
	2	2.4	10.6	0.282	4.96	0.99	93.4	15.60
	3	2.4	10.9	0.293	5.01	0.95	89.7	15.61
	Mean	2.4	10.6	0.284	4.96	1.04	85.5	15.58
Differences between culture system				(P>0.05)	(P<0.01)	(P>0.05)	(P>0.05)	(P<0.01)

Table 2. Effect of stocking density on daily gain, specific growth rate (SGR), feed conversion ratio (FCR), and condition factor of 10-40 g size-range fingerlings of the grouper *E. coioides* held for 42 days in tanks.

Density	Mean weight (g)		Weight gain	SGR	FCR	Survival	Condition
(fish•m^{-3})	Initial	Final	(g•f^{-1}•d^{-1})	(%)		(%)	factor
250	13.3	38.4	0.599	2.53	1.07	99.2	14.14
250	12.9	39.0	0.621	2.64	1.34	96.4	16.60
250	12.1	28.8	0.397	2.06	1.28	98.0	16.85
Mean	12.8	35.3	0.539	2.41	1.23	97.9	15.86
500	13.0	38.5	0.607	2.58	0.99	97.8	17.52
500	12.1	34.3	0.529	2.48	1.31	99.6	16.48
500	12.9	31.7	0.447	2.14	1.24	100	16.53
Mean	12.7	34.8	0.528	2.40	1.18	99.1	16.84
1000	12.8	34.4	0.514	2.35	0.99	100	16.33
1000	12.6	31.8	0.458	2.21	1.13	100	16.22
1000	12.7	27.5	0.353	1.85	1.27	99.2	16.03
Mean	12.7	31.2	0.442	2.14	1.13	99.7	16.19
Differences among stocking densities			(P>0.05)	(P>0.05)	(P>0.05)	(P>0.05)	(P>0.05)

within reasonable limits for fingerlings in the size range of 10-40 g, and had no detrimental effect on any of the tested variables. Water temperature averaged 26.1 °C (25.1-26.7) and salinity ranged from 35 to 37 ppt.

Experiment 3

The different stocking densities had no significant effect (P>0.05) on growth, survival, and feed conversion (Table 3). The stocking rate at the highest densities (80 fish$\cdot$m^{-3}) in the cages reached 33.5 kg$\cdot$m^{-3} with no adverse effect on the performance of fish of this size range (200-400 g). On the other hand, the effect of the culture system on growth was highly significant (P<0.01), whereby the fish in cages grew at a higher rate (2.95-3.45 g$\cdot$f$^{-1}\cdot$d^{-1}) than those in tanks (2.34-2.98 g$\cdot$f$^{-1}\cdot$d^{-1}). However, survival and feed conversion were not different (P>0.05) between tanks and cages. There was no significant interaction (P>0.05) in growth and survival between the density and culture system effects, thus indicating that density effect was similar in cages and tanks in terms of growth and survival. However, feed conversion showed significant interaction (P<0.05) between density and culture system, which is evident in Table 3, whereby feed conversion in tanks improved at higher densities; but no such improvement is evident in cages. Water temperature averaged 25.2 °C (24-26.5) in the tanks, and 27.8 °C (24.5-30.6) in the cages. In the tanks, salinity averaged 36.9 ppt, while in the cages it was 41 ppt.

Experiment 4

The different stocking densities had significant effects (P<0.01) on growth and feed conversion (Table 4). In the cages, average daily gain decreased from 6.07 to 4.93 g$\cdot$f$^{-1}\cdot$d^{-1} as density increased from 10 to 40 fish$\cdot$m^{-3}; while in the tanks, no such decline is observed. The culture system also affected growth and feed conversion (P<0.01), with cages showing higher growth (4.66-6.41 g$\cdot$f$^{-1}\cdot$d^{-1}) and better conversion ratio (1.02-1.30) than tanks (daily gain ranged from 2.98 to 3.54 g$\cdot$f$^{-1}\cdot$d^{-1}; feed conversion ranged from 1.32 to 1.46). The interaction between culture system and density was also significant (P<0.01) in growth and feed conversion, indicating that the responses to the different densities was different between cages and tanks. On the other hand, survival was not significantly (P>0.05) affected by different densities and culture system or the interaction between them. In the tanks, water temperature averaged 25.5 °C (25-26), while in cages it was 29.5 °C (26.2-31.6). Salinity in the tanks and cages averaged 35.1 and 42 ppt, respectively.

Discussion

The present study was undertaken to determine suitable stocking densities in tanks and sea cages throughout the nursing and grow-out stages, which will be used in planning for commercial culture of the grouper *E. coioides* in Kuwait. The results showed that the growth rate in cages was

Table 3. Effect of stocking density and holding in tanks and cages on daily gain, specific growth rate (SGR), feed conversion ratio (FCR) and survival of *E. coioides* yearlings at the 200-400 g size-range, grown for 70 days.

Stocking density (fish·m^{-3})	Tanks						Cages					
	Mean weight (g)		Weight gain (g·f^{-1}·d^{-1})	SGR (%)	Survival (%)	FCR	Mean weight (g)		Weight gain (g·f^{-1}·d^{-1})	SGR (%)	Survival (%)	FCR
	Initial	Final					Initial	Final				
20	203	412	2.98	1.01	100	1.32	210	441	3.30	1.06	99.2	1.30
20	180	344	2.34	0.93	100	1.31	202	442	3.43	1.12	100	1.26
20	189	383	2.76	1.01	99.2	1.32	199	431	3.32	1.10	100	1.26
Mean	191	379	2.69	0.98	99.7	1.32	204	438	3.35	1.09	99.7	1.27
40	188	380	2.73	1.01	100	1.27	218	445	3.24	1.02	100	1.39
40	182	370	2.68	1.01	100	1.20	207	449	3.45	1.11	100	1.23
40	196	380	2.64	0.95	99.6	1.26	206	441	3.35	1.09	100	1.27
Mean	189	377	2.68	0.99	99.9	1.24	211	445	3.35	1.07	100	1.30
80	185	373	2.70	1.00	99.8	1.18	205	416	3.02	1.01	99.8	1.27
80	185	368	2.60	0.98	100	1.21	208	429	3.17	1.03	99.8	1.31
80	185	366	2.59	0.97	100	1.18	205	412	2.95	1.00	100	1.29
Mean	185	369	2.63	0.99	99.0	1.19	206	419	3.05	1.01	99.9	1.29

Significance of differences due to:	Wt. Gain	SGR	Survival	FCR
Stocking density	($P>0.05$)	($P>0.05$)	($P>0.05$)	($P>0.05$)
System (tanks vs cages)	($P<0.01$)	($P<0.01$)	($P>0.05$)	($P>0.05$)
Interaction (density x system)	($P>0.05$)	($P>0.05$)	($P>0.05$)	($P<0.05$)

Table 4. Effect of stocking density and holding in tanks and cages on daily gain, specific growth rate (SGR), feed conversion ratio (FCR) and survival of *E. coioides* yearlings at the 400-800 g size-range, grown for 70 days.

Stocking density (fish·m^{-3})	Tanks						Cages					
	Mean weight (g)		Weight gain (g·f^{-1}·d^{-1})	SGR (%)	Survival (%)	FCR	Mean weight (g)		Weight gain (g·f^{-1}·d^{-1})	SGR (%)	Survival (%)	FCR
	Initial	Final					Initial	Final				
10	404	628	3.19	0.63	98.3	1.44	427	844	5.96	0.97	100	1.08
10	381	592	3.02	0.63	100	1.39	430	878	6.41	1.02	100	1.02
10	400	633	3.33	0.66	100	1.42	425	833	5.83	0.96	100	1.13
Mean	395	618	3.18	0.64	99.4	1.42	427	852	6.07	0.99	100	1.08
20	394	632	3.40	0.68	100	1.40	433	804	5.30	0.88	100	1.26
20	400	648	3.54	0.69	100	1.45	426	784	5.11	0.87	98.3	1.29
20	415	643	3.25	0.63	99.2	1.45	440	810	5.30	0.87	100	1.24
Mean	403	641	3.40	0.66	99.7	1.43	433	799	5.24	0.88	99.4	1.26
40	408	648	3.42	0.66	99.2	1.32	432	776	4.91	0.84	100	1.30
40	403	643	3.43	0.67	98.8	1.46	425	752	4.66	0.81	100	1.28
40	393	602	2.98	0.61	100	1.41	428	792	5.20	0.88	100	1.25
Mean	401	631	3.28	0.65	99.3	1.40	428	773	4.93	0.84	100	1.28

Significance of differences due to:	Wt. Gain	SGR	Survival	FCR
Stocking density	(P<0.01)	(P<0.01)	(P>0.05)	(P<0.01)
System (tanks vs cages)	(P<0.01)	(P<0.01)	(P>0.05)	(P<0.01)
Interaction (density x system)	(P<0.01)	(P<0.01)	(P>0.05)	(P<0.01)

mostly higher than in tanks due to higher temperature in cages through out the production season (April to November) in which these experiments were carried out, but survival rate was not significantly different between tanks and cages. Ellis et al. (1997) found that higher seawater temperature resulted in increased growth of juvenile Nassau grouper (*E. striatus*) due to significant increase in feed consumption. They also found that survival of 3.2 g fingerlings reared for 63 days was high (96.4-100%) and was not significantly different at the tested temperatures (22-31 °C). However, in Kuwait, ambient seawater temperature decreases to below 20 °C during winter (December to March), and may reach below 13 °C in some years, resulting in severe mortality of *E. coioides* fingerlings, especially in cages. Growth and survival during winter in tanks supplied with warm well water was found to be superior to that in cages (Thani A. Ahmad, unpublished data). Therefore, the advantages offered by cage culture during the growth season are not realized throughout the year, and winter mortality in cages remains a problem in need of further research.

The stocking densities used in the nursing and early yearling's experiments in this study did not have significant effects on growth or survival upto 400 g in body weight. However, higher stocking densities in the 400-800 g size range resulted in significant reduction of growth in cages. In an earlier study, Abdullah et al. (1987) nursed fingerlings of *E. tauvina* (currently known as *E. coioides*) in raceways from 17.1 to 63.7 g in 53 days with no apparent differences in growth and survival at densities of 200 and 400 fish$\cdot$m^{-3}; they concluded that maximum loading rate was not reached in their experiment and higher densities should be tried. In the present study, we tried higher densities of upto 1000 fish$\cdot$m^{-3}, and achieved a final loading level of 31.2 kg$\cdot$m^{-3} without adversely affecting the growth or survival rates, thus indicating that even higher densities could be tried during the nursing stage. Abdullah et al. (1987) also compared production at densities of 5, 20 and 60 fish$\cdot$m^{-3} in which they grew fish in raceways from 150 to 770 g in 215 days. Highest growth was achieved at 5 fish$\cdot$m^{-3} in their experiment, and they recommended using a density of 60 fish$\cdot$m^{-3} for commercial production because it resulted in the highest production level per m^{3}. In the present study, increasing the density of 400-800 g yearlings from 10 to 40 fish$\cdot$m^{-3}; resulted in lowering the growth rate in cages from 6.07 to 4.93 g$\cdot$f$^{-1}\cdot$d^{-1}, respectively. Chua and Teng (1978) determined that a stocking density of 60 fish$\cdot$m^{-3} was optimal for commercial production *of E. salmoides* in floating net-cages in Malaysia because it combined the high growth and survival rates of the lower densities (15 and 30 fish$\cdot$m^{-3}) with the high net-yield and production of the higher densities of 90 and 120 fish$\cdot$m^{-3}. In a later publication, Chua and Teng (1980) indicated that net production could be substantially increased by a combination of adding hiding space, high stocking densities, and enhancement of feeds and feeding regimes.

Survival rate in all the present experiments was high (73-100%) and was not affected by either stocking density or culture system. Other factors were also examined in the literature and were found not to affect grouper survival. In a weaning study, Chou et al. (1987) achieved 75-96% survival rate of *E.*

tauvina ranging in size from 4 to 45 g. Also, *E. tauvina* grew from 200.2 to 631.2 g in cages when fed on dry pellets for 153 days in Singapore (Chou and Wong 1985); the fish achieved a growth rate of 2.82 $g \cdot f^{1} \cdot d^{-1}$ at a density of 40 $fish \cdot m^{-2}$, and survival ranged from 84.7 to 96.9%. Hasma and Kasim (1992) found that *E. tauvina* is highly suitable for culture in India because of their good growth and high survival rates. Nassau grouper grew from 2.4 to 14.2 g in 56 days, and survival was high (90.5-96.4%) but not significantly different among the different diets used by Ellis et al. (1996).

In conclusion, the present study shows that cages are suitable for nursing *E. coioides* fingerlings starting as early as 2 g in body weight, then holding them until reaching market size of 800 g. It was also evident that stocking densities greater than 1000 $fish \cdot m^{-3}$ should be tried during the nursing stages (2-40 g); and for fish weighing less than 400 g, densities of more than 80 should be used; for larger fish, reducing the density to the 40 $fish \cdot m^{-3}$ level is recommended through grading. Further research is needed for improving survival of fingerlings during periods of low water temperature in winter months. Breeding and larval rearing of groupers, along with improvement of feed and feeding regimes are additional areas in need of further research.

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