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Comparative Growth of Brown-Marbled Grouper *Epinephelus fuscoguttatus* (Forsskål) and Camouflage Grouper *E. polyphekadion* (Bleeker) Under Hatchery and Growout Culture Conditions

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Abstract

The growth of the brown marbled grouper *Epinephelus fuscoguttatus* (Forsskål) and the camouflage grouper *E. polyphekadion* (Bleeker) was evaluated under hatchery, nursery and growout culture conditions in the hypersaline waters off the Red Sea coast of Saudi Arabia. Under hatchery culture conditions, the growth of *E. fuscoguttatus* larvae was significantly faster ($P<0.05$) than that of *E. polyphekadion* after day 30 and larval metamorphosis initiated from day 35 onwards in *E. fuscoguttatus* and after day 40 in *E. polyphekadion*. On day 45, the metamorphosed larval size of *E. fuscoguttatus* was significantly higher ($P<0.001$) than that of *E. polyphekadion*. The fast larval metamorphosis of *E. fuscoguttatus* compared to that of *E. polyphekadion* is of great advantage for commercial applications. Faster growth rate and high food conversion efficiency of *E. fuscoguttatus* compared to *E. polyphekadion* during the nursery rearing period shows that it is possible to obtain about 50g-sized fingerlings of *E. fuscoguttatus* for stocking in the growout production facilities in about two months compared to the four months required to achieve the same size in *E. polyphekadion*. Under growout culture conditions using a flow-through tank culture system, the growth performance of these groupers under different stocking densities of 5, 15 and 45 fish m^{-3} was evaluated for the first time. After seven months, the size of *E. fuscoguttatus* averaged 578.0-618.5g, with FCR averaging 1.24-1.73. After 12 months, *E. polyphekadion* size averaged 513.3-544.6g, with FCR averaging 2.05-3.75. A significant increase ($P<0.05$) in growth (2.34 ± 0.11g fish^{-1} d^{-1}) and yield (26.07 ± 2.28kg m^{-3}) in *E. fuscoguttatus* at a high stocking density of 45 fish m^{-3} compared to *E. polyphekadion* (growth 1.31 ± 0.77g fish^{-1} d^{-1} and yield 17.33 ± 0.53kg m^{-3}) show that *E. fuscoguttatus* is more suitable for commercial applications than *E. polyphekadion*. The present investigation suggests the possibility of raising groupers to marketable size in land-based intensive tank culture systems, instead of in conventional sea cages.

Introduction

The epinepheline serranid groupers are commercially important marine food fish in several countries, especially in Southeast Asia and the Middle

East. Since market demand for groupers is more than the supply from capture fisheries and considering the fast gaining economic importance of grouper cultures in recent years, many countries are concentrating on developing commercial grouper farming technology (Al-Thobaiti and James 1996). Many commercial grouper fish farms depend mainly on seed collected from the wild due to hatchery constraints and poor larval survival, which limits commercial expansion of grouper farming in Southeast Asian countries (Chen 1979; Tseng 1983; Quinitio and Toledo 1991). The groupers are conventionally farmed using floating net cages or in earthen ponds (Kohno *et al.* 1988; Manzano 1990; Hanafi *et al.* 1991). Due to the shortage of sufficient quantities of fingerlings of desired species either from the wild or from the hatchery, the stocking density of commercial grouper fish farms varies from 10-100 fish m^{-3} up to marketable size (Tookwinas 1990). Most of the literature available on the growth and productivity of groupers are based on laboratory aquarium studies or small-scale time bound experiments in net-cages with short culture duration, suggesting the industrial infancy of grouper culture and experiments (Lim 1985; Abdullah *et al.* 1987; Kohno *et al.* 1989; Tacon *et al.* 1991a; Orvay *et al.* 1992; Kayano *et al.* 1993; Chen and Tsai 1994). Literature on the growout production of groupers using hatchery produced fingerlings in land-based tank culture system is scarcely available.

Kuwait in the Middle East was the first country to report on the culture of *Epinephelus coioides*, previously reported as *E. tauvina*, in Persian Gulf waters (Hussain *et al.* 1975). Among 25 species of groupers reported from the Red Sea (Heemstra and Randall 1993), the camouflage grouper *E. polyphekadion* and the brown marbled grouper *E. fuscoguttatus* are commercially important species, frequently occurring along the nearshore coral reef area on the southern part of the Red Sea coast of Saudi Arabia. Hatchery breeding and fingerling production of *E. polyphekadion* was reported for the first time by Rasem *et al.* (1997) and James *et al.* (1997). However, there is no information available on the comparative growth of *E. fuscoguttatus* and *E. polyphekadion* under hatchery, nursery and growout culture conditions. The present investigation aimed to evaluate the growth performance of these species from hatchery to growout production in the hypersaline waters off the Red Sea coast of Saudi Arabia. Under growout culture conditions using a flow-through tank culture system, the growth performance of these groupers in relation to different stocking densities was evaluated for the first time.

Materials and Methods

Larval Rearing

The eggs for larval rearing were obtained from natural spontaneous spawning of *E. fuscoguttatus* and *E. polyphekadion* maintained in six $25m^3$ capacity broodstock holding tanks at the Fish Farming Center in Jeddah. Hatching and larval rearing procedures, including tank and feed management, were the same for both species and were carried out as described by James *et al.* (1997) for *E. polyphekadion*. The newly hatched larvae, one to two hours old, were stocked in 2.8m^3 capacity round fiberglass (1.5m deep) in-door hatchery larval rearing tanks at a stocking density of 30 larvae l^{-1}. Four replicates were used for each species. Aliquot fish samples from the larval rearing tanks were made once in five days untill day 45 of the larval rearing period to monitor the fish growth. Considering the slow growth of *E. polyphekadion*, the larvae were kept in the larval rearing tanks until day 50 before transfering to the nursery tanks.

The source of seawater used in the facility was from borewells dug near a coral lagoon on the Red Sea coast. The seawater used in the hatchery was pre-treated using pressurized sand filters and biofilters. The water salinity was 43‰ and water temperature was 28-29°C. The water quality in the tanks, particularly dissolved oxygen, was maintained at >5mg l^{-1}. The water pH varied from 7.3-7.6. The NH_3-N ammonia level was within the safe limits of <0.01mg l^{-1} throughout the larval rearing period.

Nursery

After a larval rearing period of 45 days, fingerlings of *E. fuscoguttatus* were graded and stocked in the nursery tanks. Considering the slow growth of *E. polyphekadion*, the fingerlings were graded and stocked on day 50 of the larval rearing period in the nursery tanks. For nursery rearing, 2.8m^3 capacity round fiberglass (1.5m deep) in-door hatchery tanks were used in four replicates of *E. fuscoguttatus* and six replicates of *E. polyphekadion*. The stocking density was 200 fingerlings m^{-3}. The fish were hand fed at ad-libitum with commercially formulated feed 'Provimi' (Provimi B.V., Rotterdam, Holland), 1.5 mm, 2 mm and 3 mm size extruded pellets with 50-51% crude protein (Table 1) in the morning, and trash fish, mainly constituted of *Herklotsichthys* spp., in the evening. The trash fish was used as part of the feed regime based on personal observations of enhanced growth rate of both the species while feeding with trash fish compared to using pellets alone in their diet. Also, trash fish is conventionally used as feed for groupers under commercial culture conditions.

Table 1. Proximate composition (dry weight) of extruded inert feed used for the nursery rearing of *E. fuscoguttatus* and *E. polyphekadion*.

Composition	Feed size (mm)	
	1.5	2.0 & 3.0
Crude protein (%)	51.0	50.0
Crude fat (%)	10.0	18.0
Crude fibre (%)	1.5	0.8
Ashes (%)	10.0	8.6
Moisture (%)	9.0	9.0
Vitamin A (IU kg^{-1})	30,000	25,000
Vitamin D3 (IU kg^{-1})	3,000	3,000
Vitamin C (Stable) (mg kg^{-1})	200	00
Vitamin E (mg kg^{-1})	100	100

The source of seawater and water quality used was the same as in larval rearing. The water exchange was about 3-4 times d^{-1} in the flow-through nursery tanks.

The fish were sampled monthly to monitor growth. During sampling, the fish were collected at random and anaesthetized with 'Quinaldine sulfate', an ionized form of Quinaldine as a water soluble crystaline powder, supplied by ARGENT Inc., USA. After recording length and weight, the fish were immediately released in aerated running seawater to recover from the anaesthetic effects before releasing them in the nursery tanks. Due to the fast growth of *E. fuscoguttatus* the nursery rearing period was terminated on the third month of the culture period and *E. polyphekadion* was kept in the nursery tanks up to four months until the fingerlings reached about 56-59g size before introducing in the growout tanks.

Growout Production

After a nursery period of 90 days, *E. fuscoguttatus* fingerlings were graded and 127-131g size fingerlings were selected for stocking in growout production tanks. *E. polyphekadion* fingerlings were graded after a nursery period of 120 days and 56-59g size fingerlings were stocked in growout production tanks. The fingerlings were stocked in 3m dia. x 1.4m deep and $10m^3$ working volume round fiberglass growout production tanks at different stocking densities of 5, 15 and 45 ind. m^{-3}. Due to restricted availability of tank facilities, two replicates were used for each treatment. The water exchange was about five times d^{-1} in the flow-through tank culture system. The fish were hand fed twice a day in the morning and evening. A locally-formulated, 4.5-6mm size moist pellet feed with 40.9% crude protein was used for feeding in the morning and trash fish, mainly constituted of *Herklotsichthys* spp., was used for feeding in the evening. Table 2 show the formulation and proximate analysis of the FFC (Fish Farming Center) moist pellet feed. The pellet and trash fish were fed at a ratio of 1:1. Although the fish were hand fed to satiation, the feed ration consisted of up to 5% of body weight during the first three months, 3% during the 4th, 5th and 6th months of the culture period and 2% from 7th month onwards until harvesting - *E. fuscoguttatus* at the end of a seven-month growout culture period and *E. polyphekadion* at the end of a 12 -month culture period to achieve final fish size. The feed rations were adopted from commercial farmers in Southeast Asian countries and to understand the growth of groupers under restricted feed regimes, since feed is a major cost of production under commercial culture conditions.

The fish were not graded throughout the seven- and 12-month growout periods to observe size diversity within the population as well as to maintain the stocking densities. The fish were sampled monthly to monitor their growth. They were not fed for 18 h before sampling. During sampling, the fish were collected at random and anaesthetized with 'Quinaldine sulfate'. After recording the length and weight, the fish were immediately released in aerated seawater to allow them to recover from the anaesthetic effects, after which they were released in the growout tanks.

Table 2. Formulation and proximate chemical composition of FFC moist pellet feed used for the growout production of *E. fuscoguttatus* and *E. polyphekadion*.

Formulation	($g\ 100g^{-1}$)
Fish meal	43
Soybean meal	15
Yellow corn meal	10
Bone and meat meal	10
Wheat bran	10
Yeast, feed grade	6
Fish oil	5
Vitamin-C	0.4
Vitamin premix*	0.1
Poultry minerals	0.1
Binder	0.4
Proximate composition	Mean of two replicates (%)
Crude protein	40.90
Crude fat	7.68
Crude fiber	4.22
Ashes	9.98
Moisture	22.39
Digestible carbohydrates	9.84
Calcium as Ca	2.35
Total Phosphorus as P	1.34
Chlorides as NaCl	1.30
Calculated metabolizable energy ($Kcal\ Kg^{-1}$) = 2675	

*Content mg per g premix: Thiamine-HCL 2.0; Riboflavin 3.0; Calcium pantothenate 6.0; Niacinamide 12.0; Pyridoxine-HCL 2.0; Folic acid 0.5; Choline chloride 60.0; Biotin 0.2; Vitamin B12 - 0.1; Vitamin A-500 IU; Vitamin D_3 25 IU; Vitamin E-20 IU; and Vitamin K 0.5.

The seawater supply was from direct pumping of seawater from two borewells located in coral beds on the Red Sea coast. The water salinity was 42-43‰ throughout the culture period. The water quality in the tanks, particularly dissolved oxygen, was maintained above 5mg l^{-1} and ranged from 4.8-6.9mg l^{-1}. The water pH varied from 7.2-7.6. The water temperature ranged from 28.6-29.8 °C. The water exchange was regulated to maintain the NH_3-N ammonia level within the safe limits of <0.01mg l^{-1} in the culture tanks. The toxic nitrite level was <0.001mg l^{-1} in all the treatments.

Statistical Analyses and Calculations

Statistical analyses were performed by one-way ANOVA and T-tests using CSS:Statistica (version 3.1), Statsoft Inc. Differences were compared using the least significant difference (LSD) test and were considered significant at $P<0.05$. Values are given as means ± standard deviation.

The specific growth rate (SGR) was calculated using the formula $(\ln W_{t2} - \ln W_{t1}) / (t_2 - t_1) \times 100$, where W_{t1} and W_{t2} represent initial and final weight of fish (g) at times t_1 and t_2 (days). The food conversion ratio (FCR) was calculated as g dry food eaten / g live weight gain.

Results

Larval Rearing

The total length of the newly hatched larvae of *E. fuscoguttatus* ranged from 1.83-1.93 mm, with a mean of 1.89±0.04 mm, while that of *E. polyphekadion* ranged from 1.55-1.71 mm, with a mean of 1.65±0.05 mm. Eight hours after hatching, the larval length of *E. fuscoguttatus* averaged 2.40 mm and that of *E. polyphekadion* averaged 2.07 mm. During the larval rearing period, larval growth was slow in the early stages, with the growth curve for this period showing a curvilinear pattern (Fig. 1) for both *E. fuscoguttatus* and *E. polyphekadion*. On day five, larval length averaged 2.61±0.04 mm for *E. fuscoguttatus* and 2.80±0.32 mm for *E. polyphekadion*. No significant difference ($P>0.05$) in larval length between these two species were evident at the early larval stages up to day 30. Larval sizes were significantly different ($P<0.05$) between *E. fuscoguttatus* and *E. polyphekadion* from day 35 onwards: 18.67±2.25 mm in the former vs. 14.93±2.54 mm in the latter on day 35, and 21.53±2.98 mm vs.17.23±1.38 mm on day 40. Larvae transformed to juveniles from day 35 onwards in *E. fuscoguttatus* and after day 40 in *E. polyphekadion*. The larval size of *E. fuscoguttatus* on day 45 averaged 34.40±4.88 mm in length and that of *E. polyphekadion* averaged 19.77±1.91 mm. On day 50, *E. polyphekadion* larval size averaged 33.40±7.01 mm in length. The larval rearing was terminated on day 45 for *E. fuscoguttatus* and on day 50 for *E. polyphekadion*. At the end of the larval rearing period, the survival averaged 0.9% for *E. fuscoguttatus* and 1.7% for *E. polyphekadion*.

Nursery

During the nursery period (Fig. 2 and 3), initial size (45 days old) of *E. fuscoguttatus* ranged from 0.76-2.22 g with a mean of 1.20±0.29 g and that of *E. polyphekadion* (50 days old) ranged from 1.00-2.10 g with a mean of 1.56±0.37 g. During the first month of the nursery rearing period, size of *E. fuscoguttatus* ranged from 8.00-18.60 g with a mean of 14.28±1.96 g and that of *E. polyphekadion* ranged from 5.20-15.20 g with a mean of 8.84±2.74 g.

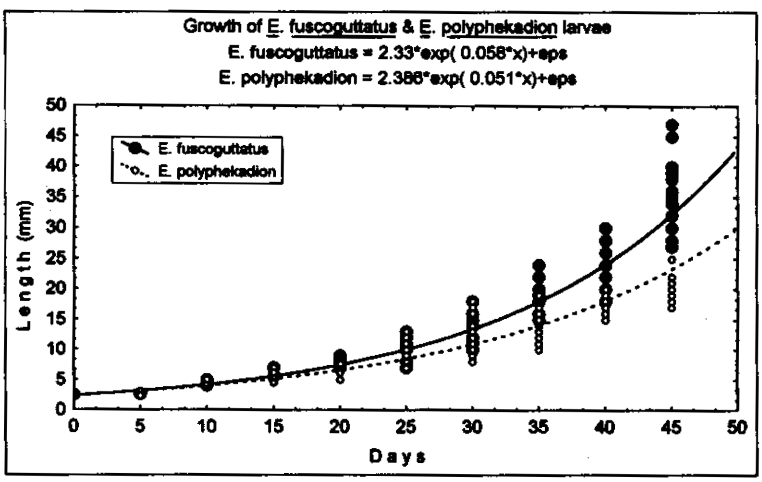

Fig. 1.Comparative growth of *E. fuscoguttatus* and *E. polyphekadion* larvae.

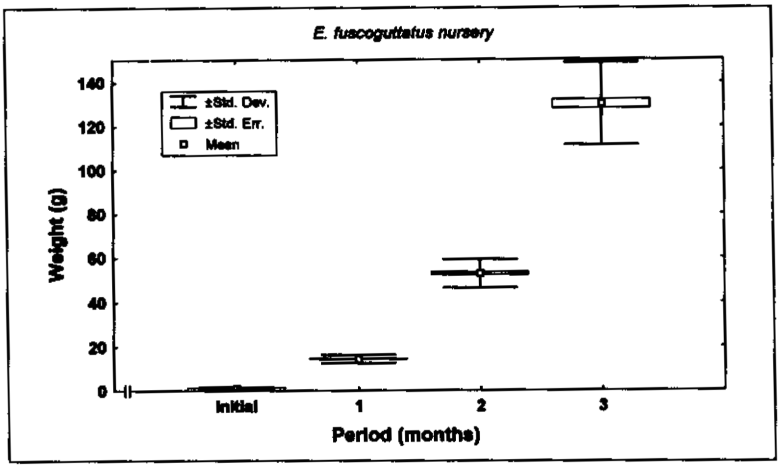

Fig. 2. Growth and size variations with reference to standard deviation and standard error observed in the *E. fuscoguttatus* population sampled during nursery rearing period.

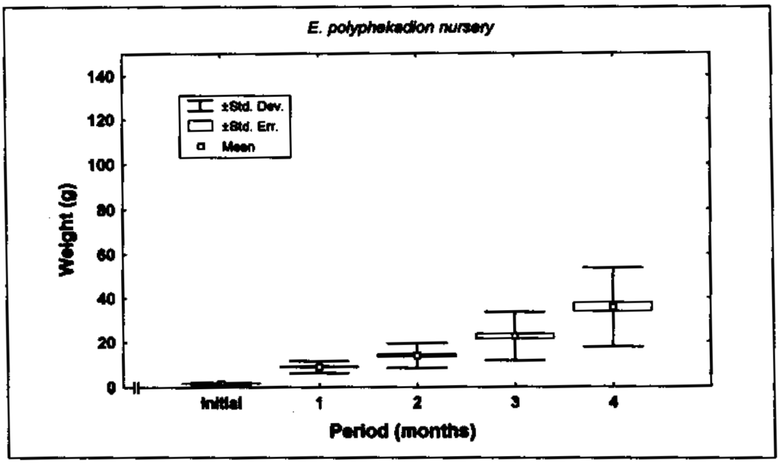

Fig. 3. Growth and size variations with reference to standard deviation and standard error observed in the *E. polyphekadion* population sampled during nursery rearing period.

During the second month *E. fuscoguttatus* size ranged from 38.50-67.30 g with a mean of 52.85±6.38 g and that of *E. polyphekadion* ranged from 8.00-28.30 g with a mean of 13.90±5.58 g. During the third month *E. fuscoguttatus* size ranged from 84.00-176.00 g with a mean of 129.94±18.57 g and that of *E. polyphekadion* ranged from 10.00-49.00 g with a mean of 22.51±10.88 g. On the fourth month of the nursery period, *E. polyphekadion* size ranged from 12.0-80.1 g with a mean of 35.64±17.890 g.

During the nursery rearing period, wide size variations were observed in both species. Figures 2 and 3 show the size variations in *E. fuscoguttatus* and *E. polyphekadion*, particularly with reference to standard deviation and standard error observed in the population sampled. During the nursery period, the average daily growth rate of *E. fuscoguttatus* (1.42±0.87 g $fish^{-1}$ d^{-1}) was significantly higher ($P<0.05$) than that of *E. polyphekadion* (0.28±0.11 g $fish^{-1}$ d^{-1}). The specific growth rate (SGR) showed a declining trend from the initial nursery rearing period and was curvilinear in relation to the growth period in both species (Fig. 4 and 5). The maximum SGR observed was 8.26±0.03 for *E. fuscoguttatus* and 5.85±0.23 for *E. polyphekadion* during the first 30 days of the nursery rearing period. The SGR averaged 5.19±2.94 during the three

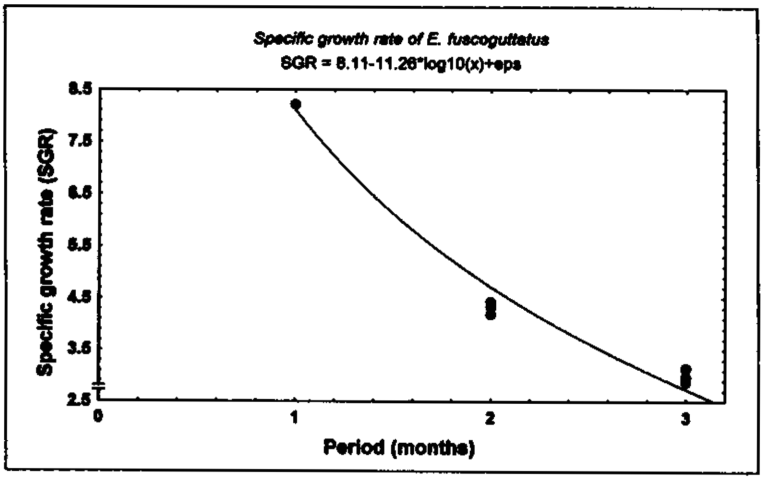

Fig. 4. Specific growth rate of *E. fuscoguttatus* during the nursery period.

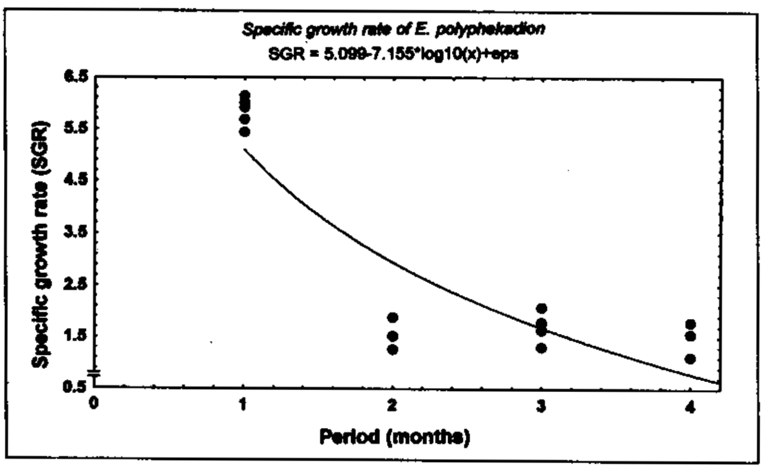

Fig. 5. Specific growth rate of *E. polyphekadion* during the nursery period.

months of rearing period for *E. fuscoguttatus* and 2.63±1.91 during the four months of rearing period for *E. polyphekadion*. The food conversion ratio (FCR in dry weight) averaged 0.91±0.26 for *E. fuscoguttatus* and 2.11±0.32 for *E. polyphekadion*. There was no significant difference ($P>0.05$) in survival observed between the two species during the nursery period. Survival averaged 96.00±3.15 % for *E. fuscoguttatus* and was 94.40±2.18 % for *E. polyphekadion*.

Growout

During the growout culture period, wide variations in sizes were observed in both species (Table 3). At the end of the seven-month growout period, the size of *E. fuscoguttatus* varied from 430-799g, with a mean of 578.00±104.69g at stocking densities of five fish m^{-3}, 474-810g with a mean of 598.00±88.13g at 15 fish m^{-3} and 401-904g with a mean of 618.50±110.71g at 45 fish m^{-3}. After the 12-month growout period, the size of *E. polyphekadion* varied from 233-900g with a mean of 544.60±170.72g at stocking densities of five fish m^{-3}, 269-864g with a mean of 540.20±150.82g at 15 fish m^{-3} and 270-812g with a mean of 513.30±134.52g at 45 fish m^{-3}. Significantly high growth ($P<0.05$) was

Table 3. Growth performance of *E. fuscoguttatus* and *E. polyphekadion* at different stocking densities in 10m^3 growout production tanks.

	Stocking densities (No. m^{-3})		
	5	15	45
Initial average weight (g)			
E. fuscoguttatus	131.8±24.12	130.3±20.96	127.0±17.52
E. polyphekadion	56.8±17.67	56.2±17.50	59.3±18.96
Culture duration (months)			
E. fuscoguttatus	7	7	7
E. polyphekadion	12	12	12
Final average weight (g)			
E. fuscoguttatus	578.0±104.69^a	598.0±88.13^a	618.5±110.71^a
E. polyphekadion	544.6±170.72^a	540.2±150.82^a	513.3±134.52^a
Average daily growth rate (g)			
E. fuscoguttatus	2.13±0.13^a	2.23±0.24^a	2.34±0.11^a
E. polyphekadion	1.49±0.74^{ab}	1.32±0.57^{ab}	1.31±0.77^b
Specific growth rate (% d^{-1})			
E. fuscoguttatus	0.71±0.02^a	0.73±0.04^a	0.75±0.01^a
E. polyphekadion	0.64±0.04^{ab}	0.63±0.00^{ab}	0.60±0.01^b
Survival rate (%)			
E. fuscoguttatus	100.0±0.0^a	95.0±5.66^{ab}	93.5±4.95^b
E. polyphekadion	98.0±2.83^a	89.5±0.71^{ab}	84.5±3.54^b
Food conversion ratio			
E. fuscoguttatus	1.73±0.16^a	1.59±0.12^a	1.24±0.02^a
E. polyphekadion	3.75±0.35^b	2.75±0.21^b	2.05±0.07^c
Productivity / yield (kg m^{-3})			
E. fuscoguttatus	2.90±0.13^a	8.53±1.20^b	26.07±2.28^c
E. polyphekadion	2.43±0.22^a	6.36±0.78^b	17.33±0.53^d

Mean values in the same horizontal and vertical rows with different superscripts differ significantly (P<0.05).

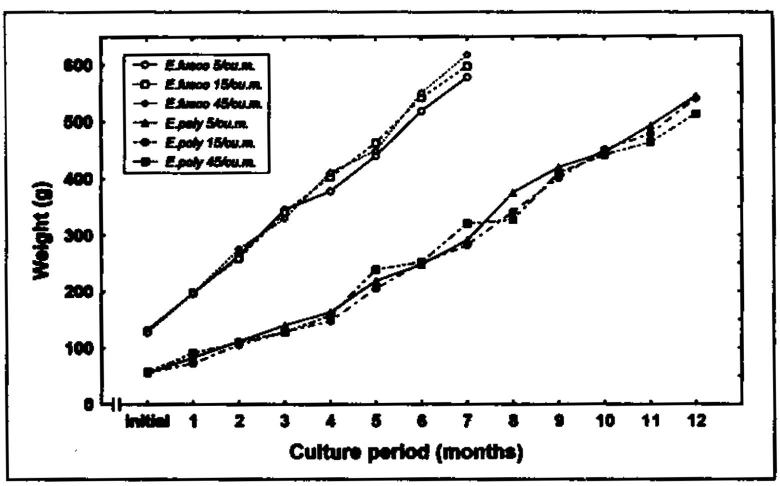

Fig. 6. Comparative growth of *E. fuscoguttatus* and *E. polyphekadion* at stocking densities of 5, 15 and 45 fish m^{-3} in 10m^3 capacity growout culture tanks.

observed in *E. fuscoguttatus* compared to that of *E. polyphekadion* (Fig. 6). The final size at harvest did not differ significantly (P>0.05) between the two species at the above stocking densities. However, the average daily growth rate as well as the SGR were significantly high (P<0.05) at 45 fish m^{-3} for *E. fuscoguttatus* compared to *E. polyphekadion*. The average daily growth rate at different stocking densities during the seven-month growout culture period ranged from 0.83-3.67g $fish^{-1}$ d^{-1} for *E. fuscoguttatus* and 0.48-3.38g $fish^{-1}$ d^{-1} for *E. polyphekadion*. The average SGR at different stocking densities ranged from 0.71-0.75% for *E. fuscoguttatus* and from 0.60-0.64% for *E. polyphekadion*.

Survival rate significantly decreased (P<0.05) with increasing stocking densities in both species (Table 3). Up to 100% survival was observed at low stocking densities of five fish m^{-3}. At a stocking density of 45 fish m^{-3}, the survival rate averaged 93.50±4.95% for *E. fuscoguttatus* and 84.50±3.54% for *E. polyphekadion*. The FCR was significantly low (P<0.05) for *E. fuscoguttatus* (average 1.24-1.73) in all the stocking densities tested compared to that of *E. polyphekadion* (average 2.05-3.75). No significant difference (P>0.05) in FCR

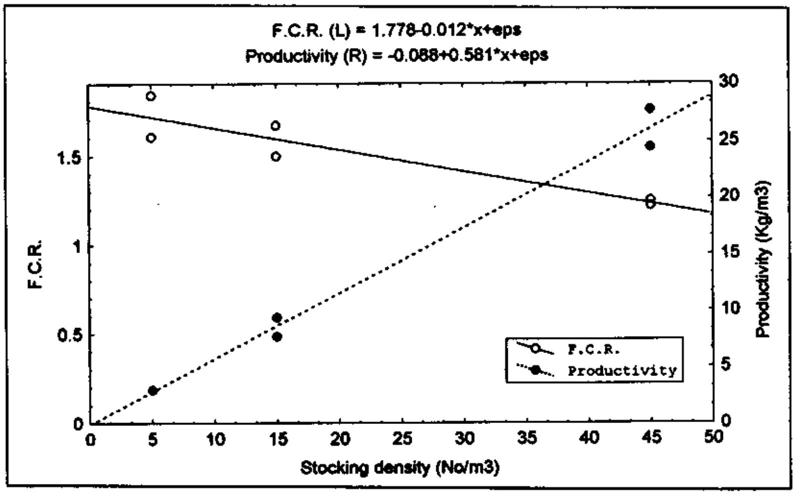

Fig. 7. The effect of different stocking densities on the food conversion ratio (FCR) and productivity of *E fuscoguttatus*.

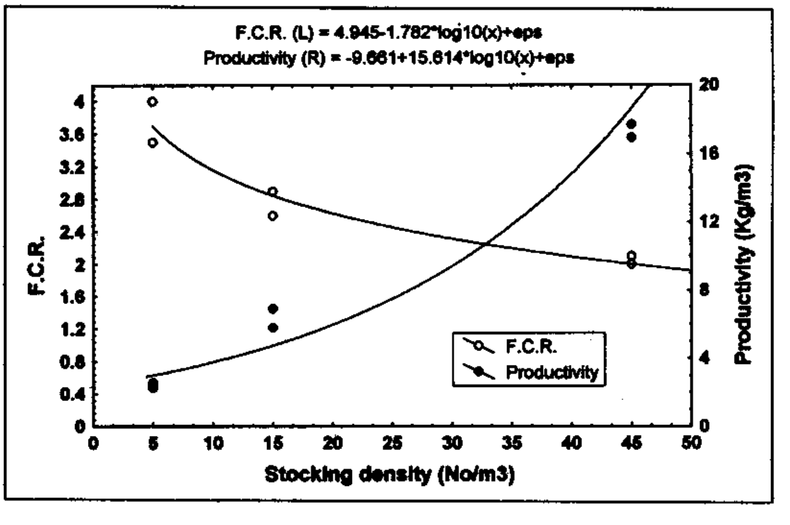

Fig. 8. The effect of different stocking densities on the food conversion ratio (FCR) and productivity of *E. polyphekadion*.

was observed between different stocking densities for *E. fuscoguttatus*, whereas FCR was significantly low ($P<0.05$) at high stocking densities of 45 fish m^{-3} in *E. polyphekadion*. Figs. 7 and 8 show the relationships between the stocking densities and FCR and biomass production/yield in the culture system for *E. fuscoguttatus* and *E. polyphekadion*. The yield in terms of kg fish produced m^{-3} of water used in the culture system significantly increased ($P<0.05$) with increasing stocking densities in both species. Significantly high ($P<0.01$) productivity was observed at a stocking density of 45 fish m^{-3} for *E. fuscoguttatus* compared to that of *E. polyphekadion*. At the above stocking density, the yield in terms of total biomass produced in unit volume of water used in the culture system averaged 26.07±2.28 kg m^{-3} for *E. fuscoguttatus* and 17.30±0.53 kg m^{-3} for *E. polyphekadion*.

Discussion

The present study investigated for the first time the growth performance of two species of groupers from hatchery to growout culture conditions under hypersaline water conditions in the Middle East. Hatchery larval rearing of groupers are still in the early stages of development due to small larval size and fragility of groupers, making this fish one of the most difficult marine fish to rear. The newly hatched larval size observed during this investigation is within the size range observed for *E. fuscoguttatus* in Singapore (Lim *et al.* 1990; Chao *et al.* 1993) and for *E. polyphekadion* in Japan (Tawada 1989). Although the newly hatched larvae of *E. polyphekadion* were significantly smaller ($P<0.05$) in size (1.65±0.05 mm) compared to that of *E. fuscoguttatus* (1.90±0.04 mm), the larvae grew rapidly during the first day after hatching. However, the growth of *E. fuscoguttatus* was significantly ($P<0.05$) faster than that of *E. polyphekadion*. Also, the growth of *E. fuscoguttatus* observed during this investigation is faster than that of *E. tauvina* (Chen *et al.* 1977), *E. coioides* (reported as *E. tauvina*, Hussain and Higuchi 1980), *E. malabaricus* (Maneewong *et al.* 1986) and *E. akaara* (Ukawa *et al.* 1966). The larval transformation to juveniles in *E. fuscoguttatus* initiated from day 35 onwards is in accord with the observations of Lim *et al.* (1990). The fast growth of larvae to juveniles in *E. fuscoguttatus* compared to that of *E. polyphekadion* and other grouper species (*E. coioides*, Hussain and Higuchi 1980; Al-Abdul-Elah *et al.* 1996; *E. malabaricus*, Maneewong *et al.* 1986) is of great advantage for commercial applications since it could save considerable hatchery space, time and manpower utilization.

The observed larval survival rate for *E. fuscoguttatus* (0.9%) in this investigation was poor compared to that of Lim (1993) who obtained about 10% survival. Under hypersaline culture conditions, Al-Abdul-Elah *et al.* (1996) obtained an average of about 13.15% larval survival for *E. coioides* that shows the possibility of achieving enhanced survival for groupers under hypersaline water conditions in the Middle East. The low survival obtained during the present investigation should be further studied in view of the improved broodstock, feed, water quality and tank management practices leading to the enhancement of hatchery fry production.

Faster growth rate and high food conversion efficiency of *E. fuscoguttatus* than that of *E. polyphekadion* observed during the nursery rearing period show that it is possible to obtain about 50g size fingerlings of *E. fuscoguttatus* for stocking in the growout production facilities in about two months of nursery rearing period instead of waiting for four months to achieve the same in *E. polyphekadion*. The average daily growth rate (1.42 g $fish^{-1}$ d^{-1}) as well as the SGR (5.19) of *E. fuscoguttatus* obtained during the present investigation is much higher than in the juvenile stages of other grouper species observed under experimental conditions (Abdullah *et al.*, 1987; Kayano *et al.*, 1990, 1993; Orvay *et al.*, 1992; Chen and Chung 1994; Chen and Tsai 1994). Previous investigations also show that the growth rate of groupers is species-specific and depends on culture conditions (Chua and Teng 1979; Lee 1982; Sakares and Sukbanteang 1985; Sakares and Kumpang 1988; Kohno *et al.*, 1989; Tacon *et al.*, 1991b; Hamsa and Kasim 1992; Chao *et al.*, 1993).

During the growout culture period, no significant differences ($P>0.05$) in growth rates were observed at different stocking densities within the same species. This finding is similar to the observations of Chua and Teng (1979) in *E. malabaricus* (reported as *E. salmoides*). However, *E. fuscoguttatus* exhibited a significantly high ($P<0.05$) growth rate (2.34±0.11g $fish^{-1}$ d^{-1}) at high stocking densities of 45 fish m^{-3} compared to that of *E. polyphekadion* (1.31±0.77g $fish^{-1}$ d^{-1}). An average daily growth rate of 2.13-2.34g $fish^{-1}$ d^{-1} observed during the present tank culture system for *E. fuscoguttatus* is comparable to that of the observations of Tacon *et al.* (1991b) for *E. tauvina* (2.87g $fish^{-1}$ d^{-1}) reared in floating net cages. The growth rate achieved for *E. polyphekadion* during this investigation (1.31-1.49g $fish^{-1}$ d^{-1}) is higher than the growth rate (1.13g $fish^{-1}$ d^{-1}) observed for *E. polyphekadion* (reported as *E. microdon*) in French Polynesia (AQUACOP *et al.* 1990).

The food conversion ratio (FCR) observed during this investigation for *E. fuscoguttatus* (1.24-1.73) shows that feed utilization for the growout production of this species is significantly efficient ($P<0.05$) compared to that of *E. polyphekadion* (2.05-3.75) under commercial farming conditions. The FCR obtained for both species show that the feeding utilized during this investigation is more efficient than feeding groupers only with trash fish (Chua and Teng 1978, 1979; Sakares and Sukbanteang 1985; Kohno *et al.* 1989). Under experimental cage culture conditions, using frozen fish and moist pellets, Tacon *et al.* (1991b) obtained FCR values ranging from 0.89-1.80 for *E. tauvina* which is comparable to the FCR observed for *E. fuscoguttatus* during this investigation. However, FCR varied with stocking densities in the culture system. The low FCR observed with increasing stocking densities in this investigation is similar to that of *E. tauvina* under cage culture conditions (Sakares and Kumpung 1988). The increasing feed efficiency (low FCR) with increasing stocking densities of groupers could partly be due to decreased metabolic rate at high stocking densities (Sakares and Kumpung 1988). Also, high stocking densities stimulate feeding (Tookwinas 1990). The high growth rate and feed efficiency achieved for *E. fuscoguttatus* as well as for *E. polyphekadion* during this investigation show that the feeding used in this investigation is adequate to achieve good growth at the present stocking densities in the tank culture system.

Regardless of initial stocking size, the growout period required for *E. fuscoguttatus* (7 months) is considerably less than the growout period required for *E. polyphekadion* (12 months). Growout period and yield in unit volume are important for commercial operations. Significant increase ($P<0.05$) in the growth (2.34±0.11g $fish^{-1}$ d^{-1}) and yield (26.07±2.28kg m^{-3}) at high stocking densities of 45 fish m^{-3} in *E. fuscoguttatus* compared to that of *E. polyphekadion* (growth 1.31±0.77g $fish^{-1}$ d^{-1} and yield 17.33±0.53kg m^{-3}) show the advantage of using *E. fuscoguttatus* for commercial applications instead of *E. polyphekadion*. The yield obtained for *E. fuscoguttatus* during the present investigation is comparable to that of Chao *et al.* (1993) in Singapore under similar stocking densities (44 fish m^{-3}) in net cages. Significantly increasing yield ($P<0.01$) with increasing stocking densities between 5 and 45 fish m^{-3} shows that the present tank culture system could sustain more biomass in terms of increasing fish stocking densities. The present investigation also suggest the possiblility of raising groupers to marketable size in land-based intensive tank culture systems, instead of using conventional sea cages. However, further studies should be pursued to determine the optimum stocking density requirement of *E. fuscoguttatus* to develop an economically viable intensive tank culture system for commercial applications.

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