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SUMMARY – The purpose for the introduction and cultivation of new marine finfish in the Mediterranean aquaculture industry has been recently recognised as one of the most important strategies for the diversification of the final products as well as the market relief from the competition among Mediterranean countries. Especially for Greece, this is imperative since it is the leading producer of European sea bass and gilthead sea bream fish in Europe today with approximately 30,000 t annually. The National Centre for Marine Research, established in 1945, has focused its research on the cultivation technology of the new species, their nutritional requirements and the production of suitable fishfeeds as well as the pathology of these species. The main species that are now under research are the red porgy, *Pagrus pagrus* and the common dentex, *Dentex dentex*. The research on the porgy has focused on the embryology and the study of the mass mortalities observed during the first days after hatching while for the snapper, on the nutritional requirements for the elimination of the cannibalism.

Key words: Marine finfish diversification, *Pagrus pagrus*, *Dentex dentex*.

RESUME – *"Progrès récents en aquaculture de nouvelles espèces de poissons marins au Centre National de Recherches Marines (Grèce)". La finalité de l'introduction et de l'élevage de nouveaux poissons marins dans l'industrie aquacole méditerranéenne a été reconnue récemment comme l'une des stratégies les plus importantes pour la diversification du produit final ainsi qu'une réduction de la compétition sur les marchés entre pays méditerranéens. Ceci est impératif spécialement pour la Grèce, car elle est le premier producteur de bar européen et de daurade royale en Europe actuellement avec environ 30 000 tonnes par an. Le Centre National de Recherches Marines, fondé en 1945, a axé ses recherches sur la technologie d'élevage de ces nouvelles espèces, sur leurs besoins nutritionnels et la production d'aliment poisson adéquat, ainsi que la pathologie de ces espèces. La principale espèce qui actuellement fait l'objet de recherches est le pagre commun,* Pagrus pagrus*, et le denté commun,* Dentex dentex*. Les recherches sur le pagre commun se sont centrées sur l'embryologie et l'étude des mortalités en masse observées durant les premiers jours après éclosion, et pour les vivaneaux, sur les besoins nutritionnels pour l'élimination du cannibalisme.*

Mots-clés : *Diversification des poissons marins,* Pagrus pagrus*,* Dentex dentex*.*

Introduction

The species *Pagrus pagrus* and *Dentex dentex* are two important commercial species for the Mediterranean fishery and members of the Sparidae family. Recently, they have has been considered as candidates for aquaculture in order to aid the process of increasing the diversification of aquaculture products in the region (Conides *et al.*, 1996; Conides and Nengas, 1998). The purpose for the introduction and cultivation of new marine finfish in the Mediterranean aquaculture industry has been recently recognised as one of the most important strategies for the diversification of the final products as well as the market relief from the competition among Mediterranean countries Even though, a lot of research has been conducted on the reproduction and cultivation of the European sea bass and the gilthead sea bream (Klaoudatos and Apostolopoulos, 1986; Marangos *et al.*, 1986; Klaoudatos, 1988; Conides and Anastasopoulou, 1992; Conides and Parpoura, 1995; Klaoudatos and Conides, 1996), the research for the red porgy and the common dentex are scarce. The first attempts to reproduce and cultivate the species for aquaculture purposes in the Mediterranean showed that there exist significant problems that have prevented the mass production of the species (Kentouri *et al.*, 1995; Stefanou *et al.*, 1995; Fostier *et al.*, this volume; Pavlidis *et al.*, this volume). These problems are mainly related to the dark coloration of the fish body and the significant mortality observed during the larval stages for the *Pagrus pagrus* and the cannibalism during the early life stages for the *Dentex dentex*. In the present study, the early growth of the *Pagrus pagrus* was studied from the point of view of management of endogenous food reserves and first feeding. This work took place at the Aquaculture Department of the National Centre for Marine Research (NCMR).

Infrastructure

The Department of Aquaculture of the National Centre for Marine Research operates a modern experimental hatchery located at Agios Kosmas, Athens (Greece). The hatchery was built in 1994 and exhibits indoor-insulated areas for the artificial reproduction of broodstock, egg hatching and larval rearing, phytoplankton and zooplankton (rotifers and *Artemia*). There are also indoor experimental feeding facilities with recirculation system for the establishment of fully controlled conditions. Additionally, there exist a series of outdoor cement and PVC tanks ranging from 1 m^3 to 48 m^3 for the rearing of broodstock and fry of various species. In addition to the two species examined in this study, there are also stocks of *Spondyliosoma cantharus, Pagellus erythrinus* and *Puntazzo puntazzo.*

Results and experience

Pagrus pagrus

The rearing techniques used for the rearing of the *Pagrus pagrus* species are similar to the techniques used for the rearing of the sea bream *Sparus aurata*. The eggs were obtained from natural spawning of a broodstock kept in captivity for 3 to 4 years in the rearing facilities of the commercial hatchery of the Rio-Pesca S.A. company (West Greece).

The incubation of the eggs was carried out in the installations of the NCMR in 1 m^3 rectangular PVC tanks, in seawater with salinity 36.8±0.4‰ and natural temperature 16.±0.9°C. The eggs were incubated at densities of 50 to 100 eggs/l without significant different hatching rates (mean 71.3±4.4%). The hatching period lasted 48 hours. The same rectangular tanks were used for the larval rearing. The green water technique was used for the maintenance of the larvae during the first 25 days of their life with a daily addition of dense phytoplankton culture. The temperature during the larval rearing gradually increased from 16 to 20°C, the dissolved oxygen was kept to saturation levels using submersible airstones and the pH varies between 7.8 and 8.3. The photoperiod was 12 h L:12 h D. The larvae received initially rotifers (*Brachionus plicatilis*) from the 3rd day when the mouth opens until the day 25. The concentration of rotifers was 10-15 individuals/ml while dense phytoplankton culture was added daily in 2 doses (morning and afternoon) for the maintenance of the green-water. On day 20 after hatching, *Artemia* newly hatched nauplii (AF grade) were introduced in the tanks at a density of 1 individuals/ml, which gradually increased, to 10 individuals/ml on day 30 after hatching. From day 30 after hatching, the larvae were fen on EG grade *Artemia* nauplii (24 hours old) enriched with highly unsaturated fatty acids (HUFA) from various combinations of commercial emulsions (Selco, Super Selco, DHA Selco). Dry food was supplied from day 35 after hatching and weaning was completed on day 45 after hatching.

Our research resulted to the identification of an embryological deficiency: the mouth of the larvae opens on the 3rd day after hatching (temperature: 16-17°C) while the yolk sac and oil globule are consumed on the 4th day and the digestive system is functional and with evidence of consumed food (rotifers) on the 7th day after hatching. This gap between the existence of internal energy reserves and the function of the digestive system actually leaves the larvae without energy for 2-3 days. Mass mortalities occur during this period reaching 70%. However, the species is robust and the larvae surviving the first 7 days after hatching show exceptional survival rates (reaching almost 80%). The subsequent use of rotifers and *Artemia* nauplii enriched with the common commercial oils increases the success of the production. In comparison with the gilthead sea bream (*Sparus aurata*) and the European sea bass (*Dicentrarchus labrax*), the red porgy requires longer feeding period with rotifers (until the 20th-25th day after hatching) and *Artemia* nauplii and meta-nauplii (until the 40th-50th day after hatching) before the exclusively changing to the artificial diets.

The aim of the research on the porgy is to determine the early growth scheme and development stages of the larvae through the transition from endogenous and exogenous food sources using as main criterion the body length gained at each development stage. The finding of the study so far show that the initial period of the specie's larval life can be divided into three phases: (a) an initial phase characterised by no motility (0-24 h time after hatching; TAH); (b) a phase characterised by active movement and exploitation of the endogenous food reserves (24 h to 96 TAH); and (c) a phase characterised by the transition from endogenous to exogenous food (96 to 168 TAH). It was observed that there does not exist an overlapping period between phases b and c and therefore, there exists a

gap of 24-48 h during which the larvae have exhausted their internal food reserves (oil globule and yolk sac) while the digestive track is not ready to digest external food items (rotifers). This resulted to mass mortality reaching almost 70% between days 3 and 7 after hatching.

Dentex dentex

The dentex (*Dentex dentex* L.) is a fast growing sparid, which represents a possible candidate for Mediterranean mariculture. Nutritional deficiencies and low acceptability of commercial dry pellet diets have been suggested as the main reasons for certain rearing drawbacks. Commercial marine fish diets would have to, therefore. be modified to provide a suitable feed for this species.

The aim of research on the dentex is focused on the investigation of the nutritional factors affecting the survival and non specific immune system. Two experiments were contacted in the National Centre for Marine Research to investigate, firstly, the ability of the species to accept dry pellets by using various feed attractants and, secondly, to examine the effect of different levels of essential fatty acids and vitamins C and E on the tissue composition and physiology of dentex. At a first stage, wild and cultured populations were analyzed to determine any possible differences of major nutrients of their body tissue. Different experimental diets (Table 1) were tested to examine the effect of the incorporation of various feed attractants on the acceptability of dry pellets, the reduction of cannibalism of snapper and growth (Table 2). Using as a basis the most effective formulation from the last experiment, different levels of vitamin C and E as well as essential fatty acid were tested (Table 3) and their effect on the growth was measured and the carcass contents (Table 4).

Table 1. Formulation of experimental diets

Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Commercial
Fishmeal LT	68.44	65.69	69.02	67.96	70.43	56.74	25.18	
Wheat meal	20.00	22.06	20.00	20.00	22.74	14.00	12.00	
Krill meal	5.00	–	–	–	–	4.00	–	
Shrimp meal	–	5.00	–	–	–	–	–	
Fish solubles	–	–	5.00	–	–	–	–	
Meat solubles	–	–	–	5.00	–	–	–	
Raw fish	–	–	–	–	–	–	58.82	
Wheat gluten	–	–	–	–	–	–	2.00	
Vitam. + min.	2.00	2.00	2.00	2.00	2.00	1.60	2.00	
Marine oil	4.56	5.25	3.98	5.03	4.82	3.64	–	
Water	–	–	–	–	–	20.00	–	
Nutrient analysis (% as fed)								
Moisture	10.10	10.01	9.90	9.90	10.14	30.00	44.01	10.00
Protein	53.82	51.00	54.66	54.04	52.47	41.97	32.00	50.00
Fat	12.21	12.00	12.00	12.00	12.00	9.60	10.26	12.00
Ash	8.00	9.14	7.82	7.97	7.72	6.20	3.93	8.00
NFE	15.00	16.50	15.00	15.00	17.00	13.60	9.16	15.00

All the experimental diets (Table 2) performed better than the commercial diet, which was a diet commonly used for sea bream rearing, but only the groups fed the diets 5 and 7 performed statistically better, according to the values determined for specific growth rate (SGR) and percent growth (Table 2). These results are in accordance with Efthimiou *et al.* (1994) who obtained better growth when they fed dentex juveniles with moist diets containing raw fish compared to commercial diet. Feed efficiency (FE) gave the lowest value for the commercial diet (60%), close to 100% for all the dry experimental formulations and approximately 80% for the two moist diets 6 and 7. These lower FE determined for the moist diets could partly be explained due to the fact that both formulations exhibited higher leaching at feeding than the dry pellets. Appetite was lowest for the group fed the commercial diet and highest for the two moist diets. The preference of dentex to consume moist diets over the commonly

used commercial marine diets is well documented (Tibaldi *et al.*, 1996). The experimental dry diets were consumed significantly better than the commercial diet. The higher fishmeal content, and the possible texture and color difference of the laboratory prepared dry formulations over the commercial feed can be suggested as probable reasons. The different dietary treatments did not influence the hepatosomatic indices or the whole body analysis of dentex.

Table 2. Growth performance

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Commercial
Initial wt	11.11	10.59	10.80	11.93	10.87	10.5	11.05	11.35
Final wt	18.0^{ab}	17.0^{ab}	16.9^{ab}	17.2^{ab}	18.3^{ab}	16.6^{ab}	19.7^{b}	13.0^{a}
SGR	1.65^{ab}	1.69^{ab}	1.59^{ab}	1.31^{ab}	1.84^{b}	1.63^{ab}	2.05^{b}	0.72^{a}
% growth	61.6^{ab}	60.8^{ab}	56.5^{ab}	45.7^{ab}	67.9^{b}	58.7^{ab}	77.7^{b}	23.3^{a}
FE	121.2	125.1	96.66	89.54	111.1	73.36	80.08	61.14
CV	0.22^{ab}	0.11^{ab}	0.18^{ab}	0.22^{ab}	0.22^{ab}	0.28^{ab}	0.20^{ab}	0.34^{a}
HSI†	2.34	2.10	2.43	2.41	2.22	2.15	2.21	1.99
Appetite	1.55^{bc}	1.14^{bc}	1.38^{bc}	1.66^{cd}	1.66^{cd}	2.01^{de}	2.41^{e}	0.80^{a}

†Hepatosomatic index.

Table 3. Formulation of experimental diets and growth performance

	Diet A	Diet B	Diet Z	Diet H
Fish meal	70.43	70.43	70.43	70.43
Wheat meal	22.74	17.74	22.74	17.74
Vitamin C	–	–	0.04	0.04
Vitamin E	–	–	0.02	0.02
Marine oil	4.82	9.82	4.82	9.82

Table 4. Growth performance

Initial weight	12.69	11.61	11.59	11.705
Final weight	30.865	28.93	31.385	30.035
SGR	1.58	1.63	1.78	1.69
Feed efficiency	135.53	132.85	149.09	144.96
Body protein (%)	17.37	17.74	17.67	17.11
Body fat (%)	6.29	6.01	6.35	7.69
Body ash (%)	4.91	4.75	5.18	5.19
Body moisture (%)	71.1	71.2	70.9	69.82

No statistical differences were identified (Table 4) among the experimental groups fed the diets with various inclusions of vitamins and essential fatty acids.

Conclusions

The red porgy (*Pagrus pagrus* L.) is a new marine finfish suitable for commercial aquaculture in the Mediterranean region. The production of red porgy fry is currently low and there are several problems that have not been resolved on a commercial scale such as the colour of the body of the fish as well as the significant mortality rates observed during the early larval stages.

Concerning the common dentex, the main problem recognised in these studies, are the species' nutritional requirements. The results show that the moist diets are more preferable than the dry pellets from the point of view of food acceptance. However, the experimental dry diets used showed better conversion and growth performance.

The results so far indicate that both species have significant advantages and perspectives for the Mediterranean aquaculture but further investigation is required before the aquaculture industry introduces these species for mass production.

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