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Culture of the red porgy, *Pagrus pagrus*, in Crete. Present knowledge, problems and perspectives

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SUMMARY - The red porgy, *Pagrus pagrus*, is a protogynous hermaphrodite sparid of increasing interest to the aquaculture industry. The first efforts for the intensive culture of the red porgy started at the IMBC in 1989, when broodstock and fry were caught from the wild and acclimated at on land installations. The present work describes data on i) reproduction (study of gametogenesis, age of sex reversal and sexual maturity, spawning strategy), ii) larval rearing (stocking density, feeding regime, water quality, timing of the developmental stages), iii) ongrowing (growth rate, conversion index, mortality, water requirements) and iv) disease problems related to the intensive farming at all stages of production.

Key words: Rearing, intensive farming, *Pagrus pagrus*,, Greece

RESUME - Le pagre, *Pagrus pagrus*, est un sparidé hermaphrodite protogyne à grand intérêt aquacole. Les premiers efforts d'élevage intensif ont débuté à l'IMBC en 1989, lorsque des géniteurs et des alevins ont été capturés en milieu naturel et acclimatés dans des installations d'élevage à terre. Le présent travail fait l'état de connaissances obtenues depuis lors en ce qui concèrne : i) sa reproduction (étude de la gamétogenèse, âge de maturité sexuelle et d'inversion), ii) l'élevage larvaire (densité d'élevage, regime alimentaire, qualité de l'eau, durée de développement embryonnaire et larvaire, iii) le grossissement (rythme de croissance, indice de conversion, mortalité, bésoins en eau), iv) les maladies de différentes classes d'âge de poissons dues aux conditions intensives d'élevage. Ces données sont comparées avec celles obtenues pour le loup et la daurade qui sont les deux espèces Méditerranéenes les plus intensivement élevées.

Mots-clés : elevage, intensif, *Pagrus pagrus*, Grece

INTRODUCTION

Mediterranean fish farming production is characterized by the dominance of two species, the sea bass, *Dicentrarchus labrax*, and the sea bream, *Sparus aurata*. The increasing supply of these high valued fish in a limited market resulted in a drop in prices, making therefore the introduction of new species very important for the profitability of the aquaculture industry. The red porgy, *Pagrus pagrus*, a new candidate for aquaculture, seems to satisfy some of the criteria for the selection of a new species in intensive fish farming such as, high market price and demand, ability to grow fast and adaptability to heavy stocking. In addition, it has a wide distribution and as a result a large market not only in Europe, but also in America.

P. pagrus closely resembles the Japanese red sea bream, *Pagrus major*, which is one of the most valuable and widely farmed marine fish (Foscarini, 1988). Although the biology of *P. major* is studied extensively and some efforts to introduce it to the Mediterranean region have been made (Lisac, 1989), data on *Pagrus pagrus*, particularly under cultured conditions, are still lacking (Manooch, 1976; Alekseev, 1982, Kentouri *et al.*, 1994a). The present work describes the efforts of our team for the successive farming of the red porgy, with emphasis on catching and adaptation of wild fish, ongrowing, reproduction and larvae rearing under intensive conditions.

TAXONOMY AND DISTRIBUTION

Pagrus pagrus (Linnaeus, 1758) is in the family Sparidae, a member of the Perciforms. Its body is oval and rather high. Head is large with small eyes and mouth rather small, terminal, low (Fowler, 1936). It has 4 superior and 6 inferior canine-like teeth; both jaws with 2 or 3 series of molar-like teeth. The long dorsal fin has 11-12 spines and 7-8 soft rays and it has 50-56 scales along the lateral line. The anal fin has 3 spines and 7-8 soft rays, and the ventral fins have 1 spine and 5 soft rays. The pectorals have 15 soft rays and the caudal has about 24 soft rays. The formula of the fins is: D, XI-XII-9/10; A, III-7/8; V, I-5; P, 15; C, 23/27.

Overall body colour is red - orange with tints of silver. There are 11 to 12 rows of small blue spots occurring from the nape region to the caudal peduncle and extending ventrally to just below the base of the pectoral fin. Ventrally, the fish are white to grey-white. There are generally two light blue laterally directed streaks, one just above, and one just below the eye. The ventral fins are light blue, while the pectoral fins are light yellow. The caudal fin is also light yellow shading to red at its posterior edge. The spiny dorsal fin is pink and the soft dorsal fin is yellow. A dark band runs from just below the eye to the articulation of the jaw.

P. pagrus, is found in the Atlantic from the British Isles (occasionally) south to Angola off the west coast of Africa, in the Azores and Canary Islands, and in the Mediterranean and Adriatic, in the Western Atlantic and Gulf of Mexico. It is generally present at depth from 30 to 60 meters (13°C to 26°C) but occasionally fish have been found at 180 meters (Manooch, 1975). *P. pagrus* do not undergo long-range migrations and local movements are not extensive .

CAPTURE AND ADAPTATION OF WILD FISH

The *P. pagrus* culture program was begun in Crete in the 1990 when wild fish were caught from the Cretan Sea by the R/V "PHILIA" using bottom trawls. The fishing strategy and their adaptation to on land culture tanks was studied and results were reported in Kentouri *et al.*,1994a. In less than 15 min after collection of the fish, red porgies are selected and introduced into a 700 l rectangular polyester tank filled with sea water (renewal: 500% per hour). As trawling duration and depth increases survival of fish decreases (Table 1).

Table 1. Effect of trawling duration and depth on the survival percentage (± 5%) of wild fish 10 days after capture

Duration (min)/ Depth (m)	20	40	60	90	120
≤ 25	85	72	62	44	30
25-50	66	50	37	33	22
≥ 50	35	31	25	24	15

A high percentage (85-100 % depending on the capture depth) of the fish reveal a distended swim blader and appropriate treatment is essential for recovery. Actually, 24 to 48 hours after capture, 10 to 40% of fish recover, but the remained express high mortalities. The puncture of the swim bladder is an effective method to reduce stress and mortalities (Table 2, 3). Punctured fish were transferred, during 4 hours, to the on land adaptation tanks.

Table 2. Effect of swim bladder puncture on the survival of the caught fish

Manipulation of the swim bladder	None	None	Puncture	Puncture
Trawl depth (m)	25	40	25	40
Fish with distended swim bladder at capture (%)	87	100	0	4
Fish with distended swim bladder 24 hours after capture (%)	5	15	0	0
Mortality during 24 hours following capture (%)	36	51	12	26
Mortality during 10 days following capture (%)	56	77	15	35

Table 3. Effect of the swim bladder puncture timing on the survival of the pagrus.

Time from capture to puncture (min)	20±15	20±15	60±15	60±15	120±15	120±15
Trawl depth	25	40	25	40	25	40
Mortality during 24 hours following catpture (%)	10	25	22	36	33	51
Mortality during 10 days following capture (%)	15	35	46	54	54	77

Adaptation of fish takes place on 10m^3 circular polyester tanks filled with sea water (temperature: same as the transportation tank; salinity 40 ‰). The first day of the adaptation period, tanks are provided with pure oxygen (7-10 ppm of dissolved O_2) and water renewal is 50% per hour (current $\leq$ 5 cm/sec). The second day, oxygen supply is discontinued, water renewal is regulated at 100% per hour and experimental treatment with antibacteria (Furaltadone: 35 ppm, 2 hours/day, for 3 consecutive days) and antiparasitic agents (formol: 4th day, 250 ppm for 2 hours and Neguvon: 1 ppm for 1 hour, once/week for two weeks) is started. Results show (Table 4) that simultaneous administration of both reagents is the most effective for long term survival.

Table 4. Effect of antibacteria (A) and antiparasitic (B) treatment on the mortality of the adapted fish.

Treatment	A+B	A	None
Mortality during 24 hours (%)	10	12	9
Mortality during 10 days (%)	15	17	24
Mortality during 1 month (%)	18	18	37
Mortality during 3 months (%)	24	40	55

Food is administered on the second day of adaptation according to the following protocol: i) fresh fish during the first week, ii) wet pellets (50% fish - 50% pellet) for 1 month (starting from the third day of adaptation) and iii) commercial pellet for sea bream (1.5 - 2 mm), provided by self-feeder, from the 10th day of adaptation. However, the majority of the fish are able to use self-feeders from the 6th day of adaptation. The above fishing and adaptation strategy result in a) high survival rate (71% of the fish catched by trawling and 85% of the fish transferred alive to the adaptation tanks) and b) good zootechnological characteristics (Table 5).

One of the biggest problems after capture and subsequent culture is the change in the body colour. The orange-red colour of the wild fish is changing to a dark silvery pink over a period of four weeks. As the change was gradual and universal it can be assumed that is not related to stress effects. Attempts to prevent discolouration of the fish by administration of astaxanthin and cataxanthin diet seem not to be successful (unpublished data). Current experiments on the role of light intensity and background colour are hoped to elucidate this phenomenon.

ON-GROWING

The rearing technology of *P.pagrus* is similar to the one applied for sea bream. Optimal biological performances with respect to growth and feeding efficiency of red porgy under intensive culture conditions have not yet been identified. Therefore, several experiments have been conducted at the I.M.B.C. and part of results have been published (Divanach *et al.*, 1993; Kentouri *et al.*, 1994 a, b). In the first series of experiments the water requirements of red porgy reared intensively were studied. Results showed that with water utilization values higher than 408 m^3/kg of fish production, daily food consumption was

2.4 to 2.6% of body weight per day, convertion index 2.4 to 2.5 and specific growth rate 0.92-1.05% body weight per day. In general, the biological requirements of pagrus are in agreement with the general stoichiometry of intensively farmed marine fish (Divanach, 1985). However, these values are approximately twice those of sea bream and sea bass of the same size. It may be speculated that this species is more dependent on water quality than others or that the water needs will be similar to the above cited species when a nutritionally adequate diet for *P. pagrus* is prepared.

Table 5. Growth performance during the adaptation period (26/10 - 18/11/92)

Characteristics	Initial		Final
Number of fish	6,922		6,873
Body weight (g)	15,8		35,9
Biomass (kg)	109,3		246,7
Biomass gain (kg)		137.4	
Mortality (%)		0.7	
Quantity of consumed pellets (kg)		98.2	
Quantity of consumed moist pellets (kg)		72.0	
Equivalent to dry weight (kg)		145.0	
Feed Convertion Index (kg of dry weight/kg)		1.1	
Consumed water (m^3)		43,200	
Consumed water (m^3)/ kg of production		314	

In the second series of growth experiments comparison with sea bass, sea bream and other candidate species was performed. Examination of fish of similar initial weight, reared in the same temperature ranges and using the same feeding regime, showed that the growth rate of red porgies is similar to those of gilthead sea bream and higher than other marine candidate species (Table 6, Figure 1)(Divanach *et al.*, 1993). At the end of the 1st year of culture, fish reach a weight of 280 g and at the end of the second year 550 g (Table 7). In general, red porgy express high growth rate during the winter (food convertion index 2 and individual growth 88%.) and decreased growth rate occurred at high temperatures. The convertion index (3.0 - 3.5) is approximately 1.5 times higher than that for sea bream with the same food, indicating that red porgy´s nutritional requirements are different from *Sparus aurata* and need to be identified. Experiments with several diets (wet pellets, diets enriched with vitamins, wet pellets and raw fish etc.) did not give significant changes in the recorded growth performance (unpublished data).

Table 6. Comparison of the seasonal variation in the percentage daily body weight increase (SGR), in winter and summer between red porgy, sea bream and sea bass (From Divanach *et al.*, 1992)

Season/ Species	Winter ´89	Summer '90	Winter '90	Summer ´91	Winter ´91
Sea bream	-	2.54	0.27	0.41	-
Sea bass	0.97	2.27	0.51	0.44	0.13
Red porgy	-	0.7	0.35	0.25	0.25

Table 7. Growth characteristics during the first two years of culture under intensive conditions

Month	Month of culture	Mean weight (g)	Convertion index	Mortality (%)
October	0	15	-	-
January	3	70	1.8	1.3
April	6	105	2.2	3.4
July	9	175	2.5	9.2
October	12	280	2.5	6.3
January	15	370	2.2	4.0
August	18	430	2.5	4.5
July	21	480	3	15.0
October	24	550	4	10.0

Survival of *P. pagrus*, on an annual basis is also similar to that reported for sea bass and sea bream. Mortality during winter months is less than 2% but heavy mortalities (30-40%) are found during summer, especially when sampling has to be performed. In general, high mortality is associated with exophthalmia, high temperatures, and repeated handling stress. Blood sampling does not contribute significantly to the observed mortality. However, netting stress causes skin and eye damages and as a consequence infections, eye loss and mortality. In general red porgy´s eye is very sensitive and exophthalmia is a common phenomenon. Cannibalism seems to contribute to the observed exophthalmia or eye loss, but the exact aetiology of this problem (disease ?) has not been confirmed.

Another problem which occurred during farming of *P. pagrus* was the development of an as yet unrecognized disease. The disease appeared only during the summer period and manifested itself as white pus-like boils, externally resembling furuncules caused by bacteria infection of the skin. The disease appeared to follow the sensory system on the face and head. Distinct v-shaped lesions formed on the head, when viewed from above, often extending to join those on the operculum and snout. Pus was released when light direct pressure was applied to the infected areas, leaving a silver scar wound. The disease was non-fatal, with most of the fish recovering and death occurring only as a result of further infections. Histological examination and blood analysis revealed no internal pathological alteration (W. Futter, pers. comm.).

REPRODUCTION

Mastery of reproduction is essential for the successful intensive farming of any fish. According to Manooch (1976) and Alekseev (1982) red porgy is a protogynous hermaphrodite, with females predominance at smaller sizes (< 400 mm total length), and a large proportion of males for the larger fish (> 450 mm). Sexual reversal takes place in fish of a length 325-425 mm and sexual maturity in fish 3-4 year-old. Spawning period is extended from January to April and spawners prefer temperatures of 16 to 21°C and depth of 21 to 100 m. However, no informations are available for fish held in captivity. Therefore

an EC financed research project (AIR2-CT93-1589) was started in 1993, between I.M.B.C., INRA, Université de Bordeaux I (France) and Univeristy of Algarve (Portugal), in order to study the sexual cycles, spawning and growth performance of *P. pagrus*, reared under intensive farming conditions. The project comprises three major parts:
(i) the analysis of growth performance by measuring, during three consecutives years, individual marked fish for which sex and sexual maturity will be determined,
(ii) the study of gametogenesis and inversion period, and the main endocrine factors likely to be involved in reproduction and growth regulations, by analysing six different groups of fish (0^+ to 5^+ year old) during one year,
(iii) the development of a treatment able to induce spawning, by testing various analogues of gonadotropin releasing hormones at various time around the natural spawning period.

It is hoped that the completion of the project will provide infomation on the reproductive biology and growth of red porgy, and the efficient technical tools for the control of reproduction. The results to date indicate that a) measuring of serum vitellogenin (by a specific developed and evaluated ELISA assay) is useful for the determination of sex, b) sex reversal seem to take place at 3^+ year old fish, c) a small percentage of spermiated males is found in 2^+ year old fish and d) *P. pagrus* spontaneous spawning is reliable under intensive conditions..

Table 8. Spawning period (SP), total number and percentage of viable eggs (V) and diameter of egg and lipid droplet (i: indoor circular polyester tank, water pumped directly from the sea, artificial illumination-normal photoperiod; ii: indoor rectangular tank provided with semitranslucent roof, water pumped from a sea well, normal photoperiod)

Year	SP	Spread of SP (days)	Peak of SP	Total number of eggs	V (%)	Egg/lipid droplet diameter (mm)
1994-i	28/02-14/04	43	27 March	67,500	2	1.00±0.02/ 0.23±0.01
1944-ii	01/02-13/05	100	27 April	7,760,800	43	1.04±0.02/ 0.23±0.01
1995-i	02/03-21/04	51	29 March	2,800,000	11	1.02±0.02/ 0.23±0.01
1995-ii	14/02-28/04	73	18 April	25,274,000	60	1.03±0.02/ 0.23±0.01

Preliminary results on spawning have been presented by Mendez *et al.* (1995). Broodstock were acclimated for 3-4 years in rearing tanks, which seems to be a critical period for expressing spawning activity. *P. pagrus* displays a similar spawning pattern to gilthead sea bream, with temperature having a critical role for the timing of spawning period and diet for the fecundity, number/quality of released eggs and hatching rates. Spawning results (Table 8) indicate that spawning is reliable without any hormonal treatment. Current research of our team is focused on the synchronization of spawning and out-of-season egg production, by manipulating environmental factors.

LARVAL REARING

The larval rearing of *P. pagrus* was started in 1993 at IMBC under both intensive and extensive conditions. The rearing technology was similar to that applied at sea bream with some specific adaptations in the different stages.

The eggs were obtained from natural spawning of broodstock kept in captivity for three or four years. The first year the quality of the eggs was poor due to the fact that it was actually the first natural spawning of the broodstock. The second year the quality of eggs was improved with more than 95% fecundation and hatching rate. The incubation of the eggs was carried out in 500 l cylindroconical tanks organised as an open or closed system, with natural sea water of 40‰ salinity and temperature between 17 and 20°C. The recirculation of the water was maintained at 100% per hour before hatching and at 50 - 60% after hatching. The eggs were incubated at densities between 50 to 200 eggs per litre, without differences in the hatching rate and the prelarval stages. The repartition of eggs and the prelarvae was managed by slight aeration with wooden diffusers. The light intensity was kept below 100 lux with photoperiod 12L:12D. The oxygen concentration was between 90-100% saturation.

Under intensive conditions, the larval rearing was carried out in 500 l cylindroconical tanks with densities of 50 - 70 larvae per litre. Initially the technology used was the pseudo-green water technique, the one applied for sea bream. The technique is based on a daily addition of phytoplankton (of a concentration of about 20 M cells/ml) to the rearing tanks, being 3-5% of the volume of the tank, for a period of 20 days after the first feeding. Several modifications have been applied to the above described technique; the addition of phytoplankton has been reduced to 1-2% of the tank volume per day and also the clear water technique has been tested. The tanks were functioning under a closed water system with recirculation maintained by an air lift pump for the same period and afterwards under the open water system. The temperature was kept at about 18°C and the photoperiod 24L:0D. The dissolved O_2 was maintained at saturation and in some cases concentrations up to 150% saturation were tested.

Knowledge on the feeding requirements of *P. pagrus* is not sufficient, therefore the feeding protocol of sea bream has been applied. Thus, the larvae, when they reached 4.5 - 5 mm in length, were fed on enriched rotifers (*Brachionus plicatilis*) followed by newly hatched nauplii and enriched metanauplii of *Artemia salina*. The enrichment of the rotifers was done using phytoplankton and different commercial emulsions (Selco, Super Selco, High DHA Selco), while for the Artemia common commercial emulsions (Selco and High DHA Selco). The weaning phase started when the larvae reached 8.5 - 9 mm in length, with artificial diets administered earlier than the respective time for sea bream.

Under all these different rearing conditions, the survival rate must still be consider far from satisfactory (between 1-3 % with maximum 6% 50 days post hatching). However, the growth performance of the larvae is satisfactory. The fish reached about 20 mm in length 40 days after hatching (Figure 2) and in a 70 - 80 days period the juveniles reached a weight of about 6 g.

Under extensive conditions, the rearing was carried out in cylindrical 40 m^3 tanks with initial larvae density of 1 per l. The larvae were introduced in the tanks at the beginning of the heterotrophic stage, while the incubation and hatching took place in tanks and under conditions similar to the intensive method. The larvae were initially fed on the natural bloom, complemented with enriched rotifers (with phytoplankton and commercial emulsions) followed by newly hatched *Artemia salina* nauplii, when the larvae reached 5 mm in length, and finally enriched metanauplii. Phytoplankton was also added to the tanks (0.1 % of the tank volume per day) for a period of 15 days. When the larvae reached 5 - 6 mm in length, they were transferred to 2 m^3 tanks and handled with the technique described for the intensive conditions. Similar growth performance to that of the intensive conditions, were reported, but the survival rate was higher, i.e. 5 - 10 % with maximum of 15 %, 50 - 60 days post hatching.

Two main critical periods during rearing were observed, resulting in high mortalities; the first (80 % of the total mortality), when larvae reached a lenght of 4.5 - 5 mm and the diet changed from rotifers to Artemia and the second when metamorphosis started (fish of 8 - 9 mm length), becoming apparent as hyperinflation of the swim bladder. The main reasons for the high mortality occurred during the first period seems to be the: i) mechanical stress caused from the function of the collector of the surface lipid film in the tanks (a technology used successfully in the rearing of sea bream), and ii) adaptation to a compulsory Artemia diet, which presented problems of digestion to the fish. The reasons for the mortality reported during metamorphosis, need to be further investigated.

CONCLUSIONS

1. Capture and adaptation techniques for wild fish have been efficiently developed, resulting in high survival rates.
2. On-growing of *P. pagrus*, is reliable resulting in high growth rates, especially during winter months. Further research is needed for prevention of discolouration and for the development of an appropriate diet.
3. Spontaneous spawning take place under intensive farming conditions. Temperature seems to have a critical role for the timing of spawning period and diet for the quality of the produced gametes. Current research is focused on the study of gametogenesis and inversion period, on the main endocrine factors likely to be involved in reproduction and growth regulations, and on the synchronization of spawning and out-of-season egg production, by manipulating environmental factors.
4. Larvae rearing is reliable with a technology resembling that of sea bream. The growth performance is satisfactory, but the survival rate need to be

improved. Nutritional and technological requirements of larvae are now under investigation.

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	Rearing of red porgy, *Pagrus pagrus*, on three different color backgrounds and two different diets. Effect on body color, growth and serum metabolites	Groth, L., Moth, L. 1995
Pathology	Description of a seasonal disease in the farmed sparid, Pagrus pagrus	Futter, C. W. 1995

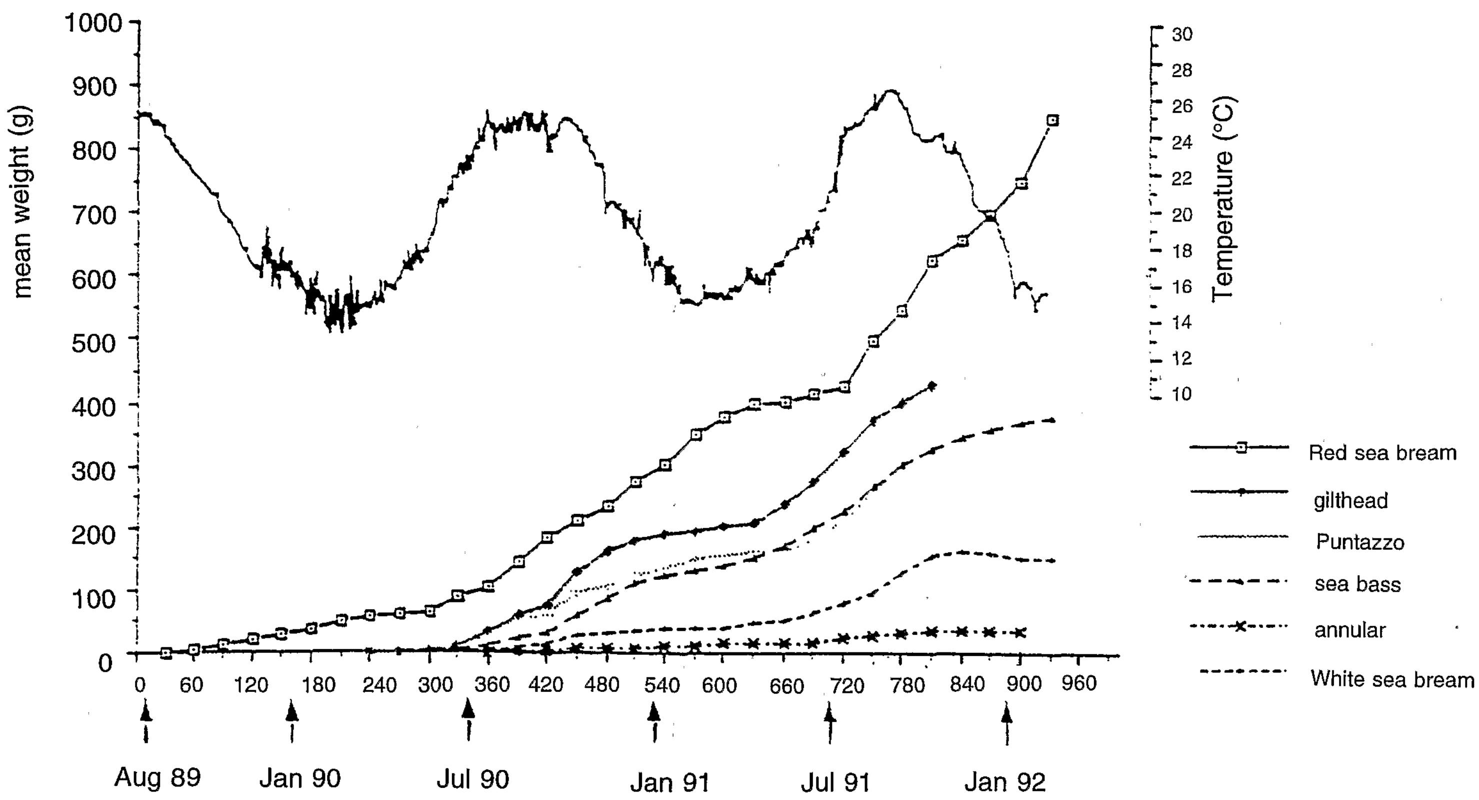

Fig 1. Comparative growth performance of fish reared in raceways in Crete, in relation to seasonal water temperature variation.

Figure 2. Evolution of length