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## Experiences in the culture of new species in the "Estación de Acuicultura" of the Balearic Government (1980-1998)

E. Pastor\*, A. Grau\*\*, F. Riera\*, S. Pou\*\*\*, E. Massuti\* and A.M. Grau\*

\*Estació d'Aquicultura, Govern Balear, Ingeniero Gabriel Roca 69, 07158 Pto de Andratx, Mallorca, Spain

\*\*SEAMASA, Foners 10, 07006 Palma de Mallorca, Spain

\*\*\*Dirección General de Medio Ambiente, Servicio de Educación Ambiental, Govern Balear, Foners 10, 07006 Palma de Mallorca, Spain

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**SUMMARY** – This paper is a review of the diverse results on marine finfish aquaculture diversification obtained at the "Estación de Acuicultura" (Port of Andratx, Majorca) from its beginnings to nowadays. We expose the results obtained with the main finfish Mediterranean species investigated, briefly describing the capture of the individuals from the natural environment, the breeding, rearing and ongrowing technics, as well as the main pathological problems observed in our aquaculture facilities. We resume our results obtained with three finfish species: the amberjack, *Seriola dumerili* (Risso, 1810), the common dentex, *Dentex dentex* (Linnaeus, 1758) and the sharpsnout sea bream, *Diplodus puntazzo* (Cetti, 1777).

**Keywords:** *Seriola dumerili*, *Dentex dentex*, *Diplodus puntazzo*, fish farming, diversification.

**RESUME** – "Expériences de culture de nouvelles espèces à la « Estación de Acuicultura » du Gouvernement des Iles Baléares". Ce travail est une révision des résultats divers obtenus à la "Estación de Acuicultura" (Port d'Andratx, Majorque) sur la diversification de l'aquaculture des poissons marins, de ses commencements à nos jours. Nous exposons les résultats obtenus avec l'espèce principale de poissons méditerranéens testée et décrivons brièvement la capture des individus de l'environnement naturel, les techniques de culture larvaire, de reproduction en captivité et de grossissement, ainsi que les problèmes pathologiques principaux observés dans nos installations d'aquaculture. Nous résumons nos résultats obtenus avec trois espèces de poissons : la sériole, *Seriola dumerili* (Risso, 1810), le denté commun, *Dentex dentex* (Linnaeus, 1758) et le charax, *Diplodus puntazzo* (Cetti, 1777).

**Mots-clés :** *Seriola dumerili*, *Dentex dentex*, *Diplodus puntazzo*, pisciculture, diversification.

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### Introduction

The "Estación de Acuicultura" of the Balearic Government, located in the Port of Andratx (Majorca), has been devoted, from its construction in 1982, to the investigation of the possibilities in marine fish farming of some potential interesting Mediterranean fish species. In its beginnings (1980-81), the facilities were limited to two floating cages of metallic structure where it were carried out the first experiences in the culture of the amberjack *Seriola dumerili* (Risso, 1810), very abundant species in the Balearic Sea and with a high price in the local market. The good results obtained in these first studies and the interest demonstrated by several co-operatives of fishermen on the topic, encourage the Balearic Government to build a small support land Station focused to the improving of aquaculture Mediterranean possibilities. The priority investigations lines of the "Estación de Acuicultura" has always been the followings:

(i) To improve the seacages farming technics and to evaluate the ongrowing possibilities of the selection fish species in these facilities.

(ii) To develop rearing technics adapted to the fish species considered potentially interesting for aquaculture and to evaluate their possibilities for Mediterranean aquaculture.

The purpose of the present paper is to summarise the results obtained at the "Estación de Acuicultura" with the main finfish species investigated during the 1980-98 period.

## ***Seriola dumerili***

The experiences with this species began in the year 80, for initiative of the Consell General Interinsular of the Balearic Islands. The first experiences consisted in growing out in seacages wild juvenile amberjacks caught from the sea and fed them with raw and frozen fish in order to establish their growth rate in an intensive ongrowing system.

### Catching individuals in the natural environment

Amberjack juveniles are traditionally captured during the months of September, October and November in the Balearic Sea. At this time, they have onshore behaviour, and there isn't a specific system of fishing. Juveniles approach to the coast, being located below floating devices (FAD's). The most traditional form of capture is by means of FAD's called "capcés" by the Balearic fishermen. Wild amberjack juveniles situate below these protecting devices and they are collected using the fishing art known as "lampuguera" (an encircling net without trelliswork). Another fish catching methods of amberjack juveniles in the Balearic archipelago are by means of Moorish seines, which consist in a small pound net located near to the cost, as well as troll lines, purse seines, pound nets called "solta" or trammel nets.

The transport of the life juveniles is made by means of live wells with running water, located in the traditional fishing vessels of the Balearic Islands. Survival is bigger using the Moorish net, as well as with encircling nets, than with trammel nets, due to the wounds that the juvenile amberjacks suffer using this last net type.

The efficiency of the capture is variable depending on the type and size of the net used and on environmental conditions (fishing zone, streams, etc.). It could be considered, as an average, the capture of 30 amberjack juveniles in each throw, needing 15 minutes/throw and a crew of 2 people. The weight of the amberjack juveniles (called "verderols" in Mallorca due to its yellow-green colour) at this time is 50-200g.

They were also carried out experiences of catching amberjack fingerlings in the months of July and August, by means of offshore FAD's. Below the FAD's we installed different types of baskets which acts trapping fish inside them. Another fish catching method was the employment of small encircling nets around the FAD's, or by means of a landing net. The catching efficiency was very low (about 2-12 fish each time) and the operation needs a crew of 1-2 people and 15 minutes to be done. The caught fingerlings weighed approximately 1.7 g. These amberjack catching methods were abandoned because of its low efficiency, which can't provide an enough amount of amberjack fingerlings to make an intensive ongrowing of the species.

### Ongrowing in cages

Before being stabled in the floating cages. Fish were treated with antiseptics. The form of the cages can be round or square: the square ones are composed more or less of a rigid framework, maintained in surface by means of floats, but its location can only be coastal, in areas under cover of storms. They are a copy of the traditional square seacages employed in Japan for the ongrowing of the "modjako" (juvenile of *Seriola quinqueradiata*). The circular cages are made on polyvinyl floating structure. These seacages are elastic and have a better buoyancy than the other ones, which allow them to install in coastal areas fewer preserved or offshore. We use this kind of cages at the present time.

The growth of the juvenile amberjacks at the beginning of the ongrowing (September-October; 22-24°C) is very quick. It decreases with the fall of the seawater temperature (November-December; 16-19°C), during the winter it is almost null (13-14°C), and it increases again in spring (15-22°C) and in summer (25-27°C). So in Balearic Islands, the juveniles captured in September with a weight of 50-100 g weigh in December 400-500 g; in the next June, with 1 year old, they weigh 1000-1200 g; at 18-20 months old they weigh 2500-3000 g and at 2.5 years old they weigh 6000 g. The maximum stocking density is approximately 10 kg/m<sup>3</sup>. The usual stocking densities are 2-3 kg/m<sup>3</sup>.

In the first experiences on amberjack ongrowing in The Estación de Acuicultura (1980-90) the fish were fed with raw and frozen fish coming from catch surpluses of low commercial value. The fish were fed with a triturated mixture of *Boops boops*, *Trachurus mediterraneus*, *Spicara smaris*, *Sardina pilchardus*, *Sardinella aurita*, *Spicara maena*, trying the blue fish doesn't overcome 50% in the diet. Frozen fish could reach to 80% on the diet. The fish were fed *ad libitum*. The number of intakes varies in function of the size of the fish and with the water temperature: we fed fish of 500-1000 g twice a day if the temperature is high and once a day when the temperature is low (from December to April). These attractive results make that several co-operatives of fishermen got interested in to create their own companies for the amberjack growth-out in cages. These fishermen's associations were dedicated to the amberjack ongrowing based on feeding with raw fish, becoming from catch surpluses of the encircling net fleet. They bought raw fish at a retreat price stipulated among the parts, and it supposes an added economic benefit to the fish catching sector, mainly those of the encircling net ones.

From 91-93 they were also carried out feeding experiences with Oregon Moist Pellet (OMP) (Fig. 1), feeding at 5% of the biomass. The growth efficiency was similar to that observed feeding with raw fish, with some advantages: smaller self-pollution production, and some better conversion indexes.

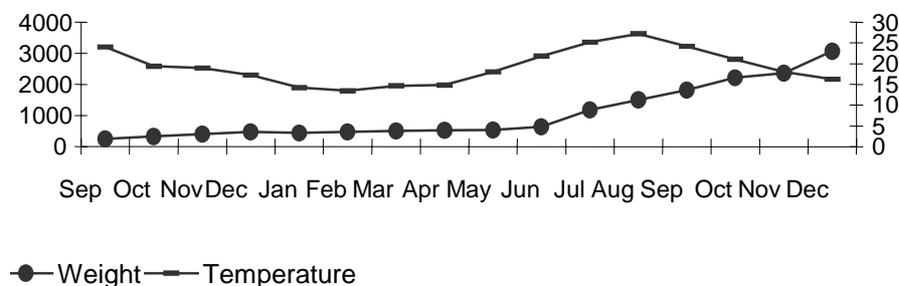


Fig. 1. Growth of *Seriola dumerili* fed OMP pellets.

Except for some outbreaks of vibriosis, only sporadic mortalities had been detected in our facilities since 1980. The survival in the amberjack ongrowing in the Port d'Andratx was always very high, reaching approximately 90%. We only detected losses at the beginning of the grow-out, mainly due to the infection of the wounds produced during the capture and handling of the animals. However, during the winter and spring months of 1988-89 and since then, mass mortalities occurred in 0+ age class due to epitheliocystis (Crespo *et al.*, 1990; Grau and Crespo, 1991), sanguinicoliiasis (Crespo *et al.*, 1992) and pseudotuberculosis (Grau *et al.*, 1993). Some cases of Ichthyophoniasis have been also detected (Grau, 1992) and the individuals showed haemorrhages in the pyloric caeca caused by Trematodes. The study of wild fish caught in Mallorca and Tarragona and revealed that the natural populations of the Balearic Sea are affected by epitheliocystis agents, sanguinicoliiasis and Trematodes inhabiting the pyloric caeca (Grau *et al.*, 1993). A most systematic survey on parasites of wild amberjacks in the Balearic Sea have revealed that the specie is naturally parasitised by *Myxobolus* sp., some trematoda (*Heteraxine heterocerca*, *Bucephalus polymorphus*, *Proisorhynchus crucibulum*, *Bucephalopsis* sp., *Hemiurus communis*, *Aponorus* sp., *Acanthocolpus liodorus*, *Stephanostomum pristis*, *Nematobothrium scombri*, *Wedlia bipartita* and *Paradeontacylix* sp.), 1 Nematode (*Philometra globiceps*), 1 copepoda (*Caligus curtus*) and 1 Isopoda (*Gnathia vorax*) (Grau *et al.*, 1999). The on-growing in cages of juvenile amberjack caught from the wild is being compromised, thus, by the import of these parasites from the natural environment into the aquaculture facilities, which could cause in the future the appearance of new outbreaks of massive mortalities when they complete their life cycles in the intensive cage system.

Also, rearing experiences with wild fingerlings were made, feeding them with weaning OMP pellets manufactured by us, supplemented with a vitamin complex, choline and inositol based on the nutritional studies of Shimeno (1991) in the close-related species called yellowtail, *S. quinqueradiata*. The feeding frequency varied from 4-5 times a day at the beginning of the experience, to 1-2 times a day at the end of the same one. The feeding rate was *ad libitum*. The fish caught in July-August with

an average weight of 1.7 g, weigh in December of that same year, after 5 months of on-growing, 275 g; in the next July, 655 g and in December of the following year, at 18-20 months old, 2000 g. The mortality was low, and it was only located in the first month of weaning, due to lack of adaptation of the wild fingerlings to the experimental pellets (21%). No more mortality was observed. The good performance of fish and the absence of diseases during the on-growing period, as well as the lack of disease fingerling carriers on the wild amberjack population, make us to believe that the large-scale intensive culture of the species in the Mediterranean Basin, is only depending in the unsolved breeding problems. On this topic, the recent advances presented by Lazzari *et al.* (this volume) are very encouraging.

## Breeding experiences

From the year 82 and during 10 years studies on reproduction were carried out. Wild breeders caught in the months of May, June and July with moorish pound nets called "morunas" by the fishermen and transported to the laboratory inside live wells situated in the fishing ships with an open seawater circuit, were injected with gonadotrophic hormone or LHRH in order to induce them to spawning. In the live wells the animals were protected with specially designed net bags in order to avoid the wounds caused by friction against the walls. On the land facilities the animals were anaesthetized with MS-222 (Sandoz) and cannulated in order to observe their state of gonadal development. Those females which presented the ovaries in phase of final maturation (with oocytes at yolk granule stage III; Grau *et al.*, 1996), with an approximately size of 500 µm were injected with GCH or LHRH. In almost all of the trials spawnings were obtained after 48-72 h hours; however, just in two occasions these spawnings were viable. The eggs generally carried out anomalous divisions, dying after 24-48 hours, or they had not been fecundated. It was not possible to carry out the artificial fecundation for structural problems of the centre. The larvae died after the opening of the mouth (7 days old).

Females maintained in captivity in rectangular land-tanks during 5 years didn't mature; only males showed an initial maturation in captivity, without reaching the phase of final maturation. The females maintained in captivity in tanks and hormonated at the next reproductive season, with successive injections of LHRH to intervals of 1 week, neither matured.

It was also attempted to hormone wild amberjack females after a week of rest into an offshore round seacage of 12.5 m of diameter, but the results were discouraging. The gonads presented oocyte atresia and they didn't respond to the hormonal treatment, neither with GCH nor with LHRH.

In the year 92 it's decided to leave the breeding experiences in captivity until having some appropriate facilities, because the reproduction tank employed didn't possess either the appropriate dimensions (12 x 6 x 1.7 m), or the appropriate form (rectangular).

## ***Dentex dentex***

Common dentex (*Dentex dentex* L.) is a member of the Sparidae family, inhabiting inshore and continental shelf waters. It's a carnivorous fish widely distributed along the Mediterranean basin and the Eastern Atlantic (Bauchot and Hureau, 1986).

It is a promising new species for Mediterranean aquaculture (Riera *et al.*, 1993; Efthimiou *et al.*, 1994). It has good adaptation to captivity conditions (Franicevic, 1991), excellent growth rate (Riera *et al.*, 1993), it's highly esteemed for its good taste and quality and has a high market value.

During these 11 years of work with the species we have carried out studies on reproduction, larval rearing, experiences of on-growing in cages with different diets, biochemical studies of requirements in larval rearing and studies of design of specific experimental pellets.

## Catch of wild juveniles

The experiences began in the year 86 with the catch of wild juveniles. They were cached at the

beginning of September with a scoop net and stabled in a 600 liters tank. They were fed on a paste based on fish flesh and squid or prawns

The first on-growing experiences with these individuals in floating cages showed the fast growth of the species. Starting from these good results we direct our effort to obtaining a stock of wild breeders.

In the year 89, 30 fingerlings of 15 g of weight, born in our facilities were fed *ad libitum* with raw fish, every 25-35 days the fishes were sampled (length and weight) and the parameters of growing were calculated [food conversion rate, growth coefficient (G)]. In Table 1 this growing parameters are showed.

Table 1. First experiences on the growing of *Dentex dentex* fed with raw fish<sup>†</sup> (Pastor *et al.*, 1995a)

Date	Length	SD	Weight	SD	G (%) <sup>††</sup>	FCR <sup>†††</sup>
16/08/89	79	9.3	15.3	4.1	–	–
15/09/89	140	13.0	50.8	12.0	4.0	3.6/1
13/10/89	178	17.0	93.2	25.6	2.1	–
10/11/89	186	16.4	142.3	36.5	1.6	6.6/1
15/12/89	224	19.1	189.5	48.2	0.8	4.8/1
22/01/89	241	20.5	213.5	56.3	0.4	5.8/1
09/03/90	258	19.9	238.4	58.3	0.2	6.9/1
14/04/90	262	21.0	267.7	67.3	0.5	4.9/1
16/05/90	270	20.5	309.0	73.2	0.8	3.5/1
14/06/90	284	20.2	355.9	85.8	0.6	4.1/1
13/07/90	300	20.4	417.3	91.0	0.6	4.9/1
31/08/90	318	24.9	503.3	122.9	0.4	–
30/09/90	335	25.8	595.0	130.2	0.6	3.6/1
31/10/90	355	26.0	685.0	139.0	0.6	3.8/1
31/11/90	360	26.3	763.0	162.3	0.5	4.6/1
27/12/90	367	26.7	831.3	183.2	0.3	3.4/1

<sup>†</sup>Mortality at the end of the experience was 6.6% (two individuals).

<sup>††</sup>G (%) = Instantaneous growth rate.

<sup>†††</sup>FCR = Food conversion rate.

## Reproduction and larval rearing

The catch of the breeders was with troll lines. The first spawning in captivity were obtained in the spring of 1988.

Spawning always took place in spring, between March and June, at temperatures of 15°C or higher, and usually in the afternoon. It's always spontaneous. Fertilised eggs were collected from the broodstock tank using a 500 µm net placed under the surface drain exit.

The eggs had a diameter of  $1.005 \pm 0.0197$  mm (Pastor *et al.*, 1995b). Development of the hatching stage was of variable duration (44-65 hours) depending on temperature. The quality of these natural spawns has been excellent during the ten years of experiences so much with wild breeders as with breeders born in captivity. The evolution of the spawn during the spawning period (year 96) is showed in Fig. 2.

The first results of larval rearing were discouraging. With the appearance of the enrichment diets for rotifer and Artemia we begun to obtain fingerlings to work with, but the results of larval survival have always been low (2-5%).

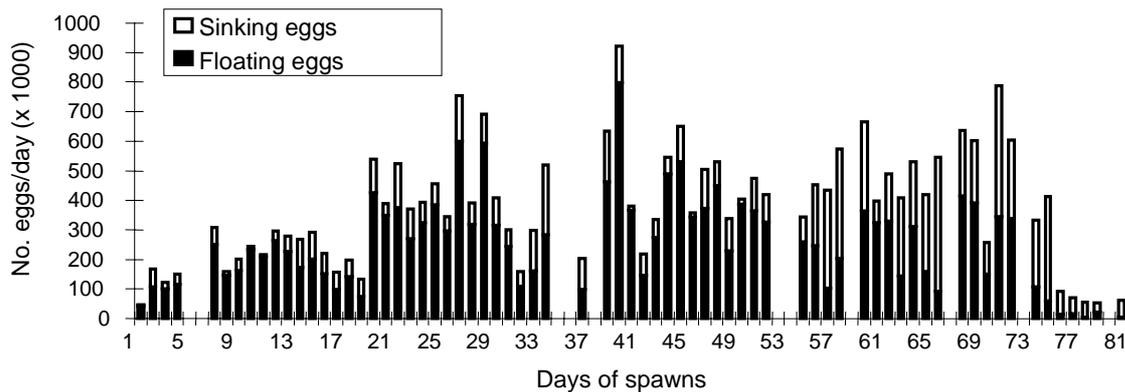


Fig. 2. Natural spawns of *Dentex dentex* (Pastor *et al.*, 1997).

### Histological studies

A histological study of the gonad of the common dentex, *Dentex dentex* (L. 1758) was done. Samples of gonads were taken from year 92 until year 99 with the goal of describe the early gonadal development, sexual maturation and sex ratio of the species. 519 common dentex aged between 6 months and 26 years old were examined (234 captivity-reared fish and 285 wild captured fish).

Gonads of 6 month were undifferentiated or ovarian in form. At 9 month of age the first hermaphrodites appear (8%) increasing at 12 months until 22% (Fig. 3A), the undifferentiated gonads and the testes represent 12% and 16% respectively. At 18 month of age undifferentiated gonads can't be observed and the number of hermaphrodites is scarce (9%; Fig. 3B). 43% of the gonads are testes. At 2 years of age bisexuals can't be observed, just ovaries or testes, being the sex ratio about 1:1.

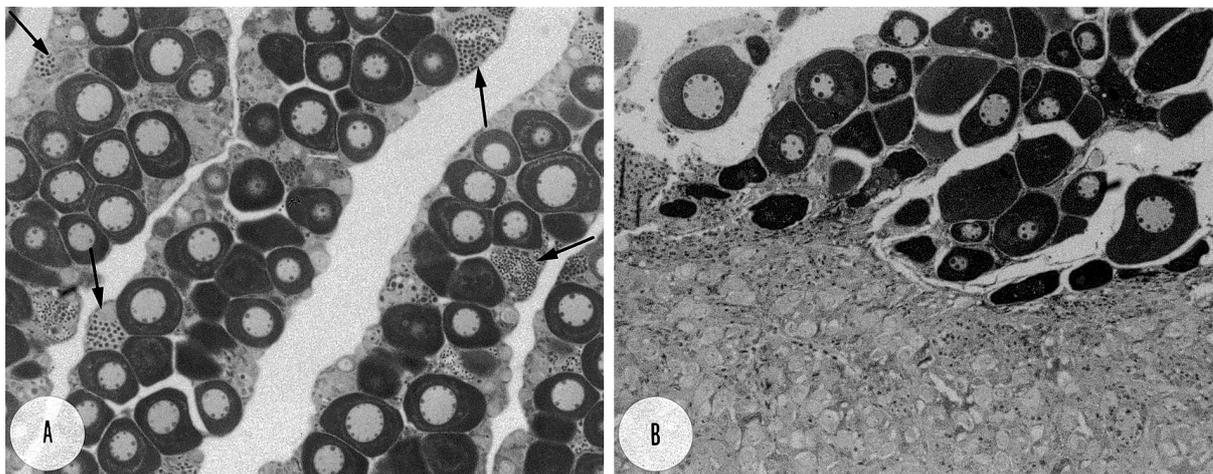


Fig. 3. Hermaphroditism in *Dentex dentex*. (A) Intersexual gonad from an individual of 12 months old; (→) spermatogenic cysts. (B) Hermaphrodite of 18 month old. Observe the two sexual territories.

Our study concluded that the sexual pattern of common dentex is Gonochorism with bisexual juvenile stage (Grau *et al.*, 1999).

## Biochemistry studies

From year 95 and during three years biochemistry studies were designed to investigate the nutritional requirements of *Dentex dentex* larvae.

First we studied the utilisation of lipids by *Dentex dentex* larvae during lecithotrophia and subsequent starvation. The utilisation of endogenous (yolk-sac) nutrients during embryonic and early larval development is one approach to define the nutritional requirements of larvae. Our conclusion is that common dentex larvae during early development and starvation consumes about 2.3% of its dry weight biomass per day (3.2 µg/larva/day) indicating a higher metabolic rate during lecithotrophia and subsequent starvation than other marine larval fishes from temperate waters. The pattern of lipid metabolism during early development is similar to that of marine larval fish whose eggs containing high levels of total lipids, including an oil globule, and which preferentially utilise neutral lipids as the primary energy source (Mourete *et al.*, 1999a).

A second study was done during year 96 with the aim of determine the effects of days after hatching (DHA) rotifer enrichment on dentex growth and survival to day 15 after hatching.

No differences were found in either growth or survival between the larvae fed with a diet of rotifers high in DHA [enriched with DHA-protein Selco (Artemia Systems)] and with rotifers low in DHA (fed just with *Nannochloropsis gaditana*) (Sanpera *et al.*, 1997).

A third study was designed to investigate the requirements for n-3 highly unsaturated fatty acids (HUFA) at the artemia feeding stage of common dentex larvae.

Our conclusion, was that optimal growth and performance of the larvae was achieved when dietary n-3 HUFA was 3.97% on dry weight basis. Larvae fed artemia enriched with apparently supra-optimal levels of n-3 HUFA (5.67-6.23%) showed significantly lower vitamin E contents and higher MDA levels indicating increased oxidative stress and poorer performance. However, despite indications of increased oxidative stress with higher levels of dietary n-3 HUFA, the activities of antioxidant enzymes in the larvae was generally not greatly affected. The study underlines the need for a balance between growth-promoting essential fatty acid (EFA) qualities of n-3 HUFA and their potentially growth-inhibiting (pro-oxidant) qualities which must be counter balanced with adequate dietary antioxidants (Mourete *et al.*, 1999b).

## *Diplodus puntazzo*

From year 83 and during 5 years we worked with this species carrying out, studies in hatchery, and grow out in cages with different diets. The fingerlings for the first trials were caught from the natural environment with a coop net in big bays with shallow waters. The growth capacity of the species in cages culture gave similar results to those of the gilthead sea bream, *Sparus aurata* (400-g in 23 months of age) (Fig. 4).

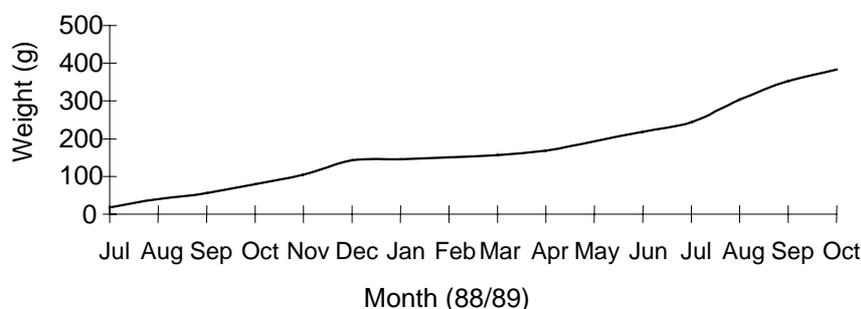


Fig. 4. Growth of *Diplodus puntazzo* fed raw fish.

*D. puntazzo* is a rudimentary hermaphrodite with bisexual gonad (D'Ancona, 1946), with an ovo-

testis in which only one territory is functional (Micale *et al.*, 1996). It's a sequential spawner. The spawning period of the specie in the Balearic islands is October – November, when water temperature decrease from 24 to 20°C.

Nine wild breeders were caught with pound nets during 1984. The first natural spawns were obtained in September of year 87. The larval rearing techniques were similar to those employed in the sea bream culture based in feeding larvae with rotifer and artemia. Survival in hatchery was 30%, with 90% of malformed fish. The introduction in 1988 of surface aerators, to clean water surface similar to those devised in the Kagoshima Prefectural Mariculture Center (Foscarini, 1988), made decreased the number of malformed individuals to 10% in year 1989. However the *D. puntazzo* has in the Balearic Island scarce commercial value, it is not a fish appreciated by its quality. For this reason and after carrying out some market studies with fish cultured in our facilities, we had decided to abandon the experiences. A group of breeders was kept for possible future performances

## Other species

Some other finfish species were object of our investigations, but their slow growth (*Diplodus pargus*) or their low market price (*Coryphaena hippurus*) makes us discarded them. Actually the "Estación de Acuicultura" has conceded an investigation project to carry out some experiences of grow out and adaptation to the cages culture of *Argyrosomus regius* in co-ordination with the centre "El Toruño" from the "Junta de Andalucía" (Spain).

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