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SUMMARY

The adhesion of Portugal to the European community in 1986 and the resulting possibility of obtaining funding from the EC for small investments, led to a progressive increase in the development of marine fish aquaculture, in particular in the southern region of Algarve. The two most prominent species currently being reared are the gilthead sea bream (*Sparus aurata*) and the sea bass (*Dicentrarchus labrax*), cultured in a semi-intensive mode which is typical of southern Portugal. The production starts with juveniles which are reared in hatcheries and fed with pellets, reaching values of 10 tons per hectare and per year. In the earth ponds (ca. 1 ha) used for rearing the fish, we have noticed the development of an important population of macrobenthic invertebrates - polychaetes, bivalves, amphipods, chironomids, phoronids - the first group being by far the most prominent (82.1%, global mean). We have also observed that in these aquaculture systems, the reared fish eat preferentially the pelleted food thus leaving the natural food sources available for other fish species which could then be reared as a co-culture. In this case, the sole (*Solea senegalensis*) seems to be the best choice for both (i) bioecological reasons: it is a locally abundant species with a benthonic diet based on the *taxa* referred above, and is already being produced in hatcheries with levels of growth and survival compatible to those observed for other commercially important species produced in similar ways and (ii) economical reasons: it is highly demanded in the market thus having a high commercial value, and it would permit a more diversified offer from the aquaculture producers. The principal obstacle encountered in the aquaculture of *S. senegalensis* is the non-existence of commercial diets adapted to this species, whose main natural food source consists of polychaetes. Or this taxonomic group happens to be the most abundant in the earth ponds commercially exploited for gilthead sea bream and sea bass, as stated above. This finding, together with the fact that there is no competion for the water column between these species, suggests that *S. senegalensis* could be a choice candidate for co-culture with *S. aurata* and /or *D. labrax* within reasonable densities to be determined according to the food capacity provided by the earth ponds. The principal objectives of this work are: (i) to describe the most common fishculture plants used, the methodologies to be applied and the goals of productivity to be achieved. (ii) to consider the implementation of the sole culture in the earth ponds based on the existent knowledge concerning its bio-ecology and the scientific data already available, which was obtained during the ecological characterisation of the earth ponds currently in use for marine aquaculture.

Key words: semi-intensive, fish culture, gilthead sea bream, sea bass, sole and benthos

RESUMÉ

L'adhésion du Portugal à la communauté europeènne en 1986 a conduit à l'obtention de financements pour des projects de dimension moyènne à partire de l'UE, ce qui a entrainé le dévelopement progressif de la pisciculture de poissons marins, surtout dans la côte sud du pays (Algarve). Les deux espèces les plus répandues dans les piscicultures en régime semi-intensif sur la côte portugaise sont la daurade (*Sparus aurata*) et le loup (*Dicentrarchus labrax*). Le système de production demarre avec des juveniles cultivés en écloseries et alimentés avec des rations et peut atteindre plus de 10 tons/ha par an. Dans ces systèmes de pisciculture s'utilisent des étangs de terre (ca. 1 ha) dans lesquels on a remarqué le dévelopement d'un peuplement important d'invertebrés macrobenthiques - polychètes, bivalves, amphipodes, chironomiens, phoronidés, dont les premiers sont nettement dominants (82.1%, moyènne globale). Il a éte aussi observé que dans ce type de culture les daurades et les loups mangent preferentiellement les rations et donc laissent l'alimentation naturelle disponible pour d'autres espèces de poissons qui pourront eventuellement être cultivés ensemble. Dans ce cas la sole (*Solea senegalensis*) s'affigure comme le meilleur choix par deux raisons: (i) Bioecologiques, vue qu'elle est localement abondante et déja produite en écloserie avec des taux de croissance et de survie du mêmme ordre de grandeur de ceux des autres éspèces commerciales cultivés; en plus, elle est aussi une éspèce benthique ayant un régime alimentaire basé sur des organismes appartenant aux *taxa* d'invertebrés trouvés dans les étangs; (ii) Économiques, dûe à la haute valeur et la grande recherche qu'elle a sur le marché, en outre de permetre diversifier l'offre des pisciculteurs. La dificultée majeure réperée à l'aquaculture de cette espèce, dont le principal resource alimentaire ce sont les polyquètes, c'est l'inexistence de rations commerciales qui lui sont adaptées. Convient rappeller ici que le groupe taxonomique le plus abondant dans les étangs de terre utilisés pour la culture du loup et de la daurade sont les polyquètes. Ce fait et l'absence de competition parmi ces espèces et la sole en ce qui concerne la colonne d'eau renforce le choix de celle-ci pour des essais de co-culture entre ces éspèces à condition d'établir des densités compatibles avec la capacité de support des étangs à utiliser. Ceci dit, ce travail envisage: (i) la description du type de pisciculture le plus commun, ainsi que les methodes y utilisées et les objectifs de productivité à atteindre; (ii) discuter l'implémentation de la culture de la sole dans des étangs de terre des piscicultures à régime semi-intensif face aux connaissances déjà disponibles concernant sa bioecologie et les données obtenues pendant une étude de characterization écologique d'étangs de terre en train d'être utilisés en aquaculture marine.

Mots-clés: semi-intensive, pisciculture, daurade, loup, sole et benthos

INTRODUCTION

The designation of aquaculture in extensive, semi-intensive and intensive modes refers to the type of use the reared animals make of the resources and to the technology applied. Thus the intensive mode represents the peak in production in this area, it is accomplished in synthetic pools (concrete or Fiberglass) measuring between 100 and 1000 m³. The pools are built in such a way as to obtain maximum self-cleaning so that faeces and left-over rations are constantly removed, and the water quality is the least altered by these factors. The water is provided continually by pumping, and the oxygen is supplied by ventilators or by the use of pure oxygen reservoirs, which are normally controlled automatically and have alarm systems. Reached productions are the highest among the aquaculture systems (20 to 30 kg/m³) and the food is totally composed of commercial pellets.

In what concerns the extensive mode, the rearing is in earth ponds (salt-work lagoons, ponds of old tide mills), where the repopulation is brought on with the juveniles that enter the pond gates with the tide and food is a natural environment product. This

system may bring some transformations needed to improve hidric circulation and some food complement, usually by-products of fisheries. In certain cases there is an insertion of juveniles, but any way the system depends on the tides for water renovation, as well as on the dimension and topography of the site: the normally achieved yields (200 to 400 Kg/ha/yr.) do not allow large investments.

Earth ponds are also used in the semi-intensive aquacultures, but they are specifically built for fish rearing. In this case, the aim being to obtain a higher production, all the built in construction has been planned and executed towards this goal. Therefore in this mode the production no longer depends on juveniles entering the floodgates nor on natural productivity but on the methods of a planned aquaculture in agreement with a previous project and the adopted structures. Water renovation is based on pumping with partial use of tides, depending on topography and depth of the site. Oxygen is provided with the entrance of new water, and with the use of special apparatus (ventilators and/or pure oxygen). Photosynthesis is also important for oxygen supply.

In these aquaculture systems it has been noticed that the main fish species hearein rearead (gilthead sea bream and sea bass) feed essentially on the pelleted food, leaving the natural food available for other species that may be reared as co-cultures. Accordingly the sole which has a high commercial value, is a possible candidate for co-culture, viewing that it is already reared in hatchery and it seems to have a growth rate compatible with that of the other referred species.

SEMI-INTENSIVE REARING MODE

Due to the high incidence of coastline land, in particular old salt-works and other water reservoirs, and to environmental legislation, which prevents the building of concrete pools, the semi-intensive rearing mode is the most sought-out and widely used in Algarve. In view of this objective artificial earth ponds are built and the yields controlled according to goals leading a specific project.

Establishment and description

For the establishment of a semi-intensive fishculture plant, the site chosen is transformed according to the topography and the end in sight, so the necessary conditions for the culture can be created (Pousão Ferreira, 1990; 1995). Pools ranging from 0.5 to 1 ha and fitted to the topography and the division of the site are the most adequate if such modifications are economically possible and/or viable. The whole production must be planned, the juveniles being obtained taking in account the carrying capacity offered by the surroundings, which is, in turn, mostly determined by the structure of the ponds. For the species referred above, the diet is based on commercial pellets but fish also takes advantage of natural food already existing in the pools. The technologies used in its juvenile production and fattening are also known, as well as those used in pellet elaboration.

The production should be programmed in such a way that it will be possible to sell fish all year round, according to market demand. To assure a yearly continuous production in every pool, the number and size of the juveniles as well as the buying and selling

seasons of fish should be planned and controlled. When offer is too abundant, the fish can remain in the ponds and continue to grow as long as the structure permits the increasing denseness. If not, the pond is partially fished to keep density within secure limits, the rest of the stock continuing to grow. In such cases the pool is divided with a net, defining a fishing zone; this avoids that the remaining specimens be disturbed. Market and the fishing capacities of the aquaculture rule the final capture of the fish production of an earth pond, which can take between a weak and a month. Initially the pool is divided trying to concentrate the fish within a section, where the fishing will commence. As the density dessens the pool is gradually emptied until the last specimens are withdrawn from the fishing and drawing ditches. The fish may be immediately killed in ice water to be packed, or transported alive to cement or fiber tanks to later be sold retail.

Pre-fattening process

Juveniles can be obtained from the hatcheries weighing between 2 and 20 gr., although it is preferable to get the smallest fish possible, since it is cheaper and the quality of the stock is greater as it has been less handled. A juvenile weighing 20 gr. may be the largest or the smallest of a group and this will influence the amount of time it is fattened until the commercial weight is reached. These juveniles should be spread in pre-fattening pools that will bear densities up to 10 Kg/m^3 if made of fiberglass or concrete - or even more with the use of pure oxygen. Their transfer into the fattening pools should be as soon as possible with a minimum weight of 20 gr. per specimen, size that enables handling without major problems for fish.

The use of a pre-fattening process presents several advantages, such as:

- Obtention of juveniles at a lesser cost and with better quality.
- Possibility of choosing an homogeneous stock for fattening.
- Possibility of desinfection and treatment of eventual problems related to handling and transport.
- Better control of growth and mortality in a phase were the fish are more vulnerable.
- Possibility of establishing year cycles in the fattening pools.

Fattening process

The juveniles are transferred from the pre-fattening zone - this can be done within the facilities or not (hatchery) - to the fattening pools and will remain there until the final fishing, being feed with pellets agreable with their size. Fattening pools should be well mineralised and disinfected prior to the introduction of the fish, preventing pathogenic damage to the stock. Also it should be avoided the presence of fish greater than those intended to be reared in order to reduce predation.

The stock growth could be evaluated by a monthly sampling design permitting to know the average size of the specimens, in order to determine both the dimension of the pellets and amount of food to be supplied every day, which is a percentage of the total weight of the stock to be reared and is a function of individual weight and water temperature. Pelleted food should be supplied by authomathic feeders, which number depends on the quantity of fish in stock - speading the pellets as to minimise competition. The distribution should be also carried out several times a day (5 - 8), specially during the Summer when the days became longer and the temperature of the

water rises. There should be a daily manual distribution as well to adjust the quantity of ration consumed. Since it is the only time the fish are clearly visible, the rations can be corrected according to the behaviour (appetite) of the fish, which may vary with atmospheric alterations or changes in the quality of the water.

Once in the fattening ponds the fish stock is not handled, thus the quality and

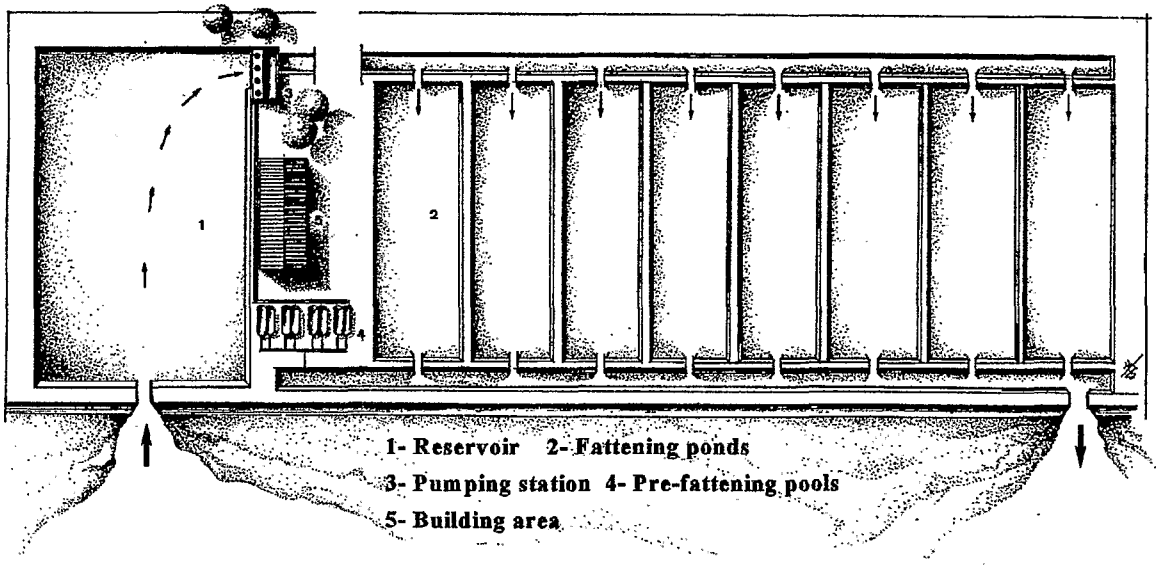

Fig.1. Fish farming lay-out

homogeneity of the initial lot is of utmost importance. Also important is the distribution of the food which must be done in such a way as to avoid a notable weight dispersion at the time of the final fishing, since specimens that don't reach commercial weight have little value. If the facilities possess equipment for live fish transportation, they may be transferred into another pond (differential handling) to accomplish its growth. In any case it is a slow process and not profitable. According to the administration of the establishment either those fish are sold for a lesser price and the pond freed, or the fishing is delayed until most of the specimens reach commercial weight. In the last case the number of profitable cycles
is affected.

Plant design

The planification of a fishculture plant should consider the following factors:

- Value of investment involved and prevision of production.
- Type of land and possible uses. Legislations in practice on the site and restrictions in land transformation.
- Availability of good quality water, accessibility to the site, local and regional facilities.
- Economic viability in function of the stated above.

An aquaculture in semi-intensive mode (Fig. 1) consists of (Pousão Ferreira, 1995):

- Reservoir that permits the pumping of water in different tide situations and in a

quantity adequate to the culture pools.

- Culture ponds with areas between 0.5 and 1 ha, and about 1.5 mt. deep; in same cases dimensions can be greater.
- A pre-fattening pool zone and a commercial sized stock of specimens.
- Access zone, dikes and parking.
- Main building zone.
- Water distribution and collecting drain (or a tube network in PVC).
- Other aid buildings (emergency generator building, pre-fattening ventilators storage...).

A vantageous use of the site will depend on what is built there, access, water discharge system and the local topography. Its use may not be linear or the cost not likely to become incorporated. A correct drawing of this type of projects is absolutely necessary for a good hydraulic functioning and a production that fullfills expectations (Tang, 1979). The distances from the site to the main infrastructures, including fences and electrical network, are important decision-making factors. The electric power should be spread for the whole aquaculture plant - storage building, pumping station, panels in every pool for connection of ventilators, feeders and other eventual equipments, lighting of main paths and installation of auxiliary equipment in the pre-fattening zone.

Sea bass and gilthead sea bream

The two most prominent species typically reared in a semi-intensive mode in southern Portugal are the gilthead sea-bream (*Sparus aurata*) and the sea bass (*Dicentrarchus labrax*). As their life cycles in captivity are known (Pousão Ferreira & Dinis, 1991), the production starts with juveniles which are reared in hatcheries and are produced in high enough quantities to supply fishculture plants. The average production is 10 tons/ha/yr. of sea bass, gilthead sea bream, or both, but it may reach 20 tons/ha/yr. in very well managed fishcultures.

For these species, the average survival rate in the fattening process is around 90%. In Portugal there have not been detected serious pathological cases in this type of culture, being the predation by birds (imputable by far to the cormorants -*Phalocrocorax carbo*) the main problem affecting survival. So, the initial stock destined for a 1 ha pond of which is expected a 10 tons final production of market size fish (ca. 350 gr) is:

10000 Kg/0.35 Kg . 90% survival ≈ 31 750 specimens

In what concerns pelleted food, and considering a common value of 1:2 for food conversion rate, it is needed according with these numbers:

10000 Kg/0.5 = 20000 Kg of commercial pellets.

It is very important to stress this calculations due to the relevant importance of this kind of food during a semi-intensive rearing of those species. In fact we have also observed that in these aquaculture systems, and in spite of the availability of the natural food sources, the reared fish eat preferentially the pelleted food. Thus most of the natural food represented by fauna and flora of the ponds remains free for other non-competing species that could be reared together with these two.

The fish could be fatten in monoculture or in policulture (sea bass + gilthead sea bream) with dominance of one of the species. An abnormal growth of macroalgae

covering an important part of the pools have been noticed from earth ponds with monocultures of sea bass. Co-culture of this species with the gilthead sea bream seems to prevent this problem. Gilthead sea bream grows faster than sea bass (Figs. 2), but this could be corrected considering the initial size of the juveniles of both species. It must also be considered that a 300-330 gr. sea bass has a market value somewhat higher than a 350-400 gr. gilthead sea bream.

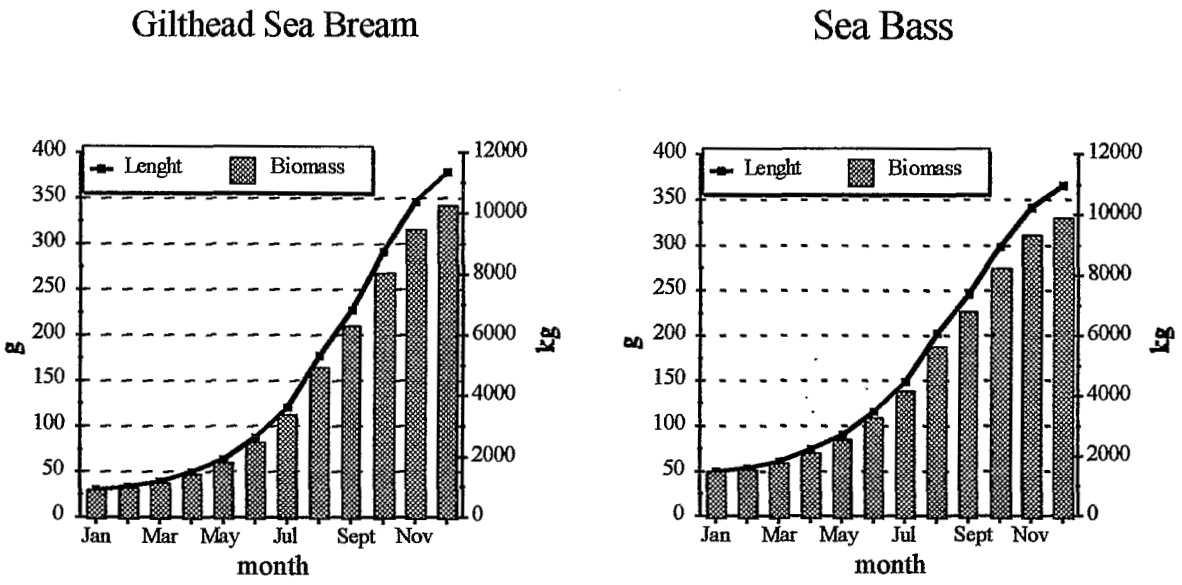

Fig. 2. Growth curves of gilthead sea bream and sea bass (lenght and biomass).

Sole

The sole (*Solea senegalensis*) is an abundant species on the coast of Algarve (south of Portugal), representing more than 90% of the captured Soleids. It is highly appreciated
and its economical value is elevated in the Portuguese as well as other European markets. Because of this it could be considered as a complementary or, in some places, as an alternative culture to those of sea bass and/or gilthead sea bream.

The reproduction and production of juveniles in captivity is possible with high survival rates since the larvae problems (decrease in survival and growth) concern only their adaptation to inert artificial food, which should be the aim of further research. In Portugal, this species was for the first time hatched in 1984 from reproducers kept two years in captivity, and juveniles were obtained (Dinis, 1986). Since then other trials have been made on bettering the technics used in juvenile production and the species' adaptation to inert food (Dinis *et al.*, 1988; Dinis, 1992). The average rate of survival from larvae to juvenile is about 40% (Dinis, 1992; Pousão Ferreira, unpublished data).

Test are being done in semi-intensive ponds in which soles and giltheads are reared together. The first results of tests from 100 mg post-larvae reared in ponds with juveniles of sea bass and gilthead sea bream provided specimens that average a total length of 352.5±1.8 cm and a total weight of 456.1±3.6 gr., after a one year fattening

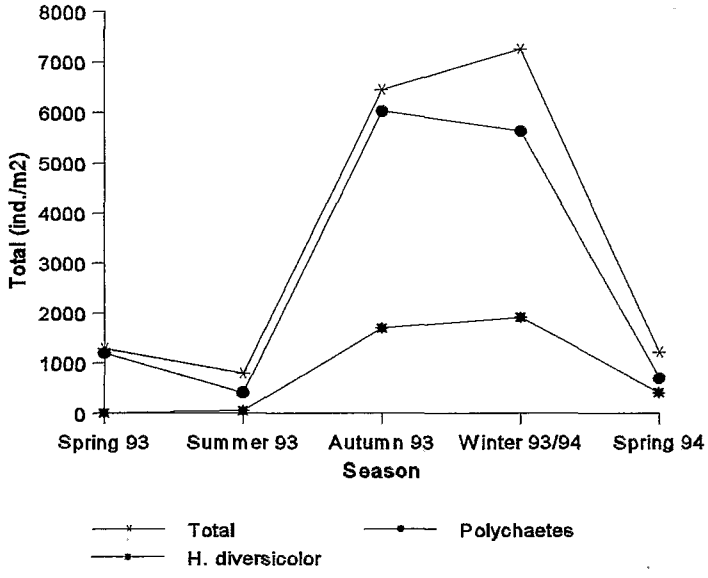

Fig.3- Average densities of Macroinvertebrates (Total), Polichaetes and *Hediste diversicolor*

period (Dinis, pers. comm.). These results are quite promising aiming a future use of the species. On the other hand, projects put in effect by Arias *et al.* (1980a, 1980b, 1989) in extensive earth ponds in the Cádiz region (Spain) showed that the sole was the second species in growth, being one of two species, combined with the gilthead, commercialised after one year of culture.Preliminary tests accomplished by Rodriguez *et al.* (1995) in earth ponds using different methodologies, with and without fertilisation and with the supplying of food propose interesting rearing strategies.

In the same aquaculture where the growth tests on the sole were made, the characterization of the macrozoobenthos is currently being done inside the gilthead rearing ponds, in order to evaluate what part of the natural food supply is being used by these fish. Results point out that the community was dominated by polychaetes which represent 82.1% of the average global densities of macrofauna. The evolution of the mean densities of macroinvertebrates during the giltheads' growth period are in agreement with this fact (Fig. 3). Bivalves, amphipods, chironomids and phoronids are also important groups in the structure of the community.

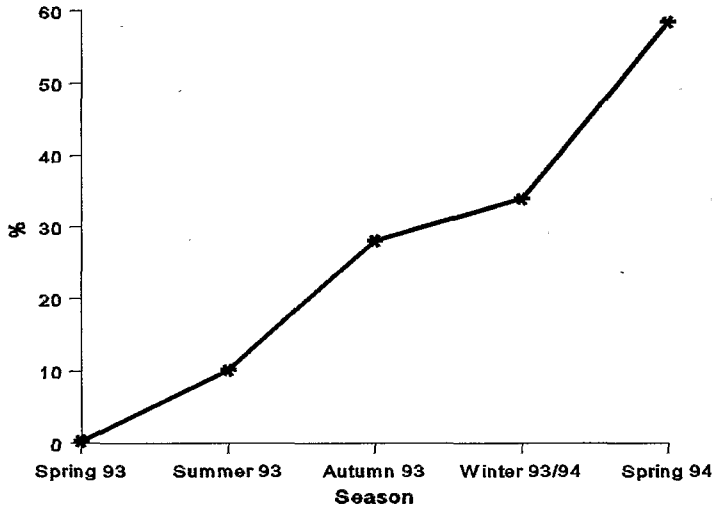

Fig.4- % of *H. diversicolor* in total Polychaetes

During this time it was noted a percent increase of *Hediste diversicolor* in the group of polychaetes (Fig. 4). This is probably due to the evolution of environmental conditions towards an increase of confinement (Guelorget *et al.*, 1983), and to the increase of organic material during the fish production cycle. These results permit an understanding of the rapid growth, above referred, of the sole, once it is known that it is a species feeding mostly on polychaetes, being *H. diversicolor* a preferred prey (Bernardo, 1990) as well as being an essential nourishment for maturing and reproduction (Dinis, 1986).

FINAL CONSIDERATIONS

The improvement of conception, design and functioning of aquaculture systems in

semi-intensive mode must be continually studied so that their productivity can be increased, particularly concerning the best fish densities required for successful growth and optimal maintenance of the ponds during co-culture of sea bass and gilthead sea bream. Another important factor to be considered for the correct administration of these systems is the water quality, its renovation and its interaction with the sediment.

The encouraging results obtained in the experimental co-culture of sole with gilthead sea bream and sea bass and its interactions with the benthic fauna in the earth ponds, make the future perspectives for the culture of this species look rather interesting. To achieve this goal, research must be implemented in the following areas:

- Obtention of viable eggs.
  - Conditioning of the "brood stock" towards the obtention of viable postures year round.
  - Nutrition, pool characteristics and male/female relationship.

- Culture in larval and post-larval stages.
  - Larval nutrition and rearing methodology - density, photoperiodicity and light intensity, pool type.
  - Adaptation to inert food - type and composition of pellets, its distribution and stability in the water.
  - Pool type and required substrate for culturing post-larval stages.
  - Behaviour of the soles towards pelleted food.

- Fattening (semi-intensive mode)
  - Study of the benthonic populations in the earth ponds to be used.
  - Study of pool repopulation viability with polychaetes, in particular with *Hediste diversicolor*, a species whose culture seems to be feasible (Fidalgo e Costa e Cancela da Fonseca, 1995).
  - Transfer to fattening pools, minimum size required, initial density per square meter, survival and final density per square meter.
  - Fertilisation of pools or use of pre-existing resources.
  - Monoculture or polyculture with gilthead sea bream and/or sea bass.
  - Relationship to other species, and the relative size required among them to avoid predation and obtain an optimal growth.
  - Fishing and marketing methods.

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