*Bol. Inst. Esp. Oceanogr. 21 (1-4). 2005: 361-373*

**BOLETÍN.** INSTITUTO ESPAÑOL DE OCEANOGRAFÍA
ISSN: 0074-0195


# Current status and perspectives of mollusc (bivalves and gastropods) culture in the Spanish Mediterranean

*M. Ramón* [1], *J. Cano* [2], *J. B. Peña* [3] *and M. J. Campos* [4]

[1] Centre d'Aquicultura Institute de Recerca i Tecnologia Agroalimentàries (IRTA), Ctra. Poble nou, s/n, km 5,5, E-43540 Sant Carles de la Ràpita (Tarragona), Spain. E-mail: montserrat.ramon@ba.ieo.es
[2] Centro Oceanográfico de Málaga, Instituto Español de Oceanografía, Puerto Pesquero, s/n, Apdo. 285, E-29649 Fuengirola (Málaga), Spain
[3] Instituto de Acuicultura de Torre de la Sal, CSIC, E-12595 Ribera de Cabanes (Castellón), Spain
[4] Centro Oceanográfico de A Coruña, Instituto Español de Oceanografía, Muelle de las Ánimas, s/n, Apdo. 130, E-15001 A Coruña, Spain

*Received October 2005. Accepted November 2005.*

**ABSTRACT**

This is a review of the current status, problems and perspectives of bivalve and gastropod culture in the Spanish Mediterranean. Along this coast, bivalve culture has traditionally been located in the two Ebro Delta bays, and in the harbours of Valencia and Mahón, where the main species is the mussel. At present, the Mediterranean mussel *Mytilus galloprovincialis* Lamarck, 1819 culture is developing in Andalusia. Ostreid culture is currently limited to two species, the Japanese oyster *Crassostrea gigas* (Thunberg, 1793) in the bays of the Ebro Delta, and the European oyster *Ostrea edulis* L., 1758 in Santa Pola (Alicante). Cultures of the grooved carpet and Japanese carpet clams, *Ruditapes decussatus* (L., 1758) and *Ruditapes philippinarum* (Adams & Reeve, 1850), are located only in the shallow areas of the Ebro Delta. In addition, beds of several species of clams and scallops are distributed along this coast, including the truncate donax *Donax trunculus* L., 1758, the striped venus *Chamelea gallina* (L., 1758), the tuberculate cockle *Acanthocardia tuberculata* (L., 1758) and the smooth callista *Callista chione* (L., 1758).

**Keywords:** Aquaculture, Mediterranean mussel, Japanese oyster, European oyster, clams, scallops.

***RESUMEN***

***Situación actual y perspectivas de los cultivos de moluscos (bivalvos y gasterópodos) en el Mediterráneo español***

*En este trabajo se revisa la situación actual del cultivo de moluscos bivalvos y gasterópodos en el Mediterráneo español, analizando su problemática y sus perspectivas de futuro. De todo el litoral, el cultivo de moluscos se ha concentrado tradicionalmente en las dos bahías del delta del Ebro y en los puertos de Valencia y Mahón, con el mejillón* Mytilus galloprovincialis *Lamarck, 1819 como la especie de mayor producción, cuyo cultivo, recientemente, se está desarrollando con éxito en Andalucía. El cultivo de ostreidos se limita en la actualidad a dos especies: el ostrón* Crassostrea gigas *(Thunberg, 1793) en las bahías del delta del Ebro y la ostra plana* Ostrea edulis *L., 1758 en Santa Pola (Alicante). El cultivo de almejas* Ruditapes decussatus *(L., 1758) y* R. philippinarum *(Adanms & Reeve, 1850) se realiza en*

*el delta del Ebro. Además, a lo largo del litoral mediterráneo español existen numerosos bancos naturales de coquina* Donax trunculus *L., 1758, chirla* Chamelea gallina *(L., 1758), corruco* Acanthocardia tuberculata *(L., 1758), almejón* Callista chione *(L., 1758) y varias especies de almejas y vieiras.*

***Palabras clave:*** *Acuicultura, mejillón, ostrón, ostra plana, almeja, vieira.*

## INTRODUCTION

Along the Spanish Mediterranean coasts, mussel culture has traditionally been located in the Ebro Delta bays and in the harbours of Valencia and Mahón, where the main species is the mussel *Mytilus galloprovincialis* Lamarck, 1819. This is due to the few sheltered areas in these waters. Farms must therefore be located offshore, where they are exposed to occasional, but severe, windstorms. Other molluscs are also cultured, but in smaller quantities. These include the Japanese oyster *Crassostrea gigas* (Thunberg, 1793), the European oyster *Ostrea edulis* L., 1758, the grooved carpet shell *Ruditapes decussatus* (L., 1758) and the Japanese clam *Ruditapes philippinarum* (Adams & Reeve, 1850). Figure 1 shows the areas and species cultured along the Spain's Mediterranean coast.

There has recently been a great increase in interest, mostly from Galician and Basque investors, in developing mussel culture in less traditional mussel-farming areas. This has led them to ask for authorizations in Andalusia (Villarías *et al.*, 2005) and Ceuta, areas that might look to mussel aquaculture as a new economic resource which could help to offset job losses in the fishing sector.

## CURRENT SITUATION OF MOLLUSC CULTIVATION AND PRODUCTION

### Mytilids

Mussel culture along the Spanish Mediterranean coast is a tradition in Catalonia, Valencia and Menorca, and is now also developing in Andalusia. Mussel culture in Catalonia began in 1903 in Tarragona Harbour (Arté, 1990). Later on, around the year 1906, 30 farms were established in Barcelona Harbour, with this

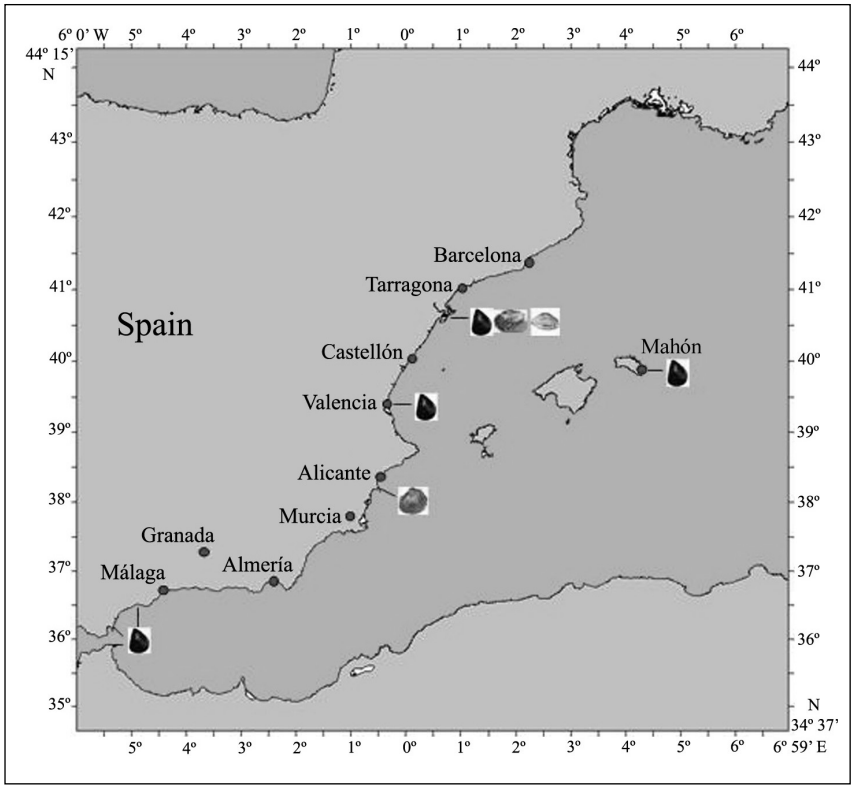


Figure 1. Bivalve species cultivated in the Spanish Mediterranean coast

number increasing to 128 by 1928 (Peitx, 1986). The establishment of mussel rafts in the Ebro Delta occurred when those in Barcelona Harbour had already disappeared. New mussel farms began with only 2-3 rafts per bay, but numbers subsequently rose to the current total of 166. Today, bivalve culture in Catalonia still largely remains in the Ebro Delta (Ramón, Fernández and Galimany, 2005b), with an average annual mussel production of about 3 000 t (figure 2). Mussels are cultured in suspension from the 166 fixed rafts that are spread between the bays of Alfacs (90 farms) and Fangar (76 farms). These mussel rafts occupy 1.8 % of the total surface area of Alfacs Bay, and 6.5 % of Fangar Bay. The mussel rafts are rectangular wooden frames measuring 200 m × 15 m, from which 2-3 m long mussel ropes are suspended. They are anchored to the seabed by concrete girders, and only stick out of the water 1 m. Sheds have been built on some of the rafts to allow mussel producers to do their work there (figure 3).

In Alfacs Bay, there are also storage facilities on land, where it is possible to prepare the ropes and process the mussels. A few years ago, a local company set up a *M. galloprovincialis* and a *C. gigas* farm using long-lines in the open sea. This is no longer done, however, due to high costs and losses caused by fish predation, mostly attributable to gilthead seabream.

The producers' associations of the Mediterranean coast are all located in Catalonia, since this is where the greatest number of producers is found. There are three organisations: the Unión de Productores de Moluscos del Delta del Ebro (Ebro Delta Mollusc Producers Union), the Asociación de Productores de Moluscos de la Bahía de Alfacs (Alfacs Bay Mollusc Producers Association), and the Asociación de Productores de Moluscos de la Bahía del Fangar (Fangar Bay Mollusc Producers Association). These three organisations control 85 % of mussel production, with the other 15 % belonging to independent producers. Along the rest of the coast, the businesses are too far away from each other for associations to be feasible.

Catalonia has 12 mussel depuration plants and 18 packing houses. All mussels harvested in the bays must be purified before commercialisation, as the area is classified as a B zone for mollusc production. Production is mainly destined for the Catalan and Valencian markets.

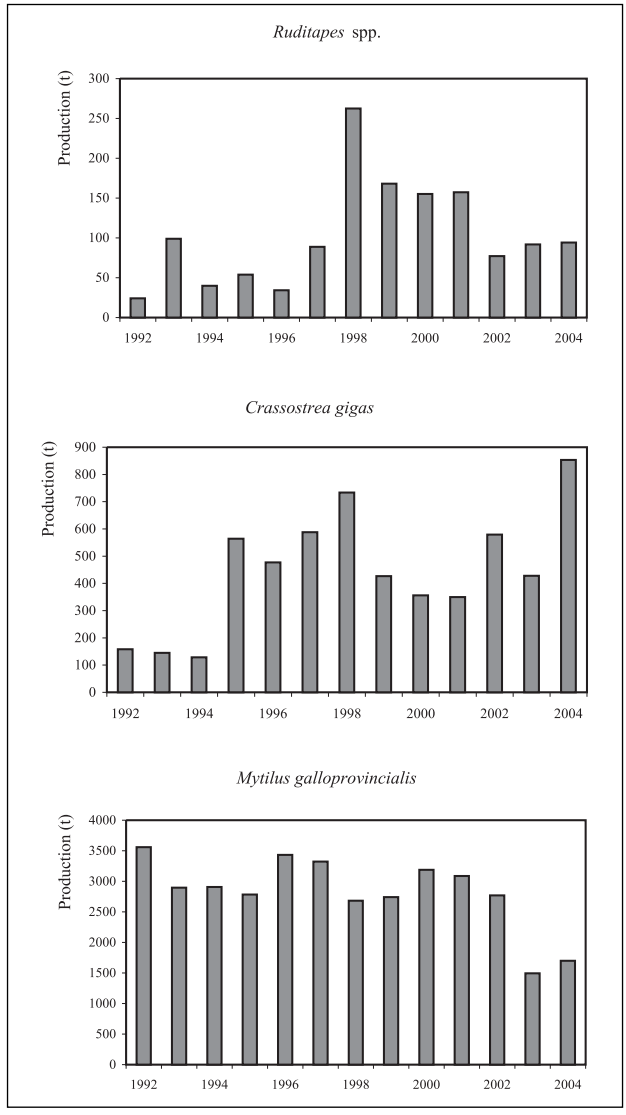


Figure 2. Evolution of the mussel *Mytilus galloprovincialis*, Japanese oyster *Crassostrea gigas* and clam *Ruditapes* spp. production in Catalonia (source: Department of Agriculture and Fishing, Catalan Regional Administration)

In the autonomous region of Valencia, the culture of *clóchina* (the local name given to *M. galloprovincialis*) is carried out from 22 fixed rafts located in Valencia Harbour. Even so, these waters are not really appropriate for mussel culture, due to their high volume of commercial traffic. The construction of a mussel depuration plant in the same harbour (Depuradora Clochi-

Figure 3. View of a typical raft of Alfacs Bay (Ebro Delta) showing the rectangular wooden framework that ropes are suspended from

na Valencia, S.L.) provides a good commercialization point, because, as in the past, production had to otherwise be transported to depuration plants in the Ebro Delta. Its entire production is sold as a fresh product on the Valencian market. A new mussel depuration plant has recently been built in Santa Pola (in the neighbouring province of Alicante).

Mussel culture in the Balearic Islands started in Mahón Harbour in 1940, where 10 farms were established (Grau, 1989). At present, there are 11 operative farms, with a production of 50 t (Valencia, pers. comm.).

Andalusia's Mediterranean production is limited to mussel cultures in Marbella (Malaga) and La Línea de la Concepción (Cadiz). In the La Línea de la Concepción, a company called Pescados y Mariscos de Mar de La Línea, S.L. carried out a series of experiments before starting to produce mussels in the summer of 1999, using an experimental mussel rope at La Atunara. In May 2000 an experimental raft was anchored for a year, although commercial culture did not get underway until July 2002, using 10 floating rafts. The depuration and packing of mussels is carried out at a mussel-treatment plant located in Cadiz. In Marbella, another company called Cultivos Marinos de Andalucía, S.L., began to farm mussels using long-lines in 1999. This same company is currently installing a raft at Caleta de Vélez (Malaga).

In 2004, total production rose to 760 t (table I), and was mostly sold on the Andalusian market.

**Ostreids**

Ostreid culture is currently limited to two species, the *C. gigas* in the Ebro delta bays and the *O. edulis* in Santa Pola (Alicante). In Mar Menor (Murcia) there was a major natural bed of *O. edulis,* from which high quantity of seed could be obtained (Rosique *et al.*, 1993; Stril, Rocamora and Cano, 1992); however, its current status has not been studied since 1994. Some growth expe-

Table I. Mussel production in Andalusia in 2004

| Company | Concession area ($m^2$) | Culture system | Location | Province | Production (t) |
|---|---|---|---|---|---|
| Pescados y Mariscos de Mar de La Línea, S.L. | 876 752 | 10 rafts | La Línea de la Concepción | Cadiz | 621 |
| Cultivos Marinos de Andalucía, S.L. | 125 000 | Long-lines | Marbella | Malaga | 140 |
| Total | | | | | 761 |

riments have also been carried out in the open sea, in front of Isla Grosa: they produced good results, as there were no mortalities (Cano and Rocamora, 1996).

In Catalonia, *O. edulis* culture was not successful, despite good initial expectations and a production of about 50 t in 1992 and 1993. A natural bed was found in the Ebro Delta in 1985 (Peitx, 1986) which provided high quality oyster seed. The growth of this seed was good in Fangar Bay; more than 70 % of the individuals obtained from collector ropes (6-7 months old) grew to commercial size after 12 months of fattening (Ramón and Arté, 1987). Later experiments showed better results for growth and condition indexes for seed fattened in Alfacs Bay than in Fangar Bay (Riera, 1990). Nevertheless, since 1997 the *O. edulis* has no longer been cultivated in the Ebro Delta, mainly because many cultures became infested with *Marteilia refringens*, which caused high mortality rates and greatly affected production (Riera, Santmartí and Durfort, 1993; Riera *et al.*, 1995a). On the other hand, *C. gigas* production has increased since 1995 (figure 2), and, especially over the last few years, due to high mortality rates suffered by mussels in summer. This is why producers opt for diversified production and combine *C. gigas* and mussel cultures. *C. gigas* are cultivated in suspension, hung from rafts of the Ebro delta, using ropes and horizontal plastic mesh bags.

In Alicante, *O. edulis* culture was begun by Promociones Marsán, S.L in Santa Pola in 2003, using long-lines. This production is expected to reach commercial level shortly (M. Marhuenda, pers. comm.).

## Venerids

Clam cultures in the Spanish Mediterranean are only located in shallow areas of the Ebro Delta. This work is carried out by local fishermen (Sant Carles de la Ràpita, L'Ampolla and Deltebre) who sow with hatchery seed in some years (Pech, Fernández and Pepiol, 1993; Pech, 1995). The farming of the two different clam species being exploited commercially has evolved differently: whereas *R. decussatus* production has progressively decreased, that of *R. philippinarum* has risen.

## Other species

There are many different bivalve beds along the Mediterranean coast. Although these cannot, strictly speaking, be considered as part of shellfish cultivation activity, they are in some ways related to aquaculture. Some of these beds are a good source of seed. Once the seed has been collected, it can be used for further growth in more favourable areas. On the other hand, seed production in hatcheries presents the possibility of sea-ranching overfished beds.

Along the Catalan coast there are beds of truncate donax *Donax trunculus* (L., 1758), striped venus clam *Chamelea gallina* (L., 1758), the smooth callista clam *Callista chione* (L., 1758), and grooved carpet shell *R. decussatus,* which are exploited by the local shellfish fishery fleet. Along the Valencian coast there are major beds of *C. gallina* and *D. trunculus*, especially in Castellón, Cullera and Gandía (Ramón, 1993). The beds of *C. gallina* at the latter two locations have, however, partially disappeared. In Andalusia there are also abundant beds of *C. gallina*, *D. trunculus*, the king scallop *Pecten maximus* (L., 1758), the banded carpet shell *Tapes rhomboides* (Pennant, 1777) and the cockle *Acanthocardia tuberculata* (L., 1758). These species are exploited by the fishing fleets of the Cadiz (Playas de La Atunara) and Malaga coasts and, on a smaller scale, by those of Granada and Almeria. Regarding pectinids, catches made by trawlers and seed collection experiments have led experts to the conclusion that there are probably beds all along the Mediterranean coast. The main species of commercial interest in Spain are: the king scallop *P. maximus*, the pilgrim's scallop *Pecten jacobaeus* (L., 1758), the black scallop *Mimachlamys varia* (L., 1758) and the queen scallop *Aequipecten opercularis* L., 1758. There used to be a bed of young *P. jacobaeus* and *M. varia* off the coast of Blanes (Gerona) (Riera *et al.*, 1995b). In the Valencia region, several studies relating to the collection of natural seed have been carried out since 1990 (Peña and Canales, 1993; Peña *et al.*, 1994; Peña, Mestre and Farías, 1995; Peña *et al.*, 1996): they

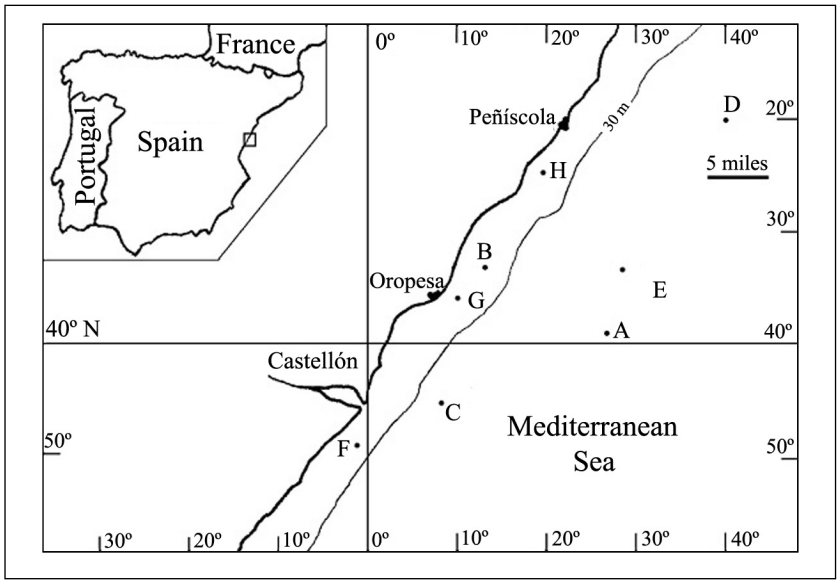


Figure 4: Map of collecting sites in Castellón. (A): El Carreró; (B): Torre de la Sal; (C): El Dátil; (D): Benicarló; (E): El Volante; (F): Burriana; (G): Oropesa; and (H): Alcocebre

involved anchoring filamentous collector ropes at eight different fishing grounds (see figure 4). Three commercial species were found at depths of between 60 and 70 m: El Carreró (A), El Volante (E) and Benicarló (D). Four other species of less commercial value –*Palliolum incomparabile* (Risso, 1826), *Crassadoma multistriata* (Poli, 1795), *Perapecten commutatus* (Monterosato, 1875) and *Pseudamussium clavatum* (Poli, 1795)– were also found. In the shallow areas off the coast of Castellón –Alcocebre (H), Torre de la Sal (B), Oropesa (G), Burriana (F) and the El Dátil fishing ground (C)– most of the species found (except for the last two mentioned) were the same as those found in deeper waters. There were also, however, new species, such as *Flexopecten flexuosus* (Poli, 1795), *Flexopecten glaber* (L., 1758), *Karnekampia bruei* (Payraudeau, 1826), *Lissopecten hyalinum* (Poli, 1795), and *Delectopecten vitreus* (Gmelin, 1791). It is important to note that, even though *F. flexuosus* is not currently commercialised, it could be ongrown and introduced on the market as a new species, due to its high abundance and rapid growth (it can reach a size of 40 mm in less than one year).

In Santa Pola, many specimens of *M. varia* attach to oyster collectors, as do some *P. jacobaeus* and *A. opercularis*. In Mazarrón Bay, trawlers catch adult *P. maximus,* and at Motril and Salobreña, a great deal of three commercial species seed has been collected from plastic bags.

Finally, there are major natural beds of the clam *C. gallina* located off the Balearic Islands (Valencia and Masutí, 2004), although in 2001 and 2002 there was high mortality due to intense rains, which resulted in the seabed being covered with large quantities of sediments (Valencia, Massutí and Navarro, 2004). Other commercially exploited bivalve beds include those of the clam *Venus verrucosa* L., 1758, the cockle *Acanthocardia tuberculata*, the grooved carpet shell *R. decussatus*, and the Noah's arc shell *Arca noae* L., 1758 (Valencia, pers. comm.).

## PRODUCTION PROBLEMS

In general, the Spanish Mediterranean coast offers good conditions for mollusc culture, with appropiate temperatures, skilled labour, and high productivity. Nevertheless, each species and geographic area presents its own particular problems.

### Mytilids

The main difficulty in Catalonia is the high level of mussel mortality during summer, especially in Alfacs Bay, where temperature can exceed 28 ºC for several weeks (Ramón, Fernández and Galimany, 2005b). Consequently, farmers must sell their product earlier than they would otherwise wish, so that the mussels are not in

these waters during the critical period. By mid-summer, the only mussels remaining for sale are those from Fangar Bay, where mortality due to high temperature is not so common (although there have been cases, such as the summer of 2003). The impossibility of commercialising production coming from nearby harvesting areas when toxic algal blooms or toxic shellfish are detected is more and more frequent. In general, natural seed collection is sufficient to supply Ebro Delta producers' needs. Even so, there are years in which the quantity collected is insufficient, or in which there is very large-scale predation by fish. On these occasions, mussel seed must be bought from other Mediterranean producers in countries such as Italy or France, producing different end results for the mussel culture (Ramón, Fernández and Galimany, 2003, 2005a).

The problems in Valencia are largely associated with other activities carried out in the harbour, but these will soon be solved when mussel production is transferred to long-lines offshore.

One major problem of mussel culture in Andalusia is the lack of seed. Until now, it has been necessary to collect it from natural beds. However, as farming activities have developed, the amount of seed collected at the sites themselves (on ropes, anchorages, etc.) has increased, as has collection from neighbouring rocky areas. Another problem is the rising presence of toxic algae blooms, which impede mussel commercialisation, mostly due to Paralytic Shellfish Poisoning (PSP) and Amnesic Shellfish Poisoning (ASP). These toxic blooms also affect natural bivalve beds, and can last for periods ranging from a week to several months. These episodes must be considered a risk factor, which companies exploiting bivalve resources must assume (Villarías *et al.*, 2005).

### Ostreids

*O. edulis* culture disapeared from Catalan waters in 1997 as a result of mass mortality. This motivated producers to change to cultivating *C. gigas*, which provides better yields because it grows faster and is less prone to disease. There is no natural seed collection or seed production in the area, so seed must be bought from elsewhere, mostly from France.

### Venerids

In Catalonia, the main clam producers are fishermen from the Ebro Delta, who focus much more on collecting than on cultivating the product. One of the greatest problems is the lack of locally produced seed. This means that producers must obtain their seed from hatcheries located in areas with different environmental conditions, which in turn results in higher levels of mortality at the beginning of the fattening period. Another problem is the high mortality rate coinciding with anoxic events and *Perkinsus* sp. infections (Santmartí *et al.*, 1995), especially during summer. No clam seed has been sown in Alfacs Bay in recent years due to increases in the amount of seaweed, which hinders culture management.

## PERSPECTIVES FOR BIVALVE AND GASTROPOD CULTURES

New structures for offshore bivalve culture were designed and developed in 2005. These include Corelsa's circular floating rafts, Extrumar's submersible rafts, and new long-line systems with hanging nets instead of ropes (called SmartLine), marketed by Gestenaval, S.L. The first two structures were tested in Galicia, and the prototypes showed quite promising results. SmartLines are already being used in Norway, Ireland and Scotland. Experiments have also been conducted with different models of long-lines, which are especially useful for pectinid cultures (López, Cestino and Salas, 2005).

Polycultures with fish and molluscs in cages and different mollusc species on long-lines (e.g., ostreids on the sea surface and pectinids on the bottom) could provide good results, and enable companies to split their production.

### Mytilids

The number of permits granted for mussel culture will not increase in either of the Ebro

Delta bays. Nevertheless, the new offshore structures, which have been specially designed to prevent fish predation, could provide a good alternative to increasing farming in more exposed areas.

At the beginning of 2005, the Catalan regional administration allowed the company Cultius Marins del Delta de l'Ebre to use a circular PVC floating raft for experimental mussel culture. This was to be installed in the Sant Jordi Gulf during 2006, and a study on mussel development is planned, which will also evaluate the possibilities offered by this kind of structure.

Mussel culture in Valencia Harbour will disappear due to modifications caused by the America's Cup 2007. The companies that exploit rafts there must move their operations offshore and use long-lines. Aquaculture in the Valencia region is mainly based on fish culture (especially gilthead seabream and European seabass), although some fish farms have started to diversify their production and to install mussel long-lines.

Mussel culture in Andalusia offers very good prospects, as a number of companies (mostly from Galicia) are interested in introducing and exploiting cultures in this region. The Andalusian government has received 30 requests to install 600 new rafts (Villarías *et al.*, 2005). In order to study these requests, the regional administration decided to analyse the potential for mussel culture in the area. This included carrying out a genetic evaluation of the autochtonous populations and the location of seed, undertaking physico-chemical and biological monitoring of the culture, and conducting pathological and sanitary surveys (Villarías *et al.*, 2005). The results of these studies have made it possible to prepare a proposal for a law in order to regulate the development of mussel culture in Andalusia.

Two additional mussel seed projects are planned for the Ceuta (North Africa) coast. Two companies, Mejillones y Mariscos de Ceuta, S.L. and Atunasa, S.L., will respectivelly set up five and four experimental rafts. A survey of the efficiency and environmental impact of these operations will then be undertaken. According to the results obtained, the number of rafts installed could subsequently be increased to 150.

**Ostreids**

*C. gigas* cultures seem to have developed very well in the bays of the Ebro delta, since the number of producers investing in this species has steadily increased. There has recently been a good level of *O. edulis* seed collection off the coast of Santa Pola (Alicante), at a depth of 30 m on muddy sand bottoms. This has been achieved using so-called hat collectors, which are anchored in spring and recovered in autumn. They remain close to the surface in 1 m columns. Each hat collects from 5-10 oysters. Farmers use 40 000 of them every season to collect up to 250 000 *O. edulis* spats. The seed is fattened in baskets made of steel mesh and covered with PVC which hang near the sea surface on 200 m long-lines. This system provides good growth results, and oysters reach commercial size (from 70-100 mm) after 18 months of culture (Marhuenda, pers. comm.).

**Venerids**

There are good perspectives for clam culture, especially in Fangar Bay (Ebro Delta), and the Catalan government has recently given new permits. Furthermore, the Aquaculture Centre (IRTA) is developing a research project to evaluate the possibilities of producing seed locally.

The beds of *C. chione* in Maresme (Barcelona) have experienced falling yields, so fishermen have asked for help from the Catalan regional administration. A study on the possibility of obtaining this bivalve seed from hatcheries is already planned, with the final objective being to establish sea ranching. Something similar is happening in Andalusia, with natural beds of *T. rhomboides*; local stock is now so depleted that the Andalusian government has shown great interest in obtaining seed from hatcheries in order to renew natural populations and improve its culture. A study performed by the Instituto Español de Oceanografía (Spanish Institute of Oceanography, IEO) has recently shown that abundant seed from these species has settled in collectors used for pectinids. Likewise, it has been reported that seed kept in baskets and bags has very low mortality and high growth rates, reaching commercial size (35 mm) after 2 years of culture.

In the Balearic Islands, successful experiments have been carried out for spawning induction and larval culture of the clam *V. verrucosa* (Grau *et al.*, 1995). There have also been initiatives to grow seed in farmed areas (Valencia, Grau and Grau, 1997). Even so, to date, no company has expressed serious interest in farming this species.

**Pectinids**

Scallops are not commercially cultivated along the Spanish Mediterranean coast, although scallop beds are exploited by artisanal fleets at Castellón, Malaga and Cadiz. Attempts have been made to fatten *P. jacobaeus* and *A. opercularis* seed collected from offshore beds near Oropesa del Mar (Castellón), at depths of 70 m, in El Carreró fishing ground (figure 4). Four suspended systems were used: plastic cages, collector bags, lantern nets and ear hanging (figure 5). The results showed good survival and growth for species cultivated in both plastic cages and collector bags (Peña, Canañes and Ríos, 1995).

Studies on *P. maximus* started in Malaga in 1982, after the discovery of beds in the area and their subsequent exploitation. Since 1997, various experiments have studied the viability of farming *P. maximus, M. varia* and *A. opercularis*. The results revealed the appropriate type of seed collectors, the best season for collector anchoring and for seed collection, the most appropiate pre-fattening and fattening systems for each species, and the best growing depths and culture densities (table II) (Campos and Cano, 2003a,b; Cano and Campos, 2003a,b).

Although the main technical problems related to pectinid culture have now been solved, there have, so far, been no companies interested in farming these species commercially. In Valencia, the best depth at which to grow them is quite far out (between 12 and 15 miles) from the coast, so the effort involved is not really worthwhile for potential producers. Furthermore, as pectinids cannot survive temperatures higher than 20 ºC, they must be cultivated at depths of at least 50 m, but these areas coincide with those trawled by fishing fleets.

In Andalusia, the situation is a bit different, and the main constraint on developing pectinid culture is the presence of biotoxins during long periods in the areas in which farming would normally take place. The considerable time that *P. maximus* needs to eliminate toxin after a toxic episode constitutes an additional problem. Current European legislation does not permit the collection of toxic *P. maximus* with values of more than 20 µg of domoic acid per gram of flesh, although extraordinary measures in the case of other species have been promulgated. The fact that high temperatures effectively reduce levels of saxitoxins has brought about a change in the European Union legislation on PSP toxins, which authorises the extraction of the cockle *A. tuberculata*

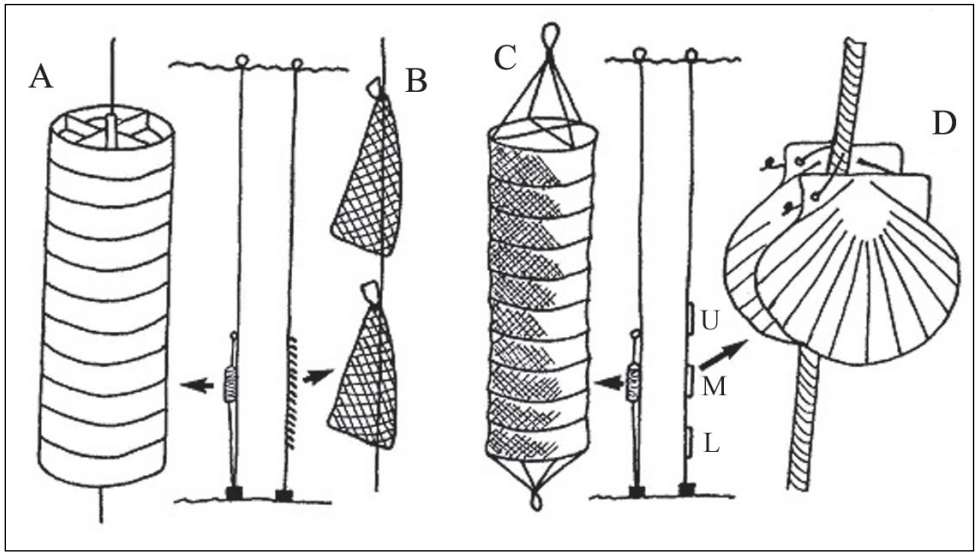


Figure 5: Ongrowing systems for the pilgrim's scallop *Pecten jacobaeus* and the queen scallop *Aequipecten opercularis*. (A): plastic cages; (B): collector bags; (C): lantern nets; (U): upper; (M): middle; (L): lower; and (D): ear hanging

Table II. Collector types and ongrowing systems tried and recommended for the culture of pectinids and ostreids in the Valencian and Andalusian coast

| Species | Tryed collector types | Advisable collector | Ongrowing systems tryed | Advisable ongrowing system | Culture spend (months) | Commercial size (mm) |
|---|---|---|---|---|---|---|
| *Pecten jacobaeus* | Two types of outer bags: raschel and monofilament (25 kg and 75 cm × 40 cm size). Inside the bags were two plastic mesh bags (35 cm × 40 cm) | Outer bag of monofilament and inside plastic mesh bags | Plastic cages, collector bags, lantern nets and ear hanging | Plastic cages, collector bags | 20-24 | 100 (length) |
| *Mimachlamys varia* | | | Plastic cages, collector bags and ropes | Plastic cages, collector bags and ropes | 12-16 | 40 (height) |
| *Aequipecten opercularis* | | | Plastic cages, collector bags | Plastic cages, collector bags | 12-16 | 40 (height) |
| *Tapes rhomboides* | | | Plastic cages, collector bags | Plastic cages, collector bags | 24 | 35 (length) |
| *Ostrea edulis* | Chinese little hats | Chinese little hats | Plastic cages and horizontal plastic mesh bag | Plastic cages and horizontal plastic mesh bag | 20-24 | Different sizes depending on quality |

having toxin levels up to 300 µg STXeq./100 g tissue (instead of the 80 previously established) when the product is destined for the canning industry.

A study into the effects of growth, environmental parameters and reproductive cycle was carried out in Andalusia by the Galician regional administration and the IEO in order to analyse the accumulation and anatomical distribution of PSP and ASP toxins in cultured *P. maximus*. The main purpose of this investigation was to establish whether this bivalve could be commercialised after removing some of its viscera. This is an option which producers currently consider highly promising. It would entail removing the digestive gland, mantle and gills, since the adductor muscle (the most valuable part for consumption) contains fewer ASP toxins than the other organs. It was concluded that this practice was good with respect to ASP toxins, but that care needed to be taken when the harvesting of adult *P. maximus* coincided with gonadal development; in such cases, the gonad should be removed, as well. The removal of viscera is not advisable for PSP, because the organ distribution of the toxin changes according to the toxicity period (García *et al.*, 2003; Blanco et *al.*, 2004; García-Muñoz *et al.*, 2004).

Toxin accumulation kinetics and detoxification remains unknown for other potentially farmable pectinid species.

**Gastropods**

Gastropod cultures in Europe are limited to the abalone *Haliotis tuberculata* (L., 1758) in Atlantic waters, and the quantities involved are very small. Research has been carried out in Spain to determine the potential of the purple dye murex *Bolinus brandaris* (L., 1758) (Ramón and Flos, 2001). This species is fished off the Spanish Mediterranean coast, where it constitutes an important gastronomic resource. Juveniles reared in a laboratory exhibited very fast growth, reaching lengths of 41 mm after 1 year of laboratory culture (they can be commercialised from 50 mm). It was estimated that commercial size could be attained after 1.5-2 years of culture. However, the main problem is how to obtain the spawns and to feed larvae once they have settled on the floor, as this is a carnivorous species.

## ACKNOWLEDGEMENTS

We would to thank Marina Albentosa for her suggestion to write this review, and subsequent encouragement. Catalonia's Centre for Aquaculture Research and Development (Centre de Referència de Recerca i Desenvolupament en Aqüicultura, or CRAq) financed a review of

mollusc culture in Catalonia. Eva Galimany edited the English text, and Malcolm Hayes made further revisions.

## REFERENCES

Arté, P. 1990. Evolution of the culture of bivalve molluscs on the North-West Mediterranean Catalan coast. In: *Mediterranean Aquaculture*. R. Flos, L. Tort and P. Torres (eds.): 15-18. Ellis Horwood Limited. Chichester, England.

Blanco, J., A. García, C. Vázquez, C. Mariño, M. J. Gómez, J. Cano and M. J.Campos. 2004. Kinetics and anatomical distribution of paralitic shellfish poisoning (PSP) toxins in the King scallop *Pecten maximus*. In: *Proceedings of the 5th International Conference on Molluscan Shellfish Safety* (June 14-18, 2004. Galway, Ireland): 12-13. Galway, Ireland.

Campos, M. J. and J. Cano. 2005. Crecimiento de *Aequipecten opercularis* (L., 1758) (Mollusca, Bivalvia) en cultivo en suspensión en Fuengirola (Málaga). In: *IX Congreso Nacional de Acuicultura (Cádiz, mayo 2003). La acuicultura como actividad económica en las zonas costeras: Libro de Actas* (May 12-16, 2003. Cadiz, España): 179-183. Consejería de Agricultura y Pesca, Junta de Andalucía. Sevilla, Spain.

Campos, M. J. and J. Cano. 2003. Preliminary data on the culture of *Chlamys varia* in Fuengirola, Málaga. In: *Proceedings of the 14th International Pectinid Workshop* (April 23-29, 2003. St. Petersburg, USA): 35-36. University of Florida. Florida, USA.

Cano, J. and M. J. Campos Loriz. 2005. Crecimiento y ciclo reproductor de *Pecten maximus* (L., 1758) (Mollusca, Bivalvia) cultivada en suspensión en Fuengirola (Málaga). In: *IX Congreso Nacional de Acuicultura (Cádiz, mayo 2003). La acuicultura como actividad económica en las zonas costeras: Libro de Actas* (May 12-16, 2003. Cadiz, Spain): 185-189. Consejería de Agricultura y Pesca, Junta de Andalucía. Sevilla, Spain.

Cano, J. and M. J. Campos. 2003. Interannual variations in pectinid spat collection in Fuengirola (Málaga, Spain), with special reference to *Chlamys varia* and *Aequipecten opercularis*. In: *Proceedings of the 14th International Pectinid Workshop* (April 23-29, 2003. St. Petersburg, USA) : 37-38. University of Florida. Florida, USA.

Cano, J. and J. Rocamora. 1996. Growth of the European flat oyster in the Mediterranean sea (Murcia, SE Spain). *Aquaculture International* 4: 67-84.

García, A., M. J. Campos, J. Cano, C. Mariño, M. J. Gómez and J. Blanco. 2003. Evolución de las toxinas ASP en la glándula digestiva de la vieira *Pecten maximus* cultivada en Andalucía. In: *Libro de resúmenes. VIII Reunión Ibérica de Fitoplancton Tóxico y Biotoxinas* (November 3-5, 2003. La Laguna, Spain). M. Norte and J. J. Fernández (eds.): 7-9. Universidad de La Laguna. La Laguna (Tenerife), Spain.

García-Muñoz, A., M. J. Campos, J. Cano, C. Mariño, M. J. Gómez and J.Blanco. 2004. Anatomical distribution of amnesic shellfish poisoning (ASP) toxins in the King scallop *Pecten maximus* throught the culture cycle. In: *Proceedings of the 5th International Conference on Molluscan Shellfish Safety* (June 14-18, 2004. Galway, Ireland): 14-15. Galway, Ireland.

Grau, A. M. 1989. Aproximació a l'evolució històrica i a la situació actual del marisc o el marisqueig a Maó (Menorca). In: *Jornades sobre conservació i desenvolupament a Menorca* (September 29-30, 1989. Llatzeret de Maó, Menorca, Spain). J. M. Vidal and J. Rita (eds.): 159-164. Programa MAB-Unesco. Institut Menorquí d'Estudis. Maó (Menorca), Spain.

Grau, A. M., E. Pastor, A. Grau, F. Riera and S. Pou. 1995. Aspectos reproductivos de la escupiña, *Venus verrucosa* (L.): inducción a la puesta y cultivo larvario. In: *Actas del V Congreso Nacional de Acuicultura* (May 10-13, 1995. Sant Carles de la Ràpita, Tarragona, Spain). F. Castelló i Orvay and A. Calderer i Rey (eds.): 155-159. Publicacions de la Universitat de Barcelona. Barcelona, Spain.

López, F. J., J. M. Cestino and M. Salas. 2005. Diseño de palangres para el cultivo de pectínidos en las costas de Málaga. In: *Libro de Resúmenes. X Congreso nacional de acuicultura: La Acuicultura, fuente de pescado de calidad para el futuro* (Gandía, Valencia, 2005) tomo II: 580-581. Universidad Politécnica de Valencia. Valencia, Spain.

Pech, A., 1995. Crecimiento de *Ruditapes decussata* en la bahía dels Alfacs, delta del Ebro. In: *Actas del V Congreso Nacional de Acuicultura* (May 10-13, 1995. Sant Carles de la Ràpita, Tarragona, Spain). F. Castelló i Orvay and A. Calderer i Rey (eds.): 294-299. Publicacions de la Universitat de Barcelona. Barcelona, Spain.

Pech, A., J. V. Fernández and A. Pepiol. 1993. Crecimiento de *Ruditapes philipinarum* en la bahia dels Alfacs. In: *Actas del IV Congreso Nacional de Acuicultura* (September 21-24, 1993. Illa de Arousa, Vilanova de Arousa, Pontevedra, Spain). A. Cerviño, A. Landín, A. de Coo, A. Guerra and M. Torre (eds.): 407-412. Consellería de Pesca, Marisqueo e Acuicultura, Xunta de Galicia. Santiago de Compostela (La Coruña), Spain.

Peitx, J. A., 1986. Cultiu de mol.luscs. In: *L'aqüicultura marina a la circumscripció de Barcelona* (Estudis i Monografies). R. Flos, F. Castelló, M. Palau, J. A. Peitx, F. Sardà, F. and L. Tort (eds.): 69-84. Diputació de Barcelona. Barcelona, Spain

Peña, J. B. and J. Canales. 1993. Captación de semilla de pectínidos en colectores filamentosos fondeados en la costa de Castellón. In: *Actas del IV Congreso Nacional de Acuicultura* (September 21-24, 1993. Illa de Arousa, Vilanova de Arousa, Pontevedra, Spain). A. Cerviño, A. Landín, A. de Coo, A. Guerra and M. Torre (eds.): 365-370. Consellería de Pesca, Marisqueo e Acuicultura, Xunta de Galicia. Santiago de Compostela (La Coruña), Spain.

Peña, J. B., J. Canales, J. M. Adsuara and M. A. Sos. 1996. Study of seasonal settlements of five scallop species in

the western Mediterranean. *Aquaculture International* 4: 253-261.

Peña, J. B., J. Canales and C. Ríos. 1995. Crecimiento comparativo de *Pecten jacobaeus* (L.) en cuatro sistemas de cultivo suspendido. In: *Actas del V Congreso Nacional de Acuicultura* (May 10-13, 1995. Sant Carles de la Ràpita, Tarragona, Spain). F. Castelló i Orvay and A. Calderer i Rey (eds.): 300-305. Publicacions de la Universitat de Barcelona. Barcelona, Spain.

Peña, J. B., J. Canales, C. Rodríguez-Babío and S. Mestre. 1994. Captación de moluscos y otros organismos mediante colectores filamentosos en la costa de Castellón durante 1991. *Cuadernos Investigación Biológica* 18: 211-223.

Peña, J. B., S. Mestre and A. Farías. 1995. Pectinid settlement on artificial collectors in Castellon, East Spain, in 1990. *Actes de Colloques Ifremer* 17: 111-114.

Ramón, M. 1993. *Estudio de las poblaciones de* Chamelea gallina *L. y* Donax trunculus *L. (Mollusca: Bivalvia) en el golfo de Valencia (Mediterráneo occidental).* Ph.D. Thesis. Universidad de Barcelona. Barcelona, Spain: 413 pp.

Ramón, M and P. Arté. 1987. Crecimiento y mortalidad de la ostra plana (*Ostrea edulis* L.) en la bahía del Fangar (delta del Ebro). *Cuadernos Marisqueros Publicaciones Técnicas* 12: 419-424.

Ramón, M., M. Fernández and E. Galimany. 2003. Desarrollo del cultivo del mejillón (*Mytilus galloprovincialis*) en la bahía del Fangar (delta del Ebro) a partir de semilla captada en zonas distintas. In: *IX Congreso Nacional de Acuicultura (Cádiz, mayo 2003). La acuicultura como actividad económica en las zonas costeras: Libro de Resúmenes* (May 12-16, 2003. Cadiz, Spain): 257-258. Consejería de Agricultura y Pesca, Junta de Andalucía. Sevilla, Spain.

Ramón, M., M. Fernández and E. Galimany, 2005a. Fittness differences in the mussel *Mytilus galloprovincialis* cultivated in Fangar Bay (Ebro Delta, NE Spain). In: *Abstracts book of the 8th International Conference on Fish Restoration* (October 2-5, 2005. Brest, France). J. Moal, P. Soudant and A. Voley (eds.): p. 66. Ifremer and Université de Bretagne Occidentale. Brest, Francia.

Ramón, M., M. Fernández and E. Galimany. 2005b. Mussel (*Mytilus galloprovincialis*) culture in the Ebro delta bays (NE Spain). In: *Abstracts book of the IV International Congress of the European Malacological Societies* (October 10-14, 2005. Nápoles, Italy): p. 31. Società Italiana di Malacologia. Naples, Italy.

Ramón, M and R. Flos. 2001. First trials to cultivate the muricid gastropod *Bolinus brandaris. European Aquaculture Society Special Publication* 29: 219-220.

Riera, V. 1990. Crecimiento e índices de condición en ostra plana cultivada en el delta del Ebro. In: *Actas del III Congreso Nacional de Acuicultura* (September 24-27, 1990. Santiago de Compostela, A Coruña, Spain). A. Landín and A. Cerviño (eds.): 497-502. Consellería de Pesca, Marisqueo e Acuicultura, Xunta de Galicia. Santiago de Compostela (La Coruña), Spain.

Riera, V., M. Bigas, M. Santmartí and M. Durfort. 1995a. Prevalencia del protozoo parásito *Marteilia refringens* en las poblaciones de ostra plana del Maresme. In: *Actas del V Congreso Nacional de Acuicultura* (May 10-13, 1995. Sant Carles de la Ràpita, Tarragona, Spain). F. Castelló i Orvay and A. Calderer i Rey (eds.): 242-247. Publicacions de la Universitat de Barcelona. Barcelona, Spain.

Riera, V., M. Monllaó, J. Riera and C. López. 1995b. Primeras experiencias de captación de semilla de Pectínidos en el litoral del Maresme en los años 1993-1994. In: *Actas del V Congreso Nacional de Acuicultura* (May 10-13, 1995. Sant Carles de la Ràpita, Tarragona, Spain). F. Castelló i Orvay and A. Calderer i Rey (eds.): 312-317. Publicacions de la Universitat de Barcelona. Barcelona, Spain.

Riera, V., M. Santmartí and M. Durfort. 1993. Presencia de *Marteilia refringens* en los cultivos de moluscos bivalvos del litoral catalán. In: *Actas del IV Congreso Nacional de Acuicultura* (September 21-24, 1993. Illa de Arousa, Vilanova de Arousa, Pontevedra, Spain). A. Cerviño, A. Landín, A. de Coo, A. Guerra and M. Torre (eds.): 539-544. Consellería de Pesca, Marisqueo e Acuicultura, Xunta de Galicia. Santiago de Compostela (La Coruña), Spain.

Rosique, M. J., V. Riera, A. Guerra and B. Garcia Garcia, 1993. Crecimiento y mortalidad de la semilla de ostra plana del mar Menor (Murcia) en el Atlántico (Rías de Arosa y Ortigueira) y Mediterráneo (delta del Ebro y Murcia). In: *Actas del IV Congreso Nacional de Acuicultura* (September 21-24, 1993. Illa de Arousa, Vilanova de Arousa, Pontevedra, Spain). A. Cerviño, A. Landín, A. de Coo, A. Guerra and M. Torre (eds.): 353-358. Consellería de Pesca, Marisqueo e Acuicultura, Xunta de Galicia. Santiago de Compostela (La Coruña), Spain.

Santmartí, M., J. García Valero, J. Montes, A. Pech and M. Durfort. 1995. Seguimiento del protozoo *Perkinsus sp.* en las poblaciones de *Ruditapes decussatus* y *Ruditapes philipinarum* del delta del Ebro. In: *Actas del V Congreso Nacional de Acuicultura* (May 10-13, 1995. Sant Carles de la Ràpita, Tarragona, Spain). F. Castelló i Orvay and A. Calderer i Rey (eds.): 260-265. Publicacions de la Universitat de Barcelona. Barcelona, Spain.

Stril, J. M., J. Rocamora and J. Cano. 1992. Determination de la Periode de Captage de Naissain d'Huitre Plate (*Ostrea edulis*, L.) en Mer Menor (Murcia, S.E. de l'Espagne). In: *Libro de resúmenes de la conferencia internacional Bordeaux Aquaculture 92* (March 25-27, 1992. Burdeos, France). G. Barnabé and P. Kestemont (eds.): 18-19. France.

Valencia, J. M., A. M. Grau and A. Grau. 1997. Crecimiento de semilla de escupiña, *Venus verrucosa* (L.) en parques de cultivo. In: *Actas VI Congreso Nacional de Acuicultura* (July 9-11, 1997. Cartagena, Murcia, Spain). J. de Costa, E. Abellán, B. García, A. Ortega and S. Zamora (eds.): 269-272. Ministerio de Agricultura, Pesca y Alimentación. Madrid.

Valencia, J. M. and E. Massutí, 2004. Comunitat dels fons d'arenes fines de la platja de Palma (Mallorca, Illes Balears). *Bolletí de la Societat d'Història Natural de les Balears* 47: 31-35.

Valencia, J. M., E. Massutí and O. Navarro, 2004. Deu anys de pesca de la rosellona. In: *IV Jornades de Medi Ambient de les Illes Balears* (December 1-3, 2004. Palma de Mallorca, Spain): p. 204. Societat d'Història Natural de les Illes Balears. Majorca, Spain.

Tirado, C., J. C. Macías, R. M. Villarías, J. M. Gaiteiro, D. Gómez, M. J. Martín, J. L. Rueda, C. Álamo, M. Manchado y C. Infante. 2005. Conclusiones derivadas del estudio sobre el potencial del cultivo de mejillón *Mytilus galloprovincialis* Lamarck, 1819 en Andalucía. In: *X Congreso nacional de acuicultura: La acuicultura, fuente de pescado de calidad para el futuro* (17-21 de octubre, 2005. Gandía, Valencia, España). C. Mosquera de Arancibia, I. Arnal Atarés, M. Jover Cerdá y F. de la Gándara (eds.). *Boletín. Instituto Español de Oceanografía* 21 (1-4): 455-464.