# II.5. BIVALVE AND GASTROPOD MOLLUSCS OF COMMERCIAL INTEREST FOR HUMAN CONSUMPTION IN THE HELLENIC SEAS

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## HISTORICAL DATA AND PRESENT STATE

Gastropods and Bivalves consist of two of the older and more evolved classes in the phylum Mollusca. Aristotle (384-322 BC) in his 'Histories about animals' and 'Genesis of animals' has included gastropods and bivalves in the animals bearing 'shell' and termed 'shell skinned animals'. Aristotle was also the first who provided information on the morphology, reproduction and life-cycle characteristics for few mainly edible gastropod and bivalve species. Plenius (23-79 BC) was the first to introduce the term 'molia' (soft body) for these animals out of which the term Mollusca is derived. Plenius has also provided information for certain gastropod and bivalve species which were used by the ancient Romans either for food or for making jewelry.

A review of the relevant literature reveals that more than 1 100 gastropod and bivalve species have been recorded so far from the Hellenic Seas (KOUTSOUBAS, 1992; ZENETOS, 1996; KOUTSOUBAS *et al*., 1997, 2000; KOUTSOUBAS, 2005; DELAMOTTE & VARDALA-THEODOROU, 2001; ZENETOS *et al*., 2005). Twenty-one of these species (Table 1) have a commercial interest particularly in fisheries and aquaculture since they are collected and/or cultivated for human consumption. Fisheries of these species is regulated by the Ministry of Agriculture (General Directorate of Fisheries) and supported by the relative legislation (Presidential Degree 86/98 as it has been recently reformed 227/03). The minimum size allowed for fisheries and the closed fisheries period for selected species, according to the Presidential

**Table 1.** Molluscan species legally exploited covered by PD 86/98, PD 227/03 & EU Regulation 1967/2006.

| Scientific name | Common Hellenic / English Names |
|---|---|
| **BIVALVIA** | |
| *Arca noae* | Kalognomi/Noah's ark |
| *Barbatia barbata* | Agriomydo/Hairy ark |
| *Modiolus barbatus* | Chavaro/Bearded horse mussel |
| *Mytilus galloprovincialis* | Mydi/Mediterranean mussel |
| *Cerastoderma glaucum* | Pourlida/Lagoon or olive green cockle |
| *Donax trunculus* | Telina, Fasolaki/Truncate Donax |
| *Spisula subtruncata* | Achivadaki/Subtruncate surf clam |
| *Chlamys glabra* | Gialistero chteni/Smooth scallop |
| *Aequipecten opercularis* | Chteni/Queen scallop |
| *Pecten jacobaeus* | Megalo chteni /Jacomb scallop |
| *Ostrea edulis* | Stridi/European flat oyster |
| *Psammobia (=Gari) depressa* | Esperos/Depressed sunset clam |
| *Callista chione* | Gyalisteri/Smooth callista |
| *Chamelea gallina* | Pseftokydono/ Stripped venus |
| *Dosinia exoleta* | Strogili achivada/Mature dosinia |
| *Ruditapes (=Tapes) decussatus* | Achivada/Grooved carpet shell |
| *Venus verrucosa* | Kydoni/Warty venus |
| **GASTROPODA** | |
| *Haliotis tuberculata lamellosa* | Afti tis thalassas/Lamellated haliotis |
| *Hexaplex trunculus* | Strobos/Banded murex |
| *Bolinus brandaris* | Agathotos Strobos/Spined murex |
| *Stramonita (=Thais) haemastoma* | Porphyra/Red-mouth purpura |

Note: The baits are not included in the table

**Table 2.** Species of minor commercial interest including species illegally exploited.

| Scientific name | Common Hellenic/ English Names |
|---|---|
| **BIVALVIA** | |
| *Lithophaga lithophaga* | Petrosolinas/European date mussel |
| *Pteria hirundo* | Fterostrido/European wing oyster |
| *Pinctada radiata* | Margaritoforo stride/Rayed pearl oyster |
| *Donacilla cornea* | Ammokochylo |
| *Chlamys varia* | Kalogria/Variegated scallop |
| *Chlamys multistriata* | Grammoto chteni/Little bay scallop |
| *Spondylus gaederopus* | Gaidouropodaro/European thorny oyster |
| *Pholas dactylus* | Daktilo, Folada/Common paddock |
| *Solecurtus strigilatus* | Samari/ Sandwich |
| *Pinna nobilis* | Pinna/Fun mussel |
| *Crassostrea gigas* | Stridi tou Eirinikou/Pacific oyster |
| **GASTROPODA** | |
| *Patella caerulea* | Petalida/Rayed Mediterranean limpet |
| *Patella ferruginea* | Sideropetalida/Ferreous limpet |
| *Patella nigra* | Mavri petalida/Black limpet |
| *Patella lusitanica* | Stiktopetalida/Ristic limpet |
| *Patella ulyssiponensis* | Agriopetalida/Rough limpet |
| *Monodonta articulata* | Arthrotos trochos/Articulate monodont |
| *Monodonta turbinata* | Trochos fraoula/Turbinate monodont |
| *Bolma rugosa* | Mati tis Panagias, Strovilos |
| *Cerithium alucastrum* | Skaltsini tou Aigeou/Spicate cerithe |
| *Cerithium vulgatum* | Skaltsini/Mediterranean cerithe |
| *Strombus decorus* | Konos tis Persias |
| *Luria lurida* | Gourounitsa/Cowry |
| *Argobuccinum olearium* | Agkathotritonas/Oil-vessel triton |
| *Charonia tritonis variegata* | Polychromos tritonas/Variegated triton |
| *Charonia lampas* | Tritonas/Knobed triton |
| *Tonna galea* | Bourou |
| *Mitra zonata* | Mitra/Zoned miter |
| *Conus mediterraneus* | Konos |

Degree 227/03 and EU Regulation 1967/2006, is provided in Chapter III.7 (Management and legislation in the Hellenic fisheries). Additional species which have been either traditionally harvested as food resources, collected for use as fish baits (PD 109/02) or intentionally imported for culture during the last decades, although not mentioned in PD 227/03, are still exploited in certain coastal areas of Hellas. These are listed in Table 2.

## SHELL PRODUCTION AND EXPLOITATION

The species of major commercial value in the Hellenic Seas (more than 90% of the total production) are the gastropod *Hexaplex trunculus* and the bivalves *Modiolus barbatus*, *Mytilus galloprovincialis* (both collected from natural banks and aquaculture units), *Arca noae*, *Cerastoderma glaucum*, *Donax trunculus*, *Chlamys glabra*, *Ostrea edulis* (most of the natural populations of this species located in the Thermaikos Gulf collapsed almost ten years ago due to overfishing and parasite infection), *Callista chione*, *Ruditapes decussatus* and *Venus verrucosa* (CHINTIROGLOU *et al*., 2005).

Common fishing gears for the collection of the commercial molluscs in the Hellenic Seas are various types of dredges (mainly used for the collection of the species *Modiolus barbatus, Ostrea edulis, Chlamys glabra*) and hookah diving "nargiles" (mainly used for the collection of *Arca noae* and *Venus verrucosa*).

Although molluscs are harvested over all Hellenic coasts, most of the production is derived from three major areas i.e. the Thermaikos, Argo-Sa-

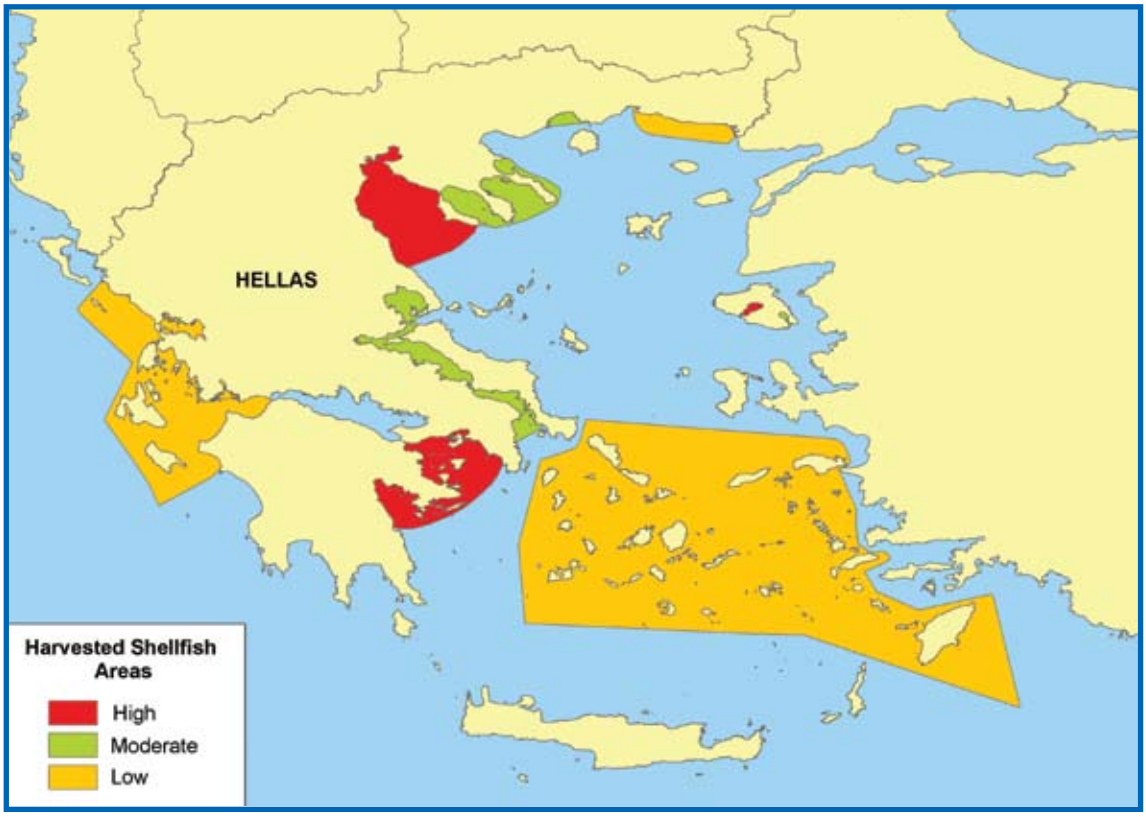


**Figure 1:** Map of the Hellenic Seas indicating areas with high, moderate and low production of shellfish (Source: HCMR based on NSSG data).

ronikos and Kalloni Gulfs which could be classified as "highly" exploited mollusc areas (Figure 1). The Chalkidiki Peninsula along with the Gulfs of Kavala, Evvoikos, Maliakos and Pagasitikos could be characterised as "moderately" exploited mollusc areas. Finally the Kyklades Plateau, Dodekanisos Islands and the Gulfs of Patras and Amvrakikos in the Ionian Sea could be considered as 'low' exploited mollusc areas (Figure 1).

Surprisingly and despite their commercial value, scientific information on life cycle characteristics (e.g. growth, reproduction, mortality rate and stock size) concerning the aforementioned species in the Hellenic Seas is rather scarce and is limited to very few species (e.g. *Callista chione, Cerastoderma glaucum, Venus verrucosa*). The production of each commercial species collected from Hellenic waters is difficult to estimate since in the available official data on the commercial species, as published by the National Statistical Service and ETANAL (a Company associated with the Hellenic Ministry of Agriculture and recording production from 12 different Fisheries' Auctions located in various areas of the Hellenic Seas) only a few are specifically reported (e.g. *Mytilus galloprovinciallis, Ostrea edulis, Callista chione* and *Venus verrucosa*), others are reported only under a generic name (e.g. *Chlamys* spp. in most cases is only *Chlamys glabra*), while the rest are usually reported as 'other shells'. Another major problem is the fact that for certain species, such as *Mytilus galloprovincialis*, which are collected both by fishermen from the natural populations and the aquaculture units, the origin is not clarified in the records kept. Figure 2 depicts trends of estimated bivalve production for the period 1980 to 2004 according to NSSG. A similar trend was apparent in the mollusc yield over time (1964-2004) in the N Aegean Sea (KALAITZI *et al*., 2007). It is well documented that the N Aegean Sea constitutes one of the most significant areas in the eastern Mediterranean Sea for bivalve production concerning both fishing and culture activities (more than 80% of the total Hellenic shellfish production is derived from this area). Analysis of data has revealed that the shellfish total annual yield fluctuated (although in low levels) up to the early 1990s when a great increase was observed due to the increasing demands for export to the European market. The high quantities of the shellfish production remained steady for the next years but

a sharp decreasing trend appeared from the year 1997 onwards (Figure 2).

A similar declining trend was also evident during the last fifteen years when fishing vessels with a main license in shell fishing with dredges are condidered (Table 2). Although many other vessels may engage in shell fishing as a secondary or non-targeted activity, the declining trend in the number of vessels with a shell-fishing main license is indicative of the overall trend in shell fishing in Hellenic waters and is in accordance with the declining trend in production. Most shell fishing vessels operate in Thermaikos Gulf and Chalkidiki and markedly fewer vessels operate in Argolikos, Saronikos, and Evvoikos Gulfs, and in other areas (Table 3).

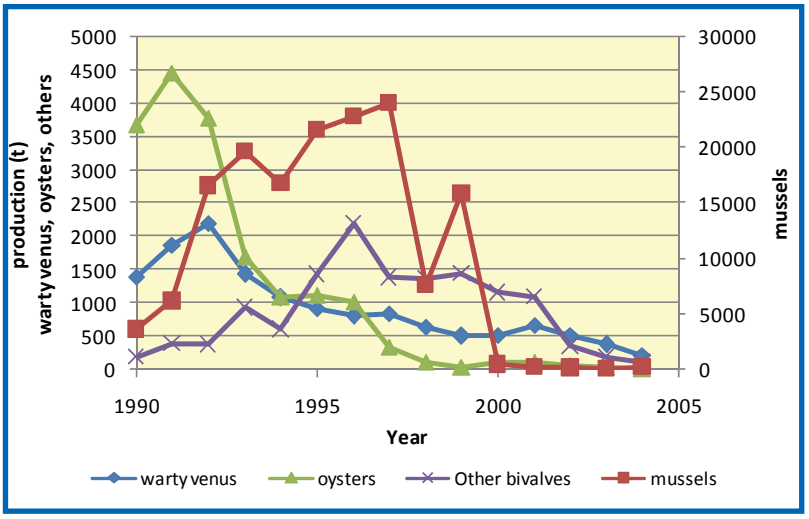


**Figure 2**: Time series of estimated bivalve production according to NSSG (extrapolated data based on sampling shell fishing vessels > 20HP). Source: IMAS-Fish, 2007.

## SPECIES OF MAJOR COMMERCIAL INTEREST

The available existing scientific information along with data on the production for the species with major commercial value in the Hellenic Seas is presented below in detail.

- ***Hexaplex* (= *Murex* /*Phyllonotus*) *trunculus* (Linnaeus, 1758)**

*Hexaplex trunculus* (Figure 3) is a very common gastropod species thriving in every type of substrate (sandy, muddy, hard bottoms and seagrass beds) and has a wide distribution in the eastern Atlantic Ocean and the Mediterranean Sea (KOUTSOUBAS, 1992; DELAMOTTE & VARDALA-THEODOROU, 2001). It is a carnivore and a scavenger feeding on bivalves, gastropods, barnacles, sea urchins, dead fish, etc. *Hexaplex trunculus* along with *Bolinus brandaris* and *Stramonita* (= *Thais*) *haemastoma* were heavily exploited during ancient and Roman times for the production of a deep purple dye (imperial purple) that was used to decorate royal garments; the dye was produced from the mucus of the hypobranchial gland of the three species. During spring and early summer, *H. trunculus* forms numerous aggregations that may reach hundreds of individuals and reproduces massively producing large egg masses that have the appearance of sponges (Figure 3). It is considered as an excellent sea food. However it is not collected in large quantities (less that 5ts/year) by divers or as a by-catch

**Table 3**. Distribution of vessels with a main license in shell fishing with dredges in NSSG areas during 1991–2006 Source: IMAS-Fish, 2007.

| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kyparisiakos and Mesiniakos Gulfs | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Argolikos and Saronikos Gulfs | 46 | 40 | 34 | 33 | 33 | 31 | 28 | 27 | 22 | 21 | 21 | 20 | 17 | 17 | 17 | 17 |
| Korinthiakos Gulf | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Evvoikos Gulf | 15 | 16 | 18 | 18 | 17 | 16 | 16 | 16 | 16 | 15 | 17 | 17 | 17 | 17 | 18 | 17 |
| Pagasitikos Gulf | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 |
| Thermaikos Gulf and Chalkidiki | 89 | 87 | 85 | 82 | 75 | 73 | 72 | 72 | 59 | 56 | 56 | 53 | 51 | 48 | 40 | 38 |
| Strymonikos, Kavala, Thassos, Thracian Sea | 14 | 14 | 11 | 11 | 11 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 9 | 9 | 8 | 7 |
| Islands of Lesvos, Chios, Samos and Ikaria | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Dodekanissos | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Kyklades | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Kriti | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| TOTAL | 175 | 168 | 157 | 152 | 144 | 138 | 134 | 133 | 115 | 110 | 112 | 106 | 100 | 97 | 89 | 85 |

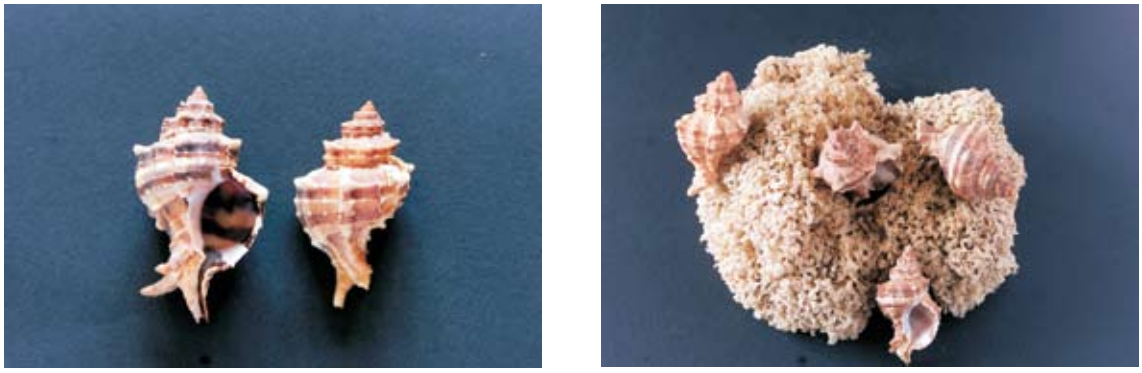

**Figure 3:** Shells of *Hexaplex trunculus* from the Hellenic Seas. In the right photo egg masses produced by the species and found on the coasts after strong storms. (Photos: D. KOUTSOUBAS).

from the bottom trawls. It is infrequently found in the fish markets in the Dodekanisos islands, the Evvoikos Gulf, the Thermaikos and Kavala Gulfs as well as in the islands of the NE Aegean.

- ***Arca noae* Linnaeus, 1758**

*Arca noae* (Figure 4) is an epifaunal bivalve of hard substratum whose distribution ranges from the eastern Atlantic Ocean, the Mediterranean and Black Seas to the West Indies. It lives attached with a solid byssus on rocks and shells occurring either solitarily or in clumps of conspecifics with the similarly byssally attached mytilid *Modiolus barbatus* at depths ranging from approximately low tide level to deeper than 100m. In some locations the species is commercially important as a seafood resource and natural populations are harvested by local fishermen and divers. On average it has a maximum length of 7cm, lives for as long as 16 years and may reach population densities of >12 ind $m^{-2}$.

It is very common in the Hellenic Seas and is mainly collected in the Evvoikos Gulf, the islands of the NE Aegean (especially Lesvos and Limnos), the continental shelf of the N Aegean (mainly the Thermaikos, Chalkidiki (Ierissos, Sithonia), Strymonikos and Kavala Gulfs) and the Ionian Sea. Its mean annual production over the last decade reached 10ts. *A. noae* is a major target species (mean annual production over 6ts for the fishing periods from 2000 to 2004) for the local fishermen in the Island of Lesvos (and in particular the Gulfs of Kalloni and Geras) where it is collected by divers (PASPATIS & MARAGKOUDAKI, 2005).

- ***Modiolus barbatus* (Linnaeus, 1758)**

*Modiolus barbatus* is a commercially important mussel, distributed in the eastern Atlantic from the British Isles south to Mauritania, including the Mediterranean Sea and lives attached to rocky

**Figure 4:** External and internal views of the bivalve shell of *Arca noae*. (Photo: D. KOUTSOUBAS)

substrata by strong byssus threads from the lower midlittoral down to depths of approximately 110 m. It grows up to 6cm long, although individuals are usually smaller. The shell (Figure 5) has an elongated oval shape and the outer surface has a yellowish-white, light yellow or reddish-brown colour. Over the posterior half of the shell the periostracum bears long, flat bristles, each with a distinctly serrated edge, which is the reason for naming the species 'bearded horse mussel'. *M. barbatus* similarly to *A. noae* is a major target species (mean annual production over 200t for the fishing periods from 2000 to 2004) for the local fishermen on the Island of Lesvos (and in particular the Gulf of Kalloni), where it is collected by divers (PASPATIS & MARAGKOUDAKI, 2005). However, the species is not consumed locally and all the production is exported either to the northern parts of Hellas (mainly the markets of Thessaloniki and Kavala)

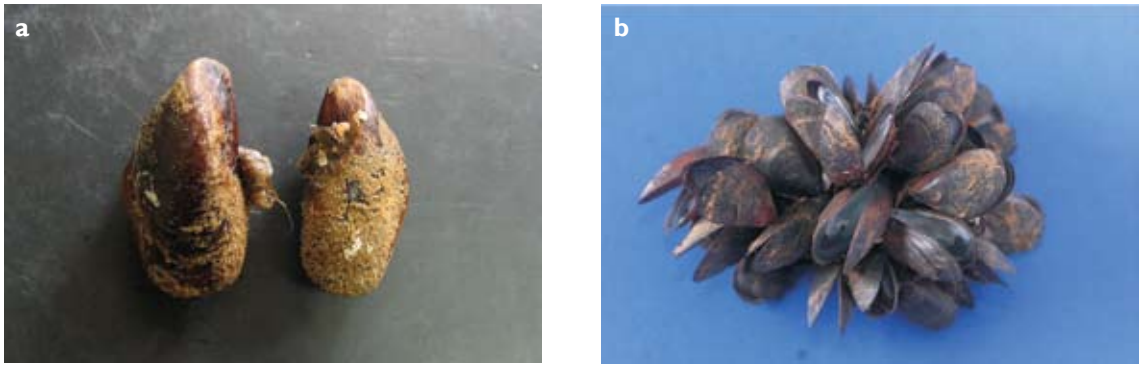


**Figure 5:** a) External view of the Bearded horse mussel *Modiolus barbatus* (Photo S. Galinou-Mitsoudi); b) Part of a mussel bed of *Mytillus galloprovincialis*. (Photo: D. KOUTSOUBAS).

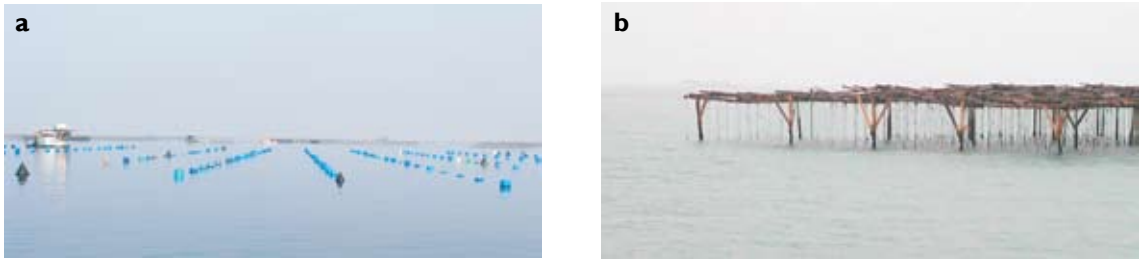


**Figure 6:** Mussel *Mytillus galloprovincialis* culture techniques (a) buoyed longline) and (b) rank-hanging in the Thermaikos Gulf. (Photos: S. GALINOU-MITSOUDI).

or abroad (Italy). The species is also exploited in the N Aegean (mainly the Thermaikos Gulf) where a mean annual production of 200t has been reported (GALINOU-MITSOUDI & PETRIDIS, 2000). Studies of the population in this area have revealed that the mean annual growth is 1.11 cm with a range of 0.3 - 1.9cm. The *M. barbatus* spatial distribution follows the contagious type including all ages which could be represented in each aggregation. This fact results in the discarding of undersized mussels (<5 cm) by the fishery which exceeds 90 % (GALINOU-MITSOUDI & SINIS, 2000). However, since 2002 fishing of *M. barbatus* is forbidden in the Thessaloniki Gulf due to the presence of high concentrations of heavy metals (Cd) detected in the edible part of the organism. This prohibition may lead to the recovery of the natural populations.

- ***Mytilus galloprovincialis* Lamarck, 1819**

*Mytillus galloprovincialis* is a Mediterranean species, whose exact range of distribution is not well defined due to the confusion with the very similar congeneric *M. edulis*. It is an intertidal species extending down to 40m depth and it may be found on all European coasts with hard substrata. It lives attached by byssus threads to rocks, piers and ropes within sheltered embayments, harbours, estuaries and on open rocky shores, while it may also form dense mussel beds directly on sandy-muddy bottoms in favourable sites (Figure 5b). The mean density in the most crowded beds may reach 24 000 mussels/m² (FAO, 2007). Intertidal specimens often remain small, rarely exceeding 6cm, while deep-water individuals often attain a length of 9cm and occasionally may reach even 15cm. Hellas along with Italy and Spain are the Mediterranean countries with the largest catches of *M. galloprovincialis* (FAO, 2007). Apart from natural populations, the species is also intensively cultured, mainly in coastal waters from the NE Atlantic (Galicia - NW Spain) to the northern shores of the Mediterranean Sea (FAO, 2007).

With regard to mussel culture, there are two systems employed (CONIDES & KEVREKIDIS, 2005); the traditional rack-hanging system installed in relatively shallow areas (-5m) and the more modern 'buoyed long-line' deployed offshore (Figure 6). Both use inland facilities. Mussels in both methods are stocked in special mesh netting, called 'socks', hanging from a wood or galvanized tube in the rack-hanging system or from the main horizontal rope in the long-line system. Mussel farming is based on natural settlement. Spat is commonly

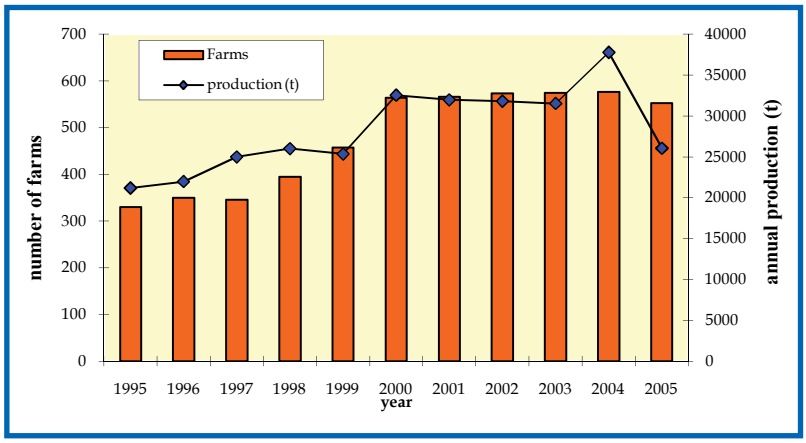


**Figure 7:** Trend in mussel farms and respective production in the Hellenic Seas over the last decade.

**Figure 8:** External and internal view of the shells of the Lagoon cockle *Cerastoderma glaucum*. (Photo: D. KOUTSOUBAS).

collected from vertical nets and ropes used as 'collectors' hanging in the water column during the two main reproductive peaks of the year (autumn, spring).

Mussel farming is one of the most dynamic sectors of Hellenic aquaculture and more than 550 mussel farms existed in 2005 (Figure 7) with the majority of those deployed in gulfs and bays of northern Hellas and especially the Thermaikos Gulf (88% of the farms are installed in this area). In this area, the presence of high concentrations of nutrients often leads to eutrophication, especially in the northwestern part of the gulf, where mussel farming is concentrated, and a significant growth of mussels can be achieved in a relative short period of time [in a period of 7-8 months from spat collection, mussels reach commercial harvested size (5-6 cm in shell length)]. Mussel production has increased over the period 1995-2004 and came to approximately 37 000 t/year (Figure 7).

However, since 2001 harmful algal blooms and biotoxins affect the mussel farmers in this area. Furthermore, mussels produced are of a poor quality, with a tendency towards deterioration. This phenomenon has been attributed to the recent lower food availability in relation to the past, which subsequently leads to undernourishment of mussels (as evidenced by the low fullness of their stomachs - GALINOU-MITSOUDI unpubl. data).

- ***Cerastoderma glaucum* (Poiret, 1879)**

The lagoon cockle *Cerastoderma glaucum* is distributed in the Mediterranean Sea and the eastern Atlantic where it inhabits the sandy and muddy bottoms of the upper sublittoral zone in coastal areas and particularly various types of transitional water ecosystems such as estuaries, lagoons, saltmarshes and saltworks (LEONTARAKIS *et al.*, 2007). *C. glaucum* (Figure 8) is able to tolerate a wide salinity (5-38‰) and temperature range (0-25°C) and therefore, can be present in numerous populations (e.g. >368 cockles/m²; LEONTARAKIS *et al.*, 2007). It is a characteristic species in many transitional ecosystems in the Hellenic Seas such as the Amvrakikos Gulf, the Gialova, Messolonghi, Nestos and Vistonis lagoons as well as the Evros Delta and the Maliakos Gulf (ZENETOS, 1996; KOUTSOUBAS *et al.*, 2000; NICOLAIDOU *et al.*, 2005). Studies from different Hellenic lagoons (GONTIKAKI *et al.*, 2003; LEONTARAKIS *et al.*, 2005; 2007) showed that each local lagoon cockle population has a characteristic strategy governing its physiological functions, affected by the local environmental conditions. It is collected by local fishermen in certain areas (e.g. Nestos and Vistonis lagoons – approximate production of 5 t) over a certain period of the year (such as before Easter) for human consumption.

- ***Donax trunculus* (Linnaeus, 1758)**

*Donax trunculus* (Figure 9) is distributed in the Mediterranean Sea and the eastern Atlantic where it inhabits the sandy bottoms of the upper sublittoral zone. On the coasts of the Thracian Sea where it is mainly harvested by dredging, it reaches a length of 4.2 cm and has a mean density of 37.5 indiv./m² (PSALTOPOULOU *et al.*, 2001). However, a decline in the annual production has been recently observed (Figure 9b), which has been attributed to fishing pressure (PSALTOPOULOU, 1999). The bivalve is not consumed in Hellas, therefore, the whole production is exported to Italy.

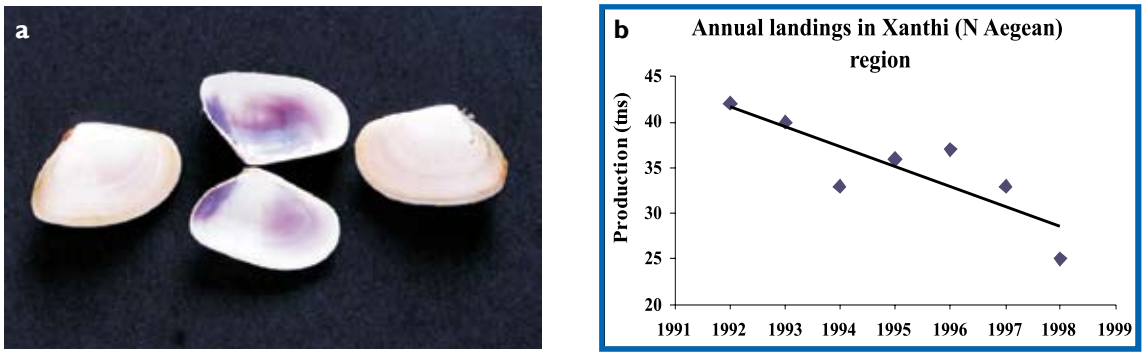


**Figure 9:** External and internal view of the shells of the Wedge shell *Donax trunculus* (left); Fisheries production of the *Donax trunculus* from the coasts of Thracian Sea (Xanthi) (PSALTOPOULOU, 1999).

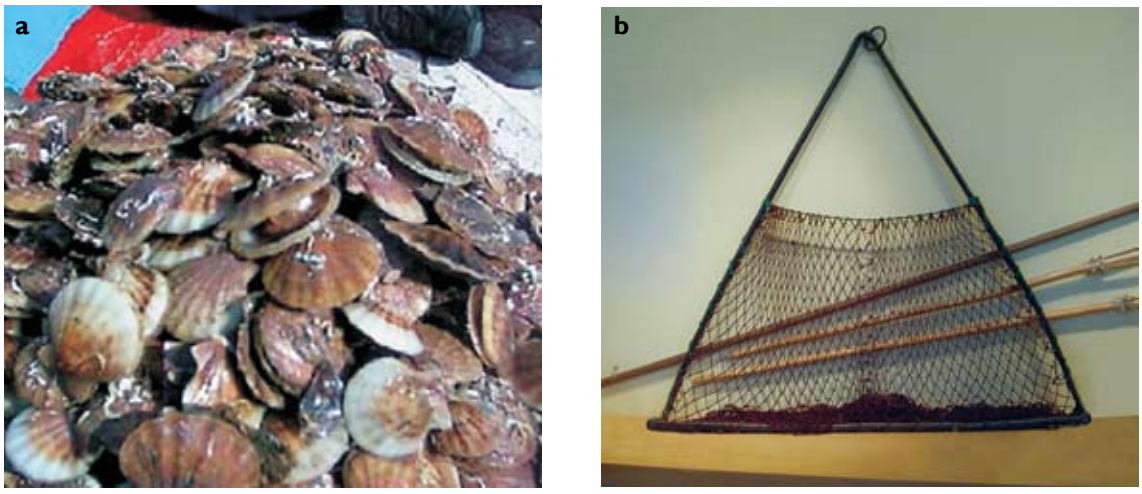


**Figure 10:** a) Harvest of the Smooth scallop *Chlamys glabra* from the Kalloni Gulf (Lesvos isl, NE Aegean) b) traditional dredge gear "argalios"(Photos: D. KOUTSOUBAS).

- ***Chlamys (=Flexopecten) glabra* (Linnaeus, 1758)**

*Chlamys glabra* is a Mediterranean species living in detritic sand and biogenic sediments down to 40m depth. Shells living in the shallower waters often remain small, rarely exceeding 6cm, while in deeper waters shells may reach a length of 9 cm (KALATHAKI, 1992). In the Hellenic Seas it is mainly collected in the continental shelf of the N Aegean (mainly the Thermaikos Gulf), and the island of Lesvos in the NE Aegean (Figure 10). It is also found in the Patraikos, Korinthiakos and Evoikos Gulfs (ZENETOS, 1996)

*Chlamys glabra* was a major target species (mean annual production over 20t between mid 1970s and late 1980s, 5 t from the late 1980s to 1990s) in the fishery of the Island of Lesvos (and in particular the Gulf of Kalloni being, along with sardines, the two most popular biological resources of this area) and it was collected either by a traditional dredge ('argalios' or 'lagamna': Figure 10) and/or by divers (PASPATIS & MARAGKOUDAKI, 2005). Unfortunately, smooth scallop stocks in the Gulf of Kalloni seem to have collapsed recently (from 2003 onwards) due to intensive harvesting and the lack of any rational management. Over the last three years most of the production of this bivalve (less than 10 t/year) is mainly derived from the thriving populations in the Thermaikos Gulf. However, the scallops fishery status in Thermaikos gulf since 2003 is similar with *M. barbatus* due to heavy metals in the scallops flesh.

- ***Pecten jacobaeus* (Linnaeus, 1758)**

*Pecten jacobaeus* (Figure 11) is endemic to the Mediterranean Sea. It is one of the largest Mediterranean bivalves, with a length that may reach 15 cm. It lives on sandy and muddy bottoms of the sublittoral zone and can actively swim to escape from predators by means of a form of jet propul-

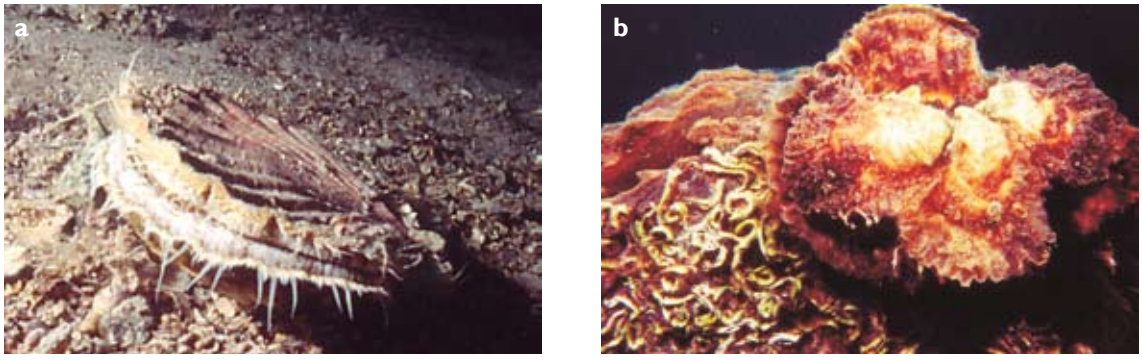


**Figure 11:** *Pecten jacobaeus* (a); *Ostrea edulis (b).* (Photos: S. KATSANEVAKIS).

sion. *P. jacobaeus* is edible but occurs in exploitable quantities only in the northern Adriatic Sea. In the Hellenic Seas, *P. jacobaeus* is widespread from the Ionian Sea and Sea of Kythira to the Aegean (ZENETOS, 1996), but its density is generally too low to support a cost-effective fishery. It is usually caught as a by catch by fishing trawls and dredges or collected by divers. The most dense scallop population reported in Hellenic waters is the one in the marine lake Vouliagmeni (Korinthiakos Gulf), with maximum density exceeding 50 scallops per 1 000 $m^2$, and a total estimated abundance exceeding 20 000 individuals (KATSANEVAKIS, 2005). However, shell fishing is prohibited in the lake, while due to its small size it could not support a substantial scallop fishery even if shell fishing was allowed.

- ***Ostrea edulis* Linnaeus, 1758**

The European flat oyster *Ostrea edulis* is the native species of oyster found throughout Europe (from Norway to Morocco, in the whole Mediterranean Basin and the Black Sea). Natural populations are also observed in eastern North America from Maine to Rhode Island, following introductions in the 1940s and 1950s (FAO, 2007). Ostrea edulis (Figure 11) has an oval or pear-shaped irregular shell with a rough, scaly surface and a distinct hooked beak, patterned with delicate foliation. The left shell is deeply concave and fixed to hard substratum, the right being flat with rougher edges and sitting inside the left acting as a lid. The flat oyster can reach large sizes (>20cm) and grow very old (>20 years).

It has been cultured for food since Roman times and used to be the basis for oyster production in many European countries. However, since the early 1970s, many flat oyster populations suffered massive mortalities due to infection by the pathogenic protozoan parasites *Marteilia refringens* and *Bonamia ostreae*. Similarly in Hellas, oyster stocks in the Thermaikos Gulf (mean annual production over 600t up to the late 1990s) collapsed (Figure 2), due to infection by *Marteilia* sp. (VIRVILIS & ANGELIDIS, 2006). Over-fishing has also been suggested as one of the major reasons for the collapse of the natural populations (GALINOU-MITSOUDI & SINIS, 2000). Recently an oyster culture unit has started on the coast of Argos (Peloponnisos, S Aegean) using the long-line cultivation system but production is directed only to the domestic market (CONIDES & KEVREKIDIS, 2005).

- ***Callista chione* Linnaeus, 1758**

*Callista chione* (Figure 12a) is a shallow-burrowing filter feeder, inhabiting the surface layers of fairly clean sandy sediments, from just offshore to a depth of about 130m. It occurs south of the Iberian Peninsula, into the Mediterranean, along the Atlantic coast of Morocco and up to the Canary Islands and the Azores. It is among the most abundant bivalve species inhabiting shallow soft-bottom Mediterranean shores (ZENETOS, 1996). Studies conducted in Hellenic waters (METAXATOS, 2004; LEONTARAKIS & RICHARDSON, 2005) have shown that *C. chione* is a slow-growing species that attains a shell height of about 6cm in 15-17 years.

*C. chione* reaches commercial size (4.5 cm) after 3-4 years. The natural mortality rate of the population in the N. Evvoikos Gulf was estimated at 0.271 $y^{-1}$. The species is gonochoristic, with multiple spawning all year round, capable of gonadal maturation after the second year of life (METAXATOS, 2004). The smooth Callista is economically important in several Mediterranean countries (Spain, Italy, Croatia and Hellas) where an extensive clam fishery is carried out by the artisanal fleet. In the western Mediterranean the most commonly used fishing method is dredging (GASPAR *et al.*, 1999),

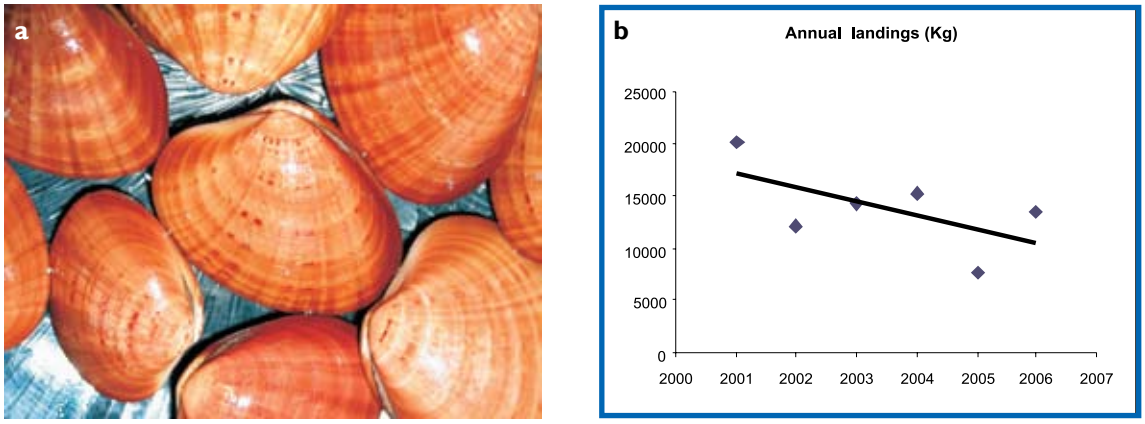


**Figure 12:** a) Individuals of the smooth clam *Callista chione* collected in the N Aegean Sea (left) (Photo: P. LEONTARAKIS); b) Fisheries' production of the Smooth clam *Callista chione* from the Hellenic Seas. Source data: ETANAL.

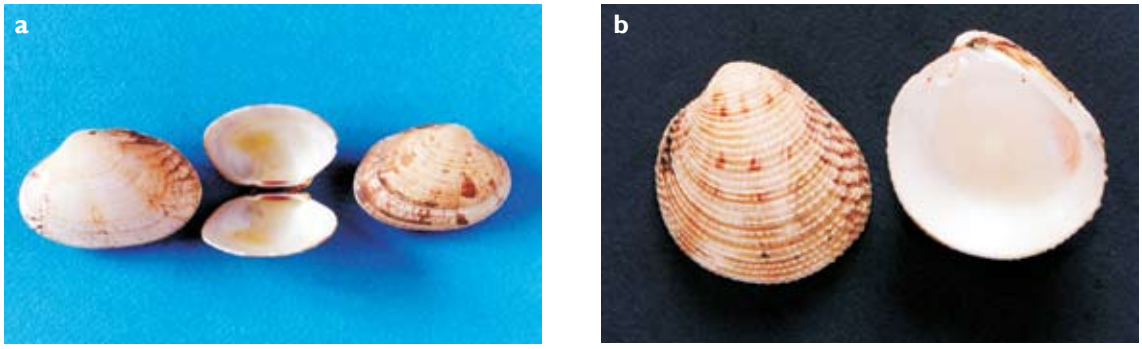


**Figure 13:** External and internal view of the shells of a) *Ruditapes decussatus* and b) *Venus verrucosa* (Photos: D. KOUTSOUBAS).

while in the coastal waters of the Aegean Sea it is mostly collected by divers (METAXATOS, 2004). Populations of *C. chione* in the Hellenic Seas are found in the Evvoikos, Saronikos and Thermaikos Gulfs as well as the Cretan Sea (DELAMOTTE & VARDALA-THEODOROU, 2001) and in the Gulf of Patras, Ionian Sea (ZENETOS, 1993). Despite the decline in the landings of *C. chione* in the fish markets as recorded by ETANAL over the last seven years (Figure 12b) the species still has a considerable production (over 10 t/year).

Studies on the population dynamics of the species in the N Evvoikos Gulf have revealed that overfishing pressure exists from divers who exploit the stocks, particularly on older and bigger clams while younger clams (<4 years old) are not selected (METAXATOS, 2004).

- ***Ruditapes (=Tapes/ Venerupis) decussatus* (Linnaeus, 1758)**

*Ruditapes decussatus* (Figure 13) is distributed in the Mediterranean Sea and the eastern Atlantic where it inhabits the sandy and muddy bottoms of the upper sublittoral zone in coastal areas and particularly various types of transitional ecosystems (e.g. estuaries, lagoons). It is collected by local fishermen in certain areas such as the Pylos and Nestos Lagoons and the Axios Delta (KOUTSOUBAS *et al.*, 2000; NICOLAIDOU *et al.*, 2005), the Evros and Vistonis Lagoons (LEONTARAKIS, unpubl. data) and the Papa Lagoon (CHRYSSANTHAKOPOULOU & KASPIRIS, 2001). In the latter lagoon *T. decussatus* reaches a size of about 5 cm in the fifth year of its life and has an approximate annual production of 10 ts (most of which is exported to Italy).

- ***Venus verrucosa* Linnaeus, 1758**

The warty venus, *Venus verrucosa* is found from Norway to Durban (South Africa) and is common in the Mediterranean on detritic sandy bottoms, sand bottoms scattered with coralline rhodoliths, gravel substrate as well as in *Posidonia oceanica* meadows, usually up to a depth of about 30 m

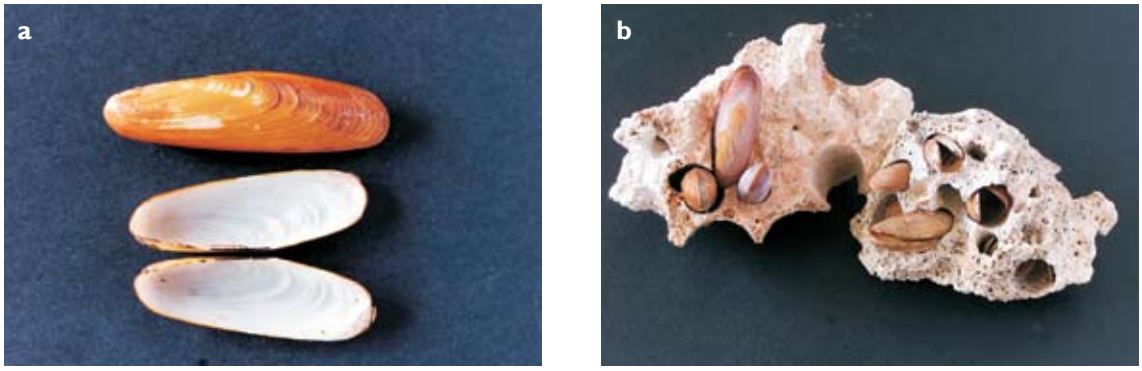


**Figure 14:** a) View of the external and internal part of the shells and b) of specimens in their natural habitat - calcified hard substrate of the European date mussel *Lithophaga lithophaga* (Photos: D. KOUTSOUBAS)

(ZENETOS, 1986). The species (Figure 13) which is very sensitive to extreme temperature and salinity variations (e.g. impact on growth, development of microbes), may attain a length of 6cm. It is fished intensively off the coasts of Normandy and Brittany and sustains commercial fisheries in some areas of the Mediterranean such as the southern Adriatic and the Aegean Sea (ARNERI *et al*., 1998).

In the Hellenic Seas it is mainly collected in the Evvoikos and Saronikos Gulfs, the islands of the NE Aegean (especially Lesvos and Limnos) and the continental shelf of the N Aegean (mainly the Thermaikos Gulf, Gulfs of Ierissos, Strymonikos and Kavala). *V. verrucosa* is a major target species (mean annual production over 15t for the fishing periods from 2000 to 2004) for the local fishermen on the Island of Lesvos (and in particular the Gulfs of Kalloni and Geras) where it is collected by divers (PASPATIS & MARAGKOUDAKI, 2005). Studies on reproductive aspects of *V. verrucosa* examined in the Thermaikos Gulf populations (GALINOU-MITSOUDI *et al*. 1997) have shown that sexes are separated, first reproduction occurring at a shell length greater than 1.9cm at the age of 1+ years. The gonads are at rest during the winter or at the beginning of gonad development during winter and spring. The maturity and release of gametes occurs during an extended period from May to November after the water temperature increase (>17.4 °C). Yields of warty venus from this part of the Hellenic Seas have stabilized at moderate quantities **(**~250 t/year) over the last years (Figure 2) while at the beginning of 1990s the annual yield was over 2 000 t.

## SPECIES OF MINOR COMMERCIAL INTEREST

Among species of minor commercial interest (Table 1), there are species characterized as endangered or threatened and protected, not only by the Hellenic legislation but also by European and International laws (Bern Convention, Protocol Barcelona Convention, EC Habitats Directive 92/43), i.e. the tritons *Charonia tritonis variegata* and *Argobuccinum olearium*, the fan mussel *Pinna nobilis* and the European date mussel *Lithophaga lithophaga*. However, all these illegally collected species are caught only in small quantities and are not sold in fish markets but only sporadically in local small restaurants. The available existing scientific information for two of these species (i.e. *L. lithophaga* and *P. nobilis*) is presented below.

- ***Lithophaga lithophaga* (Linnaeus, 1758)**

The European date mussel *Lithophaga lithophaga* (Figure 14) is endemic to the Mediterranean Sea and is an inhabitant of hard substrata (calcified) communities in the midlittoral and upper sublittoral zones (GALINOU-MITSOUDI & SINIS, 1994). The autoecology (ecology, population dynamic, biology) of *L. lithophaga* has been extensively studied in the Evvoikos Gulf (GALINOU-MITSOUDI & SINIS, 1994, 1995). The population density of this species which seems to be dependent on the substratum type (limestones), the presence of other organisms (e.g. endolithic), predation and environmental conditions is higher in the N. Evvoikos (36 indiv./dm$^3$). The age of the first reproduction is 2+ years and the reproductive activity is annual and continuous. The main reproductive period is during the summer and autumn in water temperatures > 14°C. *L. lithophaga* is a long-lived species (> 54+ years) and its growth rate is one of the slowest among bivalves. The highest growth rate is observed at the end of spring and early summer. Annual productivity of *L. lithophaga* is 1659.6 g/m$^2$. The annual turnover ratio (P/B) was 0.845 in the


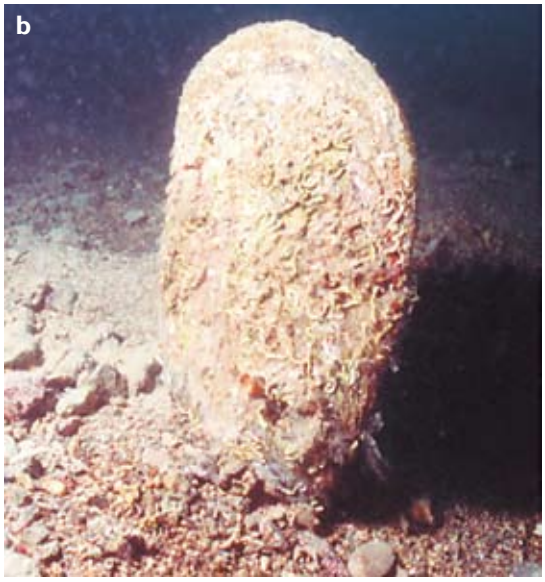


**Figure 15**: Photos of live specimens of the fan mussel *Pinna nobilis* in its natural habitats a) *Posidonia* meadows (Photo: D. Koutsoubas); b) sandy bottoms (Photo: S. KATSANEVAKIS).

Evvoikos' population and among the lowest values reported in the literature. Besides the Evvoikos Gulf, populations of the species are also found in the Ionian islands, Ipeiros coasts, Korinthiakos Gulf, Sea of Kythira, N Sporades Islands, Dodekanisos, Kriti, Lesvos isl., Maliakos, Argolikos, Chalkidiki (ZENETOS 1986; 1996; GALINOU-MITSOUDI & SINIS, 1994, 1997a; GEROVASILEIOU *et al*., 2007) and are still sporadically exploited (however, with a reduced frequency due to existing legislation) by divers as a food resource.

- ***Pinna nobilis* (Linnaeus, 1758)**

The fan mussel *Pinna nobilis* (Figure 15) is endemic to the Mediterranean Sea and occurs at depths between 0.5 and 60 m, mostly in soft-bottom areas overgrown by seagrass (mostly *Posidonia* meadows) but also in unvegetated sandy bottoms (KATSANEVAKIS 2006, 2007a). It is the largest Mediterranean bivalve and one of the largest in the world, attaining lengths up to 120 cm. *P. nobilis* is long-lived and may live over 20 years (GALINOU-MITSOUDI *et al*., 2006). Fan mussels live partially buried (usually >35 % of their length) by the anterior portion of the shell and attached by their byssus to the substratum.

Reproduction of *P. nobilis* takes place by means of external fertilization and its success depends on the proximity of other individuals spawning synchronously. When a population becomes sparse (as is the case for most fan mussel populations in the Mediterranean) failure of fertilization becomes a critical issue for the survival of the species. The planktonic period is short, hence populations (especially in closed embayments) which are relatively isolated are not easily recolonised if depleted. The global population of *P. nobilis* has been greatly reduced over the past few decades as a result of recreational and commercial fishing for food, the use of its shell for decorative purposes, and incidental mortality by trawlers, bottom nets, or anchoring. Although *P. nobilis* has become rare in many parts of the Mediterranean, important local populations still exist in the Hellenic Seas (HAMES *et al.,* 2001; GALINOU-MITSOUDI *et al*. 2006; KATSANEVAKIS 2006, 2007a; GEROVASILEIOU *et al*., 2007) especially in the Korinthiakos, Evvoikos, and Thermaikos Gulfs, the islands of Chios and Lesvos (NE Aegean), NW Kriti as well as the Ionian Sea (ZENETOS 1986; 1996).

Despite being a protected species, in certain areas fishing mortality greatly exceeds natural mortality and is a critical determinant of the spatial distribution of the species. In Vouliagmeni Lake a marked zonation of *P. nobilis* individuals occurred with the species being restricted in the shallow peripheral zone at depths <22 m, with a major peak at depths between 12 and 13 m and was attributed to mortality due to illegal fishing by free divers (KATSANEVAKIS, 2007b). Natural mortality in this population was strikingly size dependent and *P. nobilis* suffered high natural mortality during the first year of life; the probability of death by natural causes quickly diminished as the fan mussels grew in size. Growth rates had a seasonal pattern, with an extended period of very slow growth between late autumn and early spring and a peak in growth rates during late spring - early summer, probably related to an optimum combination of temperature and food availability (KATSANEVAKIS, 2007b). The abundance of *P. nobilis* in lake Vouliagmeni was estimated between 5 450 – 8 400

individuals (KATSANEVAKIS, 2007a). The mean fan mussel populations' density in Chios Island was found to be 0.06 inds/$m^2$ with a range of 0.05 - 0.07 inds/$m^2$ (GALINOU-MITSOUDI, unpubl. data), while the mean density from Kefallonia Island (Ionian Sea) was 0.05 inds/$m^2$ with a range of 0.02-0.08 inds/$m^2$ (HAMES *et al.,* 2001). Recently, an undisturbed *P. nobilis* population was found in very shallow depths (2-3m) on the eastern coast (north of the Epanomi port) of the Thermaikos Gulf (GALINOU-MITSOUDI *et al.* 2006). The population density of *P. nobilis* in this area reached 1.3 inds/$m^2$, which is the highest reported value in the Hellenic Seas and among the highest in the Mediterranean. The fan mussels in the Thermaikos Gulf reached an age of 27 years, which is the highest reported value in the Mediterranean.

## CONCLUSIONS

Despite their commercial value, scientific information concerning exploited molluscan species in the Hellenic Seas is rather scarce and limited to very few species such as *Callista chione, Cerastoderma glaucum* and *Venus verrucosa*. Similarily, the distribution, degree of exploitation and the status of populations have not been assessed for other molluscs that are not commercially exploited as a food resource but are collected for other uses (e.g. fishing bait, drug production, cosmetics, jewellery, shell collections, etc.).

Based on archived data from the ETANAL and the National Statistical Service, it appears that the shellfish production which peaked in the early 90's, has declined or even collapsed followed by an analogous decline of the vessels with a main license in shell fishing. These indicate that the respective legislation (PD 86/98 and PD 227/03) had a rather poor effect on molluscs' natural population sustainability. It is evident that assessment of exploited stocks is urgently needed towards a rational management of these biological resources in the Hellenic Seas.

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