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# RESEARCH FOR PECH COMMITTEE - THE CLAM FISHERIES SECTOR IN THE EU - THE ADRIATIC SEA CASE

**STUDY**

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DIRECTORATE-GENERAL FOR INTERNAL POLICIES

POLICY DEPARTMENT B: STRUCTURAL AND COHESION POLICIES

FISHERIES

# RESEARCH FOR PECH COMMITTEE - THE CLAM FISHERIES SECTOR IN THE EU - THE ADRIATIC SEA CASE

STUDY

This document was requested by the European Parliament's Committee on Fisheries.

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STUDY


Abstract

Clams are an important fishery resource in the European Union. The Adriatic Sea clam fishery shows a declining trend and is losing market share. There is increasing interest to reduce the minimum landing size in order to allow further landings to reduce the socioeconomic impact. This particular situation is examined in this paper and an expert opinion is produced on the way forward.



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# CONTENTS

# LIST OF ABBREVIATIONS

| | |
|---|---|
| ANCIT | Italian Association of Canning and Tuna Industries |
| CFP | Common Fisheries Policy |
| CNR-IRPEM | Consiglio Nazionale delle Ricerche - Istituto di Ricerca per la Pesca Marittima |
| CPUE | Catch Per Unit Effort |
| DCF | Data Collection Framework |
| DCR | Data Collection Regulation |
| EAFM | Ecosystem Approach to Fisheries Management |
| EC | European Commission |
| EU | European Union |
| EUMOFA | European Market Observatory for Fisheries and Aquaculture Products |
| FAO | Food and Agriculture Organization of the United Nations |
| GPS | Global Positioning SystemGlobal Positioning System |
| GT | Gross tonnage |
| IREPA | (Italian) Institute for Economic Research in Fishery and Aquaculture |
| MIPAAF | (Italian) Ministry of Agricultural, Food and Forestry Policies (Ministero delle Politiche Agricole Alimentari e Forestali) |
| MLS | Minimum Landing Size |
| PRUs | Position Recording Units |

# LIST OF TABLES



# LIST OF MAPS

# LIST OF FIGURES

# EXECUTIVE SUMMARY

## Background

Fishing for clams (Chamelea gallina) by means of hydraulic dredges is of paramount importance in the Adriatic. The fishery is divided into Districts (Compartimenti Marittimi) and for each District a fixed number of dredgers are licensed to operate.

### Production

Annual landings reached a peak value of about 100,000 tonnes in the early 1980s and subsequently declined because such high fishing pressure was not sustainable (Froglia, 1989). The fishery experienced a drop in catches and at present annual landings are roughly of the order of 14,000 tonnes with an approximate first sale value of about €32M (EU Member States for the 2015 DCF fishing fleet economic data call). Such reduction in catches spurred the Italian government to impose a number of management regulations on gear characteristics (technical measures), the number of fishing days per year (fishing effort or inputs) and individual catch quota per day (catches or outputs).

### Management

The scientific advice for such regulations is based mainly on resource assessment surveys conducted once per year by scientific institutions (e.g., CNR – IRPEM, etc.). These surveys provide an estimate of relative abundance of the resource at sea in terms of biomass and an estimate of the size-distribution of the clam populations.

The fishery is therefore managed by a number of general regulations issued by the Italian Directorate for Fisheries. Within the scope of these general regulations the local Consortium of Clam Fishermen can add additional rules such as diminishing the daily individual quota or imposition of a rotation of the fishing areas inside the District. Scientific advice on these decisions is required from an official scientific institution.

Summarizing, it seems clear, that in its early years the fishery that is the subject of this work recorded high fishing yields, but they soon started declining at a steady rate in spite of various measures adopted to limit the fishing effort and such a negative trend progressively reduced the commercial output to approximately one sixth of that from initial times.

### Causes of decline

Causes of the decline in clam production remain uncertain and negative impacts both by the high exploitation rate (Froglia, 1989a; Morello et al., 2005a) and unknown environmental factors (Froglia, 2000) have been assumed. Moreover, the possible impact on C. gallina eggs and larvae by the large phytoplanktonic aggregates recorded in the Adriatic during the summer of 1989 was tentatively invoked to explain an exceptionally low level of landings in 1991 (Stachowitz et al., 1990; Del Piero et al., 1998; Froglia, 2000). According to Romanelli et al., (2009) the progressive reduction of freshwater flow into the

Adriatic Sea, as well as of its phosphate content, have been playing a relevant role in the clam reduction.

Morello et al., 2011 presented the outcomes of fishery-independent surveys conducted in the Ancona (AN) and S. Benedetto (SB) Maritime Districts from 1984 to 2001 to assess the C. gallina stock. The study revealed a considerable year-to-year fluctuations and the results are indicative of a resource and fleet heavily dependent on stochastic substantial recruitment events. Large recruitment events followed by significant natural mortality episodes and the paucity of older individuals may suggest a shift in the allocation of energy, from growth to reproduction.

### Impact

From an Ecosystem Approach to Fisheries Management (EAFM) perspective, the hydraulic dredging determines strong physical disturbances of the sea bed. As a matter of fact the impact of hydraulic dredges not only scrapes the surface of the substratum but also dig into it, re-suspending significant amounts of sediment. It has been found that hydraulic dredging contributes to destabilisation and partial modification of sediment conditions, resulting in an overall decrease in habitat complexity with direct implications for the benthic community (Godcharles 1971; Meyer et al. 1981; Brambati and Fontolan 1990; Pranovi and Giovanardi 1994; Tuck et al. 2000; Kaiser et al. 2002). Drastic reductions in abundances of infaunal organisms are widely reported as a consequence of mechanical, suction and hydraulic dredging (Hall et al. 1990; Hall and Harding 1997; Pranovi and Giovanardi 1994; Tuck et al. 2000). Shifts in benthic community structure in favour of a few dominant opportunistic species have been observed (Dayton et al. 1995; Pranovi and Giovanardi 1994). This is a condition that Warwick (1986) associated with disturbance.

Short-term effects of inshore fisheries such as hydraulic dredging are widely reported in the literature (Godcharles 1971; Hall et al. 1990; Hall and Harding 1997; Tuck et al. 2000). Communities living in high-energy environments and constantly subjected to natural environmental stress will be less susceptible to fishing disturbance (Currie and Parry 1996; Kaiser et al. 1996; Ball et al. 2000; Craeymeersch et al. 2000; Jennings and Reynolds 2000; Zajac and Whitlatch 2003). This may be the case for the microbenthic community inhabiting the shallow sandy bottoms of the area considered in this study. Frequent small-scale disturbances, such as dredging operations, may thus be masked by large-scale environmental perturbations, such as storms, and prevailing hydrodynamic processes may be among the key factors determining the extent to which an area will be resilient to fishing disturbance.

Morello et al. (2005b) has highlighted important aspects of medium-term effects of hydraulic dredging in the Central Adriatic Sea. The results of this study have emphasised the fact that, despite intensive fishing that has been going on for decades and a benthic community that is typical of a moderately disturbed environment, above threshold intensity, the effects of fishing on community structure were still discernible over and above natural variation and this was particularly true for the shallower assemblages. Furthermore, whilst the results described indicate a relatively rapid recovery of the system (within 6 months), longer-term recovery studies are necessary to understand the complexity of benthic successional dynamics in the area.

# Aim

The new Common Fisheries Policy (CFP) includes the application of the ‘precautionary principle’ to fisheries management, and the progressive implementation of an ecosystem approach. Consequently, the Commission defined objectives for CFP management decisions to be based on the best available knowledge about the interactions between fishing and ecosystems, and that both direct and indirect impacts on the marine environment are minimised, in particular by reducing the overall fishing pressure.

Taking into consideration such objectives, the clam fishery historically carried out in the Adriatic sea needs to be examined in the light of the European Union (EU) approach to protect the ecological balance of our oceans as a sustainable source of wealth and well-being for future generations. In particular the present study focuses on the high fishing pressure on the commercial bivalve resources, on the socio-economic cascade due to the decrease of the resources and on the impact on the environment caused by the fishing gear employed.

# 1. CONTEXT - CLAM FISHERIES IN THE EU

**KEY FINDINGS**

- Clams are a high value seafood product in the European Union which is a net importer since production is relatively low. Italy is the main producer (mainly from the Adriatic Sea) and Spain the main importer, representing this movement a significant flow of product.
- The EU clam fisheries sector exploits several species in the Atlantic and Mediterranean coasts with different situations and management.
- In the Atlantic coast the main species found include the European clam or (cross-cut) carpet-shell clam (Ruditapes decussatus), the pullet carpet-shell clam (Venerupis pullastra) and the introduced Japanese clam (Tapes philippinarum).
- In the Mediterranean coast, the stripped venus clam (Chamelea gallina) presents fisheries with relevant socio-economic importance particularly in the Adriatic Sea.
- The European Union Council Regulation 850/98 sets the minimum size for several clam species of Atlantic origin in 38-40 mm, whilst for the Mediterranean Council Regulation 1967/2006 sets the minimum legal size at 25 mm. The Turkish clam with a minimum legal size of 17 mm generates market competition which derives in socioeconomic impact for the Adriatic Sea clam fisheries sector.

Clams are bivalve molluscs that can be harvested or cultured in sandy or muddy bottoms in the littoral. For the harvest, the main gear used is a dredge, hydraulic or manual, incorporating a sieve to select sizes. The dredge is operated from small size boats, often with 1-2 fishers on board. Bottom trawls are also used in certain fisheries.

High fishing pressure, pollution and reduction of natural habitat due to expansion of urban areas and ports are some of the causes of the decline of clam populations.

## 1.1. Importance

Despite a relatively low production in Europe, clams are a high value seafood product, economically important in many European countries, particularly in Spain, Italy and Portugal.

From 2001 to 2013 the landings of clams of the European Union (EU) totalled to 393,240 tons. Italy alone accounted for half of it (201,286 tons) followed by Spain (70,884 tons) and Portugal (26,060 tons). The north east Adriatic Sea was the main production area.

From 2001 to 2015, the EU exported a total of 5,915 tons of clams outside the EU and a total of 184,174 tons inside the EU; the total exported quantity being 190,089 tons. The main exporting countries (mainly for the internal EU market) were Italy (51,262 tons), Portugal (30,000 tons) and Spain (26,800 tons). In the same period, the EU imported a total of 218,719 tons of clams from outside the EU and a total of 225,311 tons from inside the EU; the total imported quantity being 444,030 tons. The main importing countries (both from the EU internal market and from outside the EU) were Spain (the largest by far with

more than half the total imports: 270,415 tons), Portugal (92,060 tons) and Italy (41,080 tons). Spain imports the majority of the product from the Italian market, mainly from the Adriatic Sea (EUROSTAT).

## 1.2. Species

The genus “tapes” is currently classified as “ruditapes”. It appears as “venerupis” in Council Regulation (EC) No 1967/2006. Commonly called “carpet-shell clams”. The genus “venus” includes other species commonly called “venus shells”.

The European clam fisheries are dominated by several species in the Atlantic coast such as the European clam (cross-cut carpet-shell clam), Ruditapes decussatus (Linnaeus, 1758), the palourde (in French), Venerupis corrugata (Gmelin, 1791), and the Manila clam, Ruditapes philippinarum (Adams & Reeve, 1850). In the Mediterranean, the dominant species is the stripped venus clam, Chamelea gallina (Linnaeus, 1758) which presents fisheries with relevant socio-economic importance particularly in the Adriatic Sea.

European clam (Ruditapes decussatus)

The European clam Ruditapes decussatus is native to the Mediterranean Sea and Atlantic coasts from the Iberian Peninsula up to the southern and western UK and to Morocco (Morales et al, 2008).

The “carpet-shell clam”, as it is also known, is harvested in Italy, Portugal, France and Spain. It is the key bivalve species in Portugal where the harvest of this bivalve represents the largest sector of molluscan mariculture with over 10,000 people directly or indirectly involved in its production. Culture of R. decussatus is clearly limited by the availability of seed. Its production is exclusively based on natural recruitment, which is subject to high annual fluctuations

This clam is more commercially important and more appreciated by consumers than the introduced Manila (or Japanese) clam, R. philippinarum. It is often consumed raw due to its high quality flesh.

Palourde (Venerupis corrugata)

Previously classified as venerupis pullastra, this clam presents a similar spatial distribution as the European clam, but reaching further north (Morales et al, 2008). The palourde is historically harvested in Spain, Portugal, France and Italy. It is particularly important in Galicia, Spain (locally called “rapotuda” or “babosa”), where harvest from natural populations in estuaries reached 2,000 tons in 1990.

Venerupis rhomboideus is also of importance in Galicia, together with R. decussatus and V. corrugata.

Manila clam (Ruditapes philippinarum)

This species is native from southern Siberia to China. T. philippinarum was introduced during the 1930s, brought over from Japan with oyster spat from Japanese oysters.

Also called Japanese clam, it shares distribution with the European clam, but it burrows shallower than it. It is a fast growing species reaching the minimum legal size of 40 mm in 2 years. This fact has spurred its expansion to UK, France, Spain and Italy where it is

harvested intensively. The majority of Japanese clam found in Spanish markets is of Italian origin.

Stripped venus (Chamelea gallina)

The species is present along the Eastern Atlantic coasts, from Norway, Lofoten and British Is., to Portugal, Morocco, Madeira and the Canary Is., as well as in the Mediterranean, including the Black Sea. It is particularly abundant in the Adriatic.

It inhabits bottoms of clean and muddy sand, between 5 and 20 m deep. It is an epibenthic suspension feeder, ingesting a variety of algae, bacteria, and small detrital particles. It reaches a maximum length of 5 cm, being commonly found at 2.5 - 3.5 cm.

It is caught with dredges and hackles, occasionally with bottom trawls. The species is commercialized fresh, frozen and canned; and usually eaten steamed.

In the Mediterranean, and outside Italy, C. gallina is presently exploited along the Albanian coast (south-east Adriatic), in the Marmara Sea (Turkey), along the Spanish and Moroccan coasts of the Alboran Sea, and along the Spanish coast of Catalonia, mostly south the Ebro delta. At the end of the eighties, Albania and Turkey with the aim of developing their national fishery, imported from Italy some boats equipped with hydraulic clam dredges. In Spain and Morocco hydraulic dredges are not yet used. Vives and Suau in 1955 estimated the annual landings of C. gallina along the Catalonian coast to be some hundreds of tons.

In Croatia a settlement of C. gallina is present at the Neretva estuary, however the fishing activity is practically negligible and most of the catches are harvested manually.

Recently, an FAO.project (FAO EastMed, 2014) has started a study to support Egypt in exploring the possibility to determine if the clam resources exists, and then assist Egypt in developing a potential fishery. The study showed that the commercial clam C. gallina has a potential for exploitation

## 1.3. Management

The European Union regulates the exploitation of clams in the Mediterranean Sea through Council Regulation (EC) No 1967/2006, which sets in 25 mm the minimum size for exploitation of mollusc bivalves. This includes Venerupis (carpet-clams) and Venus (venus shells) genus. This regulation affects the catch, retention on board, transhipment, landing, transfer, storage, sale or display of clams under this measure, which are considered “undersized marine organisms” and therefore illegal.

EU Council Regulation (EC) 850/98.sets in 40 mm the minimum size for the European clam and the Manila clam from Atlantic waters, while it sets 38 mm for the pullet carpet-shell clam.

The management measure based on MLS has often generated controversy in the sector having requested in several occasions a reduction in the legal size based on new scientific studies indicating lower sizes of sexual maturity.

For example, the minimum landing size (MLS) was reduced for Venerupis pullastra, the pullet carpet shell clam, only for specific areas of Galicia inside territorial waters, from the 38 mm (set by the EU Regulation 850/98) to 35 mm (similar to Portugal) because in these areas and due to environmental factors, this clam species usually dies before reaching the

legal size of 38 mm and reproduces at lengths bellow 35mm. The measure was taken after scientific and market evolution studies supported it.

In the case of Chamelea gallina, the stripped venus clam, the Adriatic Sea fishing industry is claiming a reduction in the MLS based mainly on the socioeconomic impact, due to market competition primarily from the Turkish clam with a minimum legal size of 17 mm. However, in their turn, Italian 25 mm clams are making good the shortfall left by Atlantic ones.
Some scientific studies show that C. gallina reaches sexual maturity at sizes between 13 and 18 mm. This particularly applies to the Atlantic coast of southern Spain with size of first maturity (i.e., the size at which 50% or more of the specimens are mature) set by some authors at 16 mm (Rodriguez et al, 2003). However, in the Adriatic Sea, the situation is quite complex and needs to be closely examined.

# 2. DESCRIPTION OF THE MAIN CLAM FISHERY IN THE ADRIATIC SEA

KEY FINDINGS

- The development of the *Chamelea gallina* fishery throughout time saw the change from a less effective manual gear to a specifically adapted hydraulic dredge, a major increase in number of fishing vessels (and licences), and an expansion in the area covered.

- The economic value of the fishery improved due to increased fishing effort and landings, favouring also a cannery industry and processing plants (80%) aside the market for fresh product (20%). The amount of product exported represented 30%.

- Due to the depletion of the resource and the scarcity of the product in the market, the average price of fresh clams increased from 0.20 € per kg in 1980 to the current 2-6 € per kg.

- In the early 1980s the need for control became evident and several measures were established such as limited licences (and thus vessels), restricted areas of operation, and a maximum daily quota to be landed, but their application was ineffective.

- At the peak of the fishery by 1984 the Italian fleet could cover the whole area of the fishing grounds in one year, whilst it takes two years for an individual clam to reach the minimum marketable size of 25 mm.

- A more constringent management plan was established in an attempt to sustainably manage the fishery. It included measures for gear selectivity and closure periods, establishment of management committees by areas, repeal of licenses, etc.

- The tolerance (10%) allowed by an Italian presidential decree on landing of undersized target species became an issue from 1994, when the EU Regulation set no tolerance threshold. Since the tolerance is impossible to determine, compliance with the rule was not effective.

- The new EC Regulation (1967/2006) establishes a distance limit to the coast, 2.5 cm of MLS and need for management plans.

Map 1: Adriatic Sea


## 2.1. The historical development of the clam fishery in the Adriatic sea

### 2.1.1. Species and fishing countries

In the western Adriatic Sea there are a number of commercially exploited clam species amongst which are Chamelea gallina, Callista chione, Venus verrucosa and Paphia aurea, but the fishery for the former is by far the most important having reached landings in excess of 100,000 t in the early 1980s (Froglia and Bolognini, 1987; Froglia, 1989a). Chamelea gallina is also exploited along the Albanian coast, in the Marmara Sea (Turkey), along the Spanish coast of Catalonia, south of the Ebro estuary and at the mouth of the Guadalquivir river (Bodoy, 1983; Froglia, 1989a; Alpbaz and Temelli, 1997).

The C. gallina fishery along the coasts of the western Adriatic Sea dates back centuries: it was first mentioned in literature by Olivi in 1792 when it was fished in the Venetian Republic and exported to the Papal States (Froglia, 1989a).

### 2.1.2. Evolution of harvesting gears

Traditionally, clams were harvested using hand-rakes (Figure 1) comprising a metal cage or basket with an opening of 1.5 m whose bottom surface bore a metal blade used to 'cut' into the top few centimetres of the sediment where the greatest abundance of clams is found (Ferretti et. al., 1989).

Figure 1: Boat mounted with a hand-rake used to harvest Chamelea gallina in the Adriatic Sea in the first half of the 20th century. The photo shows the hand operated winch used to warp on the stern anchor and the rake's long pole (modified from Froglia, 1989a)

The basket was attached to a long wooden pole with the purpose of allowing the crew to shuffle the rake from aboard a small boat (6 – 7 m length), so as to enable the escape of any sediment collected in the basket (Ferretti et al., 1989). The clams were collected within the cage, whose bottom surface was composed of mesh so as to retain the greatest proportion of clams whilst allowing through as much sediment and debris as possible (Ferretti et al., 1989). The angle of the pole with the horizontal axis of the basket could be regulated, permitting more or less penetration (Ferretti et al., 1989). The hand-rake was towed along the bottom for a maximum of 100 m by warping on a stern anchor; it was then hauled and the catch sorted using a hand-operated sieve (Froglia & Bolognini, 1987; Froglia, 1989a). On a good day, under calm conditions, this method would allow a five-man crew to land approximately half a tonne of clams with 12 hours work (Ferretti et al., 1989). Thus, clam fishing by means of hand-rakes was very time consuming and a substantial amount of effort was required to land a relatively poor catch. Furthermore, the exploitable area was very much limited by the length of the pole, which never exceeded 8 m.

In the late 1960s, a modernised version of the hand-rake was introduced to increase its efficiency and decrease the effort required to operate it (Figure 2). Initially, a series of nozzles were added in front of the 'blade' on the anterior part of the basket (Froglia & Bolognini, 1987; Ferretti et al., 1989; Froglia, 1989a). Water under pressure was pumped through the nozzles, both in front of and inside the basket, resuspending the substratum and, thus, increasing the ease of tow and helping the escape of sediment collected in the basket, respectively.

Figure 2: (a – b) Modernised version of the traditional hand-rake where nozzles were added to the cutting blade on the anterior part of the basket. The rake was still attached to a pole (a) and water under pressure was pumped through the nozzles (b)

This saw the start of clam fisheries with hydraulic dredges in the western Adriatic Sea. Soon hydraulic rakes and pioneer hydraulic dredges (Figure 3) replaced hand-rakes and by 1974, of 440 vessels operating in the Adriatic Sea, only 60 made use of traditional gear (Froglia and Bolognini, 1987; Froglia, 1989a). By the 1980s the pioneer hydraulic dredge (Figure 3) was replaced by more and more advanced versions and nowadays it is very similar to the Nantucket dredge used for Macrocallista nimbosa fisheries on the west coast of the USA (Stokes et al., 1968).

Figure 3: Pioneer hydraulic dredges used in the 1970s to harvest Chamelea gallina in the Adriatic Sea

### 2.1.3. Commercial importance

With the advent of the modern hydraulic dredge, the C. gallina fishery in the western Adriatic Sea escalated progressively, reaching a status of extreme importance for the economy of the fishing community. Technological improvements caused an increase in fishing effort and, therefore, in landings: in the last years a maximum of 600 kg of clams

can be landed per vessel per day. Traditionally clams were sold fresh on local markets, but, from the 1960s onwards, demand exploded and other ways of marketing the product were sought.

Canneries and processing plants were established: until the late 1940s one single cannery was present on the eastern Italian coast, in 1974 the number of processing plants had risen to 13 and by 1985 there were 15, with a maximum total daily processing capacity of 50 - 70 t (Froglia, 1989a). Exports of fresh clams started, the chief buyer being Spain (Froglia & Bolognini, 1987). It is estimated that in 1987, of an annual catch of approximately 100,000 t of clams, 50% was processed, 30% exported and only 20% was sold fresh on the Italian market (Froglia & Bolognini, 1987).

At the end of the 1990s, the Ancona Consortium for the management of clam fisheries (Co.Ge.Vo.) and neighbouring consortia were thinking of exporting their product to European countries other than Spain and, maybe, to the USA. Nevertheless, the annual catch of C. gallina has not increased proportionally with fishing effort throughout the years and, as a consequence, prices have risen dramatically. In 1980 the average price of fresh clams on the market was 0.20 € kg-1; in 1991 it had risen to 1.00 - 2.50 € kg-1. Currently the price at landing undergoes fluctuations depending on the variable availability of the product and is usually between 2 and 6 € kg-1 with peaks at Christmas time (Morello, 2005a).

The progressive depletion of the C. gallina stocks since 1984 gave the processing plants serious problems. Prices increased so much that it was no longer economically viable for them to buy clams from the Adriatic, its product being no longer competitive with that from elsewhere (Paphia undulata from Thailand or Tivela mactroides from Venezuela, for example). The result was that processing plants initially switched from processing C. gallina to the larger, more fragile, Paphia aurea (Froglia, 1989a; Froglia, 2000) and finally closed down.

## 2.2. Clam fishery regulation

### 2.2.1. Limited entry policy (Licences)

Until 1979, the C. gallina fishery was regulated by the local port authorities, which attempted to set laws on dredge and sieve selectivity and impose a closure period in June so to safeguard juvenile clams under 25 mm shell length and larval settlement, respectively. This strategy had little or no success because undersized clams had a lower price and were in great demand by processing plants; furthermore, it proved very difficult to convince fishermen of the importance of a closure period (Froglia, 1989a). There were no restrictions on fishing area and vessels; when one site had been exploited, a vessel could safely proceed to deplete an adjacent one, with no geographical limitation. Fisheries scientists soon realised that some sort of control needed to be mandatory and in 1979 the first legal action was taken to manage the resource. A ministerial decree (D.M. 30/07/1979) was issued introducing a limited entry policy. Each vessel operating a hydraulic dredge was allotted a licence that allowed it to fish within the Maritime District it was registered in, only. No new licences were to be issued with the exception of those boats already under construction in August 1979. Unfortunately, due to economic and political pressures, this policy was not adhered to, and by 1985 the number of licences had increased by 20% (Froglia, 1989a). Licences were issued free of charge but, with the increase in value of the resource added to the fact that they were transferable with the vessel, and could, thus, be sold with it, they became very expensive (Froglia, 1989a).

Each vessel was licensed to fish exclusively within its district of registration: this was a first attempt to involve the fishermen in the management scheme by giving them ‘something to look after’. Other conditions of the decree included a maximum daily quota per fishing unit of 2.5 t, a fishing closure in June, an allowance of 10% undersized clams per daily catch, and the duty to report landings and fishing sites monthly. To aid the enforcement of such legislation and to help fishermen, a central management committee was appointed.

### 2.2.2. Gear selectivity measures

In 1980, a new decree (D.M. 20/07/1980) officially fixed minimum values for the spacing in dredge and sieve grids in an attempt to avoid exploitation of undersized individuals. The recommended spacing between grid bars was set at a minimum of 12 mm following an investigation on selectivity by Froglia and Gramitto (1981) and is still applied now. As an alternative to bars, the grid was, and is, allowed to consist of a square metal mesh minimum 17 by 17 mm; or a rectangular metal mesh minimum 25 by 12 mm; or a perforated metal surface with holes minimum 21 mm in diameter and having a ratio of non-perforated surface to perforated surface of less than a half. Such legislation could, potentially, be very efficient but it is very difficult to enforce for two reasons. The first reason is that all grids can be altered, so as to be used to exploit more than one species and, therefore, selectivity of the gear can be readily changed on leaving from or on returning to the harbour. The second is that it is virtually impossible to size-check all the clams landed by one boat, let alone the total clams landed in one District after a day’s fishing.

### 2.2.3. Effort limitation

In 1981 new laws (D.M. 22/05/1981) were set to officially regulate the characteristics of any new fishing vessels. A maximum weight of 10 t (GT) and a maximum engine power of 150 hp were imposed, but rarely were these complied with, rendering these limitations, too, inadequate in the control of total fishing effort.

It is obvious that the management/control procedures adopted were inappropriate to protect the C. gallina stock from overexploitation; nevertheless up to 1984 the fishery remained very healthy in terms of landings. The major problem was, as previously mentioned, that, whilst landings increased by approximately 20% between 1974 (the estimated annual catch was 80,000 t) and 1984, the fishing effort saw a 50% increase (Froglia & Bolognini, 1987; Froglia, 1989a) clearly indicating a decline in yield. It is estimated that by 1984 the fleet had expanded in such a manner as to be able to cover the whole area of the fishing grounds in one year, whilst it takes two years for an individual clam to reach the minimum marketable size of 25 mm.

### 2.2.4. Catch limitation

In 1985, following a preliminary scientific survey of the C. gallina stock in the entire western Adriatic Sea, a new fisheries act (D.M. 26/10/1985) maintaining most of the previous laws was drawn up. The only new improvement was that the maximum daily catch quota per vessel was decreased to 1.2 t and a new management committee was set up. However, the first measure this new committee took was to increase the number of licensed vessels by 10% (Froglia, 1989a), on the basis that the increased fishing effort would be counterbalanced by the reduced daily quota, hence the 1985 Act resulted in no real change, except a probable worsening of the situation. Subsequently, the daily quota per vessel was further reduced to 600 kg by a ministerial decree issued in 1989 (D.M.

03/05/1989), which also imposed a peremptory ban of fishing activities in the months of June and July.

### 2.2.5. Gear characteristics

In 1992, the 1985 act was modified and new laws on the technical characteristics of the dredges and vessels were introduced. It was decreed (D.M. 25/09/1992) that the dredges should have a maximum width of 3 m, a maximum weight of 0.6 t and that the centrifugal water pump delivering water to the dredge should not create a water pressure greater than 1.8 bar. The propeller-operated towing method was banned.

Furthermore, the management committee was divided into sub-committees, each being responsible for a single Maritime District. For several years these laws were abided by, but then, slowly, as the vessels became progressively larger (against previous laws), the characteristics of the dredges changed, especially in terms of weight. The latter increased dramatically with the increased use of the (interdicted) propeller-operated towing method (the ban was mostly ignored).

### 2.2.6. Co-management

In 1995 a positive change took place in the management of the C. gallina fishery in the western Adriatic Sea. The ministerial decree of December 1st 1995 (D.M. 01/12/1995) entrusted the management of the fishery within each Maritime District to distinct Consortia for a period of three years, on an experimental basis. The primary objective of each Consortium would be that of increasing and protecting the bivalve resource through seeding, restocking, control of the landings and the establishment of fallowing areas. Furthermore, each Consortium should draw a plan for the professional training of the staff involved in the fishing activities. According to the decree, the Consortia would be responsible for proposing adequate daily quotas within a maximum allowable daily catch per boat of 0.6 t, and implementing criteria for the granting or repealing of licences and assignment of areas to restocking activities, amongst other things.

### 2.2.7. Closures (area and period limitations)

A further fisheries act issued in July 1998 (D.M. 21/07/98) summarised all the current laws and the Consortia's duties and added new legislation. The latter included the duty of each licence-holder to hand in fisheries statistics to the Consortium by the 5th of every month and the duty of each Consortium to hand in the statistics for the entire Maritime District to the Ministry of Agricultural Politics by the 15th of each month. It also included leaving the harbour between 5 and 7 am; fishing from Monday to Friday only between October 1st and March 31st, and having three days off per week (including Saturday and Sunday) between April 1st and September 30th. Furthermore, it provided for the agreement of a closure period of at least two months between April and September, at the discretion of the Consortium; fishing only in areas beyond 3 m depth; and the collection of all landings within a certain time of the day (to be decided by the Consortium, usually by 2.30 pm) and at few selected landing sites, so that Consortia and port authorities could carry out necessary controls on daily catch quotas. Such strict and well-defined legislation can only be enforced in the presence of a managing body (each Consortium) and should, ideally, aid the improvement and protection of the precious C. gallina resource.

### 2.2.8. Reduction of licences (withdrawal of licences)

In 1996 and 1998 two laws (No. 107 of 28/02/1996 and No. 164 of 17/05/1998) were issued by which the Italian government, in an attempt to decrease total fishing effort on the C. gallina resource in the western Adriatic, proposed the repeal of hydraulic dredge licences to a certain number of fishermen in exchange of a 125,000 € reward. Considering that the value of a hydraulic dredging licence can, nowadays, reach a maximum of 500,000 € in Maritime Districts where the resource is abundant, this initiative was agreed to only in Districts where resource reduction was severe. A total of 134 licences were withdrawn.

From 1996 onwards, progressive importance has been given to the local management Consortia, with most technical and executory decisions being placed into their power. Thus, European and National legislation delimit overall management conditions within which each Consortium can freely act. For example, hydraulic dredging by means of the propeller technique can only be used where a management Consortium allows it; national legislation has fixed a maximum daily landing quota for C. gallina of 600 kg per vessel, but each local Consortium can diminish this at any time, according to availability of the resource. Since August 2002 (D.M. 05/08/2002), the local management of bivalve fisheries has been definitively entrusted to the Consortia.

### 2.2.9. Minimum Landin Size (MLS)

One of the major items of discussion regarding the legislation linked to hydraulic dredging for C. gallina was the tolerance allowed on landing of undersized target species. Before 1994, the minimum landing size (MLS) for C. gallina was set by presidential decree (D.P.R. No. 1639 of 1968) at 25 mm and a 10% tolerance (in weight) of undersized individuals was allowed on the total quantity landed by each vessel. Since 1994, the technical measures for the conservation of fishery resources in the Mediterranean Sea are set by Council Regulation (EC) No 1626/94 which fixes, among other things, the MLS of C. gallina at 25 mm but with no tolerance on landing of undersized catch. Confusion resulted on which of the two laws should be applied. Reg. (EC) 1626/1994 takes precedence over National legislation with the sole exception of when the latter is more restrictive (a factor which was not applied in this particular case). Despite this, the most recent National legislation, which still applies to bivalve fisheries in Italy today (D.M. 22/12/2000), reaffirms the 10% tolerance mentioned above, which is, among other things, impossible to determine as it implies measuring every single clam landed by a vessel on a fishing day.

The new EC regulation 1967/2006 in force since June 1st, 2010 in art. 13, paragraph 2, prohibits the use of hydraulic dredges within a distance of 0.3 nm from the coast. The Article. 15 establishes the minimum landing size for clams to 2.5 cm. Moreover Article. 19 obliges Member States to adopt a management plan for fishing hydraulic dredge within their territorial waters. It also fixed the maximum width of the dredge to 3 meters. Some of these standards reflect what indicated the Italian national regulations while others, such as the distance of 0.3 nm from the coast and the obligation of a management plan are new.

# 3. THE BIOLOGY OF COMMERCIAL CLAMS

KEY FINDINGS

- Venerid clams are mostly found in temperate and tropical regions where they inhabit the particulate sands of the infralittoral and circalittoral zones with sand percentages in excess of 90%.
- Growth is slow and it takes one year to reach a size of 18 mm and two years to reach the minimum marketable size of 25 mm. It is heavily dependent on environmental conditions and density of population.
- Sexual maturity is reached by a percentage of the population at the end of the first year and by all individuals within the second year of life with an average size of 20- 25 mm.
- Fecundity, which is known to vary with size, increases above 20 mm. A clam of 30 mm would produce 4.5 times more eggs than it produces at 20 mm, dramatically increasing the reproductive potential of the population of clams.
- Fishing pressure seems to have a negative influence on growth performance.

## 3.1. Habitat

Chamelea gallina is an infaunal clam of the Veneridae family (Bivalvia: Lamellibranchiata: Veneridae), locally known in Italy as ‘vongola’ or ‘lupino’ and, collectively with other exploited species, known with the English trade-name of ‘baby-clam’.

Venerid clams are mostly found in temperate and tropical regions where they inhabit the particulate sands of the infralittoral and circalittoral zones (Froglia, 1989a).

In the Adriatic sea, C. gallina inhabits the fine well-sorted sand biocoenosis described by Pérès & Picard (1964) and is so abundant and dominant as to constitute a ‘facies a C. gallina’. A study by Barillari et al. (1979) on the presence of C. gallina in relation to the nature of the sediment in the north-western Adriatic Sea, near Venice, showed that C. gallina does not extend to substrata having a redox potential below +50 mV (i.e. does not tolerate reduced conditions) and a percentage composition of sand below 90%.

## 3.2. Reproductive cycle

C. gallina is a gonochoristic species, although Corni et al. (1985), amongst others, reported cases of hermaphroditism, both rudimentary and functional. The sex ratio has been reported to be approximately equal (1:1) in all studied populations (Valli and Zecchini-Pinesich, 1981, 1982; Froglia, 1989a) and this agrees with Ansell (1961) on the Atlantic equivalent of C. gallina, C. striatula. Chamelea (= Venus) striatula was formerly thought to be of the same species but has recently been proved to be a separate species (Backeljau et al., 1994).

In C. gallina, sexual differentiation takes place after an initial juvenile stage when the follicles are undifferentiated (Corni et al., 1980). Macroscopic and histological studies of the gonads enabled the determination of the reproductive cycle of the species. Poggiani et al. (1973) described this cycle, categorising each stage, as did Chipperfield (1953) for Mytilus

edulis in British waters. Poggiani et al. (1973) reported that the reproductive cycle of C. gallina starts in November with the maturation of the gonads in both sexes when a significant number of spermatids and oogonia are present in the follicles. This stage follows on into December, and in January the first individuals with fully developed gonads appear. The numbers of these progressively increase until, between April and June, the highest percentage of fully mature individuals is present. In June and July the first individuals with partially void gonads appear and these become the majority in August, when the resting stage starts and this is protracted through September and October. It follows that the spawning period is long, running from April to August; it takes place at intervals during this period and it is never complete, since residual oocytes are always found in the gonads following spawning (Ansell, 1961; Poggiani et al., 1973). Spawning seems to be followed by a resting stage and gametogenesis starts again in autumn when female gonads (ovogenesis) start developing earlier than male gonads (spermatogenesis) (Salvatorelli, 1967; Guerin, 1973; Valli and Zecchini-Pinesich, 1982). An exception to this appears in a study by Marano et al. (1982) where no resting stage was reported and gametogenic activity started straight after spawning. Guerin (1973) and Massé and Guerin (1978) in the Gulf of Marseille, Froglia (1975) in the central Adriatic, Bodoy (1983) in the Gulf of Marseille and Cano et al. (1990) in Spain observed two subsequent spawning periods, the first, of greatest intensity, between May and July and the second, quantitatively of lesser importance, between September and October.

In C. striatula, following spawning a trochophore larva is produced which, once the egg membrane is shed, becomes free-swimming and pelagic (Ansell, 1961). The larval shell is then secreted bringing the larva into the veliger stage. In this pelagic stage the larvae form part of the meroplankton (Guerin, 1973) where they are especially abundant in summer and early autumn. The length of such pelagic life is not known, but probably does not extend beyond 20 to 30 days (Froglia, 1989a), following which the larvae settle in the substratum, becoming benthic.

## 3.3. Sexual maturity

Size and age at sexual maturity are invariably linked to growth rate and, consequently, to water temperature and productivity. Mature specimens have been observed with a length of 10 mm (Corni et al, 1980) and, 13-15 mm (Poggiani et al., 1973; Marano et al., 1985; Cordisco et al., 2005). Sexual maturity is reached by a percentage of the population at the end of the first year and by all individuals within the second year of life with an average size of 20- 25 mm (Froglia, 1989a). Casali (1984) indicates that, in waters around Fano, length at first maturity is between 10 and 11 mm, but fecundity, which is known to vary with size, is minimal at this length, while it increases above 20 mm (Marano et al., 1985). Observation made by the same author confirm that the deposition extends from April to October, while the period in which most larvae settle to the bottom is very variable.

Notwithstanding the importance of the reproductive cycle is crucial to consider the fertilization process. The phase of planktonic larval dispersal and the success rate of the settlement (stage mere meio-benthic, from 100 to 120 μ) have not yet been subject to comprehensive assessment and are independent of the consistency of the stock of breeding (Carlucci et al., 2015).

In conclusion, the literature indicates that the reproductive period of clam is extended between April and October, with multiple deposition for the same individuals during the breeding season. The size at which begins gametogenesis was treated differently by the authors, the processes of growth and development of gametes begin even before the size

of 10 mm and continue according to the season. The release of gametes was found in sizes smaller than 15 mm during the breeding season.

The number of eggs that are emitted is dependent on the size of the clams during the breeding season. The fecundity of the clams is still very high, according to Delgado et al. 2013, the fertility of 11 to 29 mm would increase from 77,000 to 797,000 eggs, and a clam of 30 mm would produce 4.5 times more eggs than it produces a clam 20 mm. This element can be useful to estimate the reproductive potential of the population of clams.

It should be mentioned that according to some observations, there are differences in growth and that the purpose of fertility age would influence the number of eggs produced and not only the size.

Table 1: Summary of the bibliographic references relative to the reproductive biology of Chamelea gallina in the Adriatic sea and in other regions mutated from a recent study carried out by Carlucci et al., 2015

| Country | Area | Zone | Reference | Method | Main outcomes |
|---|---|---|---|---|---|
| Italy | Adriatic Sea | Chioggia | Salvatorelli (1967) | Histological | Spermatogenesis starts in spring and spawning is observed in summer. Oocyte maturation continues slowly in the winter to be completed in the spring. There is no reference to the sizes. |
| Italy | Adriatic Sea | Northern Adriatic | Poggiani *et al*. (1973) | Histological | The maximum size observed was 46 mm while the minimum was 4 mm. The minimum size of mature was reported as 16-18 mm. There were no indications of multiple emissions. |
| Italy | Adriatic Sea | Central Adriatic | Froglia (1975) | Macroscopic | (see text) |
| Italy | Adriatic Sea | Manfredonia gulf | Marano *et al*. (1980); (1982) | Histological | Maturity is reached at the first year of life. It is noted that at 14-15 °C the first mature eggs are released into the follicular lumen. Age range between 1 and 4 years old (LFD analyses). The most intense spawning phase was observed in the months of June, July and August. |
| Italy | Adriatic Sea | | Valli and Zecchini-Pinesich (1981) | Histological | Gametogenesis starts in October, with a decrease in the following months. The sex ratio is balanced. |
| Italy | Adriatic Sea | Cesenatico | Corni *et al*, (1985). | Histological | Discrepancies with previous studies. |
| Italy | Adriatic Sea | Grado | Valli *et al*. (1985). | Histological | Gametogenesis starts in September, the specimens are mature in April. |
| Italy | Adriatic Sea | Po river mouth | Ambrogi *et al*. (1997) | - | Continuous recruitment from May to November. |
| Italy | Adriatic Sea | Molise-Apulian regions | Cordisco *et al*. (2003); (2005) | Macroscopic | Larval phase observed in spring-summer. Sex is not detectable in specimens below 13 mm. |
| Italy | Adriatic Sea | Pescara | IZS Abruzzo e Molise (2006); | - | Reproduction starts in spring until the end of summer. Size at first maturity 12 mm. |

| | | | | | |
|---|---|---|---|---|---|
| Italy | Adriatic Sea | | Romanelli *et al*. (2009) | - | Sex ratio is 1:1. Spawning period: April-October in one or two phases. Specimens mature at 13-15 mm and fully mature at 20-25 mm. |
| Italy | Adriatic Sea | Chioggia | Rizzo *et al* (2010); (2011) | Macroscopic | The highest percentage of mature specimens is observed in June and July. A potential link between thermal anomalies in the autumn and anticipation of gametogenesis is explained as a recovery of energy budget, with possible impairment of the probability of survival of individuals and severe repercussions on the quality and quantity of gametes. |
| Italy | Adriatic Sea | Chioggia | Franceschini and Bernarello (2013) | - | Bibliographic study |
| Italy | Adriatic Sea | | Italian Management plan for the hydraulic dredges (2014) | - | The achievement of the first reproduction is after one year. Clams with ripe gonads already in sizes of 10 mm, but more than 50% of the clams of 15 mm is able to reproduce. |
| Portugal | Atlantic | Algarve | Joaquim *et al*. (2014) | - | Relationship between chlorophyll concentration and gonad index |
| Spain | Western Mediterranean | Valencia | Ramon (1990) | Macroscopic | Constant emissions with possible peaks in June |
| Spain | Western Mediterranean | Valencia | Rodriguez de la Rua *et al*, (2003). | Histological | Three populations showing extended spawning period, specimens analysed histologically. |
| Spain | Atlantic | Gulf of Cadiz | Delgado *et al*., (2013) | Histological | Size at first maturity estimated 10.29 mm for females and 8:41 mm for males. Number of oocytes estimated: 76.835 to 797.424. Female of 30 mm would produce 4.5 times number of eggs produced by one of 20. |
| Turkey | Marmara Sea | | Oray *et al*., (1991) | - | Early maturation phase in May, June and July |
| Turkey | Marmara Sea | | Erkan, (2002) | - | Minimum reproduction size 18 mm. |
| Turkey | Black Sea | | Erkan, (2009) | Histological | Spawning begins in June and continues until July, sea temperatures 20 ° C, dimensions investigated:> 20 mm. |

## 3.4. Growth

In the central Adriatic the growth rate of C. gallina seems to be high in the first three years of life (Froglia, 1989a) and then progressively decreases, reaching a maximum length of 49-50 mm, which corresponds to approximately 6 years of age (Polenta, 1993; Arneri et al., 1995). Nevertheless, growth is slow and it takes one year to reach a size of 18 mm and two years to reach the minimum marketable size of 25 mm (Froglia, 1975).

The growth of this species, similarly to other fossorial bivalves, is influenced by various factors, primarly the temperature, but also the trophia of the water, the nature of sediments (Barillari et al., 1979) and the density of the population

In very eutrophic waters, such as in the Bay of St. Gervais in France, a size of up to 21 mm shell length is reached in the first year, whilst in very oligotrophic waters, such as the Bay of Verdon (France), life-span is rarely over one year of age and those individuals that do survive are significantly smaller (Bodoy, 1983). This is because C. gallina is a suspension feeder that relies on a significant phytoplankton biomass and thrives in waters with high primary productivity. As previously mentioned, growth also depends on water temperature. Froglia (1975) showed that noticeable adult growth is restricted to temperatures above 10°C. The Adriatic Sea is subject to seasonal temperature fluctuations with a winter minimum of 7 – 8°C, implying growth does not take place in winter (Froglia, 1989a). With the advent of spring and summer, when water temperature may reach 24 – 25°C and algal production increases, growth is resumed (Froglia, 1989a). Furthermore, C. gallina appears to exhibit density-dependent growth rate and mortality. Years of exceptional recruitment may lead, the following year, to very poor stocks of large individuals due to juvenile mortality, or to very large stocks of small individuals due to growth inhibition and resource competition. Thus, it is clear that physical, chemical and biological factors play a very important role in controlling the longevity and growth rate of this species and this explains why its reproductive cycle may change from one year to another depending on environmental conditions. These factors are important for recruitment too as they may affect spawning.

Ansell (1961), on C. striatula, showed that a rise in water temperature could be the stimulus for spawning because, in the laboratory, no animals spawned at temperatures below 11°C.

The growth rate of C. gallina decreases with age, showing changes due to the combination of several factors. In particular, periods of slow growth are in coincidence of reproductive events during the summer period which in any case determine a condition of stress (Ramón and Richardson, 1992).

These observations are corroborated also by studies conducted by Keller et al. (2002). The author confirms both the growth seasonal variations and the reduction calcium carbonate deposition with increase in age (Ramón and Richardson, 1992).

Also fishing pressure seems to have a negative influence on growth performance, as has been observed in the Black sea a higher growth rate in areas not impacted by fishing with hydraulic dredges than those exploited with this gear (Dalgic et al., 2010). Effects of mechanical impact have also been studied in the Northern Adriatic Sea (Moschino et al., 2003), identifying the different types of damage suffered by shells and the disturbance in growth. Finally, also water acidification can contribute to the reduction in the thickness of the shell (Bressan et al., 2014).

The variability in growth observed in different areas can be partially explained by the different productivity of a certain area, as observed for mussels and Philippine clams reared. Taking into consideration that clams live in a narrow coastal strip, highly subject to human impact but also to freshwater inflow, with the nutrients that affect productivity of the system. As a matter of fact the different growth observed between clams population in the northern Adriatic and Tyrrhenian sea (Carlucci et al., 2015).

For sure also density-dependent processes interact with the individual growth, areas with greater competition for food usually show a reduced growth of clams.

Overall it can be argued that the clams have a growth rate quite variable in term of space and time (Table 2).

Table 2: Growth rate of Chamelea gallina

| Area | Method | $L_{max}$ | $L_{inf}$ | k | Age at $L_{25mm}$ | $t_0$ | Reference |
|---|---|---|---|---|---|---|---|
| Eastern Adriatic (Croatia) | Shell thin sections | 46.0 | 39.50 | 0.52 | - | -0.13 | Arneri *et al*. (1997) |
| Marseille Gulf (France) | Size-frequency distribution analysis | 23.00 | - | - | - | | Bodoy (1983) |
| Marseille Gulf (France) | External rings | 32.00 | - | - | 2 | | Massè (1972) |
| Tyrrhenian sea | External rings | - | 39.11 | 0.50 | - | -0.30 | Costa *et al*. (1987) |
| Central Adriatic, Ancona (Italy) | Size-frequency distribution analysis | 50.00 | - | - | 2 | | Froglia,(1975); (1989a); (2000) |
| Central Adriatic, Ancona (Italy) | Acetate peels | 49.00 | 52.20 | 0.21 | 2 | -0.97 | Polenta (1993) |
| Central Adriatic, Ancona (Italy) | Shell thin sections | - | 41.60 | 0.48 | - | -0.01 | Arneri *et al*. (1995) |
| Central Adriatic, Fano - Pesaro (Italy) | External rings | 46.00 | - | - | 3 | | Poggiani *et al*. (1973) |
| Southern Adriatic, Bari (Italy) | External rings | - | 42.82 | 0.79 | - | -0.03 | Vaccarella *et al*. (1996) |
| Southern Adriatic, Bari (Italy) | External rings | 47.00 | - | - | 3 | | Marano *et al*. (1982) |
| Atlantic, Algarve Coast (Portugal) | Size-frequency distribution analysis | 40.00 | 37.55 | 0.71 | 2 | | Gaspar *et al*. (2004) |
| Atlantic, Algarve Coast (Portugal)) | External rings | 40.00 | 38.95 | 0.47 | 2 | -0.24 | Gaspar *et al*. (2004) |
| Atlantic, Algarve Coast (Portugal) | Acetate peels | 40.00 | 42.15 | 0.32 | 3 | | Gaspar *et al*. (2004) |
| Western Mediterranean, Ebro (Spain) | External rings | 41.00 | - | - | 3 | | Vives and Sau (1962) |
| Western Mediterranean, Valencia (Spain) | Acetate peels | - | 36.12 | 0.35 | 2 | | Ramón and Richardson (1992) |
| Western Mediterranean, Valencia (Spain) | Size-frequency distribution analysis | - | 40.05 | 0.40 | - | | Ramón (1993) |
| Atlantic, Huelva (Spain) | External rings | - | - | - | 3 | | Royo (1984) |
| Western Mediterranean, Mazarrón Bay (Spain) | External rings | - | - | - | 2 | | Cano and Hernández (1987) |
| Black Sea (Turkey) | Shell thin sections | 27.10 | 27.50 | 0.61 | - | -0.14 | Boltachova and Mazlumyan, (2001) |
| Marmara Sea (Turkey) | External rings | 34.50 | 34.17 | 0.43 | 3 | -0.49 | Deval and Oray (1998) |
| Marmara Sea (Turkey) | Shell thin sections | 34.30 | 33.46 | 0.37 | 4 | -0.69 | Deval (1995) |
| Marmara Sea (Turkey) | Acetate peels | 34.30 | 33.46 | 0.37 | 4 | -0.69 | Deval (2001) |
| Marmara Sea (Turkey) | Size-frequency distribution analysis | 39.00 | 33.00 | 0.39 | - | -0.43 | Çolakoğlu and Tokaç (2010) |
| Black Sea (Turkey) – Area without dredging | Shell thin sections | 31.50 | 28.88 | 0.21 | - | -1.29 | Dalgic *et al* (2010) |
| Black Sea (Turkey) – Area with dredging | Shell thin sections | 28,70 | 26,0 | 0,16 | - | -1,96 | Dalgic *et al* (2010) |
| Black Sea (Turkey) – Area without fisheries | Shell thin sections | 29,10 | 26,6 | 0,22 | - | -1,21 | Dalgic *et al* (2010) |

## 3.5. Predation

Very little is known on species that prey upon C. gallina in the Adriatic Sea, especially on its larval stages. It is assumed that, due to the presence of larvae in the planktonic community, their main predatory species are planktophagous ones (Corni et al., 1980).

Froglia (1989a; 1989b) reported that the starfish Astropecten bispinosus and A. jonstoni could be two of the major predators on 2 - 5 mm spat. Solustri (2001, in Morello, 2005) found very large numbers C. gallina spat, as well as some adults, in the stomachs of Astropecten jonstoni and Astropecten irregularis; and Christensen (1962, in Thorson, 1966) reported over 400 spat of C. gallina and Spisula subtruncata in Astropecten irregularis stomachs. Adults could be subject to predation by the fish Gobius niger and Lithognathus mormyrus, as remains of large clams have been found in their stomach contents (Froglia, 1989a). Furthermore, Froglia (1989a; 1989b) found that a significant number of dead shells were found to bear holes and this was attributed to predation by the drilling gastropod, Neverita josephinia. A significant source of mortality can be ascribed to summer phytoplankton blooms. These render the near-bottom water and the sediment anoxic, causing death of benthic organisms, amongst which is C. gallina. Death by anoxia is also caused by intense precipitation events that cause large volumes of detritus and mud to be washed into coastal waters from rivers. Such events are rather frequent in the Adriatic towards the end of the summer and are critical for the survival of newly settled clams. But, exploitation by man is by far the major cause of mortality amongst C. gallina populations and, therefore, the resource needs to be carefully managed and regulated.

# 4. THE EXPLOITATION OF COMMERCIAL CLAM SPECIES IN THE ADRIATIC SEA

KEY FINDINGS

- In the early 80s the annual landings of C. gallina were estimated to have reached around 100,000 tonnes, a figure ten times higher than that of 30 years earlier and six times higher than current figures..

- Nearly 95% of catches came from the northern and central Adriatic Sea.

- The presence of fairly large fractions of slightly undersized specimens among marketed clams was observed even from the mid-1970s, and the clam mean weights progressively decreased by 20%-40% in the Adriatic landings.

- During the last 25 years clam landings on average have been decreasing by 3,500 tons each year, down from the 110,000 t peak of 1984 to the current annual average below the 20,000 tons level.

- The fishing fleet doubled from 383 dredges in 1974, to a peak of 778 hydraulic clam dredgers in 1993 and then the fleet started decreasing under an EU-funded reduction plan to around 585 in 2002 where it remains stable.

- The fishing activity takes place over the whole distribution area of the clams.

- Different exploitation patterns are used in different areas being the rotation strategy quite efficient. However, fishing effort is quite high considering that certain areas could be fished up to 30 times per year. In fact, at the current level of fishing effort, on average every square meter of clam fishing ground has been fished at least once during the fishing season.

- Inter-annual variation is very high both in estimated biomass values and in the length structure of the population. This is due to both high fishing pressure and natural mortality, which is mostly unknown. Consequently, recruitment varies widely from year to year and thus the fishery is completely subject to year-class strength and to possible mass mortalities.

- Low selectivity of the hydraulic dredge results in considerable quantities of undersized clams and other benthic invertebrates being caught causing additional mortality. C. gallina presents considerable natural fluctuations in the recruitment being the new year-class highly dependent on good recruitment events.

- High intensity of fishing effort ensures the capture of the majority of an annual cohort when it reaches the MLS. Thus the importance of establishing an appropriate MLS to ensure the reproduction of these individuals before the capture.

- Seeding or restocking seems a good option for certain areas. However, additional surveys in both the donor and receiving areas would be necessary. Restocked areas would have to be closed to fishers until most of the seeded clams had reached marketable size.

- Even in the presence of a good recruitment a depleted area will take not less than two years to rebuild a commercial stock.
- The potential for commercial exploitation in the Adriatic of other alternative species of clams is worth investigating.
- Control of fishing effort and adequate enforcement of the management rules are essential to maintain the fisheries for C. gallina.

## 4.1. Chamelea gallina production in the Adriatic sea

The Adriatic sea landings of C. gallina have been reconstructed from 1982 to 2005 by Romanelli et al. (2009) using different sources while in the last decade the catches have been estimated in the framework of the EU Data Collection Regulation/Data Collection Framework (DCR/DCF), both series are presented in the in Fig 4.

According to Romanelli et al. (2009), since the late 1970s – early 1980s, data on the Adriatic and national C. gallina landings have been intermittently collected by surveys based on different methods (mainly interviews with fishermen and fish dealers as well as declarations by local associations of dredgers, and in a few cases extensive harbour inspections); although the precision of such estimates often remain undetermined they are considered fairly accurate because they are much larger than official fishing statistics based on declarations compulsorily filled by the fishermen each month. In 1974 the Adriatic clam landings were reckoned to be around 80,000 metric tons (Froglia, 1975) on the basis of the number and capacity of the national shellfish canning plants, customs declarations issued for the fresh product exported abroad and estimates of the fraction of the catches sold locally.

According to the minutes of a debate held in Ancona (Italy) in late June 1975 among scientists and officials on the fishermen or canneries associations such annual clam output was 10 times higher than about 30 years earlier (Anonymous, 1975).

In 1983 the Italian association of shellfish farmers estimated the national production of several bivalves, and the figure of 90,000 metric tons was put forth for C. gallina (i.e. “common clams”) as the inter-annual mean during 1980- 1981 (Federmolluschi, 1983). Specifically, nearly 95% of catches came from the northern and central Adriatic Sea. In 1982 an extensive survey aiming at assessing the total output of the Italian fisheries (Cingolani et al., 1986) showed similar annual Adriatic clam landings.

Further estimates of the annual national clam landings in 1983-1993 are anonymously reported in the C. gallina sheet filled in a monograph summarising all data available on the catches and biology of marine shellfish and ground fish targeted by Italian fishermen (Relini et al., 1999). Estimates were based on data gathered by the Italian Association of Canning and Tuna Industries (ANCIT; indeed, most clams were cooked and canned) and probably are not very accurate and include fairly small amounts of the Venerid Paphia aurea (Gmelin) as it is known that since the mid-1980s an undefined fraction of the authorised dredgers turned to that resource (Froglia, 1989a). In any case the new resource was mainly exploited in the central Adriatic (Froglia et al., 1998) and seemed that was relevant only in 1991 (Romanelli et al., 2009; Fig. 3.1), with an annual estimate of about 6,000 tons. Thus, the clam landings for that year have been accordingly modified.

Similar corrections have also been adopted for 1988-1990 and 1992-1993 assuming, in the absence of more appropriate information on the matter, that the Paphia/Chamelea ratio was constant in the Adriatic clam landings. However, this procedure was not used from 1997

onwards because the Paphia adult biomass was low in scientific surveys performed in 1997-2001 and the activity of the hydraulic dredgers from the central Adriatic has been progressively decreasing since the mid- 1990s (Relini et al., 1999;).

Since 1997 Adriatic clam landings have been regularly estimated by extending the catches recorded from small groups of dredgers, and a decreasing pattern over time was found, down to 12,000 tons in 2002 (Irepa , 1998, 2000, 2001, 2002, 2003, 2006; Labanchi, 2007). Moreover, the Irepa staff had previously recorded 62,300 tons C. gallina during a 12-month survey in 1986-1987.

In spite of the minimum legal limit of 25 mm, the mean size of the C. gallina specimens landed yearly probably decreased with time because the dredgers dealt with impoverished commercial resources and routinely caught undersized clams during operations at sea (Romanelli et al., 2009). It should be noted, however, that the presence of fairly large fractions of slightly undersized specimens among marketed clams was observed even in the mid-1970s, when the fleet was not so large and fishing yields were high (Froglia, 1975, 1989a), because the product was mainly sold to canneries (Relini et al., 1999) and all clams had the same price (maybe smaller specimens were preferred because of the supposed higher flesh content, after Froglia 1975a).

Thus, the 23-27 mm marketable range presumably decreased to a limited extent in sand areas where the size selection of clams is mainly performed in the submerged fishing cage but to much lower values, say 20-25 mm, in sites with more mixed sediment implying that the clam mean weights progressively decreased by 20%-40% in the Adriatic landings (Froglia, 1975; Marano et al., 1982; Arneri et al., 1995).

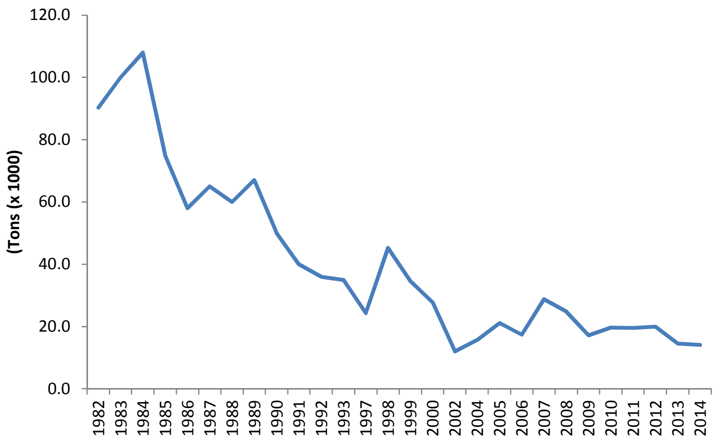
In turn, such changes in the size structure of the C. gallina landings mean that comparisons are restricted to data collected simultaneously or only a few years apart. Anyway, if all available data are summed up we see that during the last 25 years clam landings on average have been decreasing by 3,500 tons each year, down from the 110,000 t peak of 1984, although much stronger drops were recorded in 1985-1986 and 1990-1991 (Fig. 4).

In 1998 landings conversely increased greatly over the previous year’s level (partly because of the long fishery closure imposed in 1997 after the 1996 massive mortality) but the output did not surpass 45,000 tons.

Broad comparisons among average landings of boats based in the northern, central and southern sub-areas of the Adriatic Sea are possible only for some years. Nevertheless, available data show that dredgers of the southernmost Manfredonia and Molfetta districts account for approximately 12% of the total Adriatic fleet but their annual output never surpassed 4.5% of the clam landings (indeed the vessels often operated with fishing gears other than the hydraulic dredges; Marano et al., 1987; Irepa , 2003) whereas boats of the central Adriatic had by far the best daily yields compared to the others during the 1980s although such prominence progressively decreased during the last 15 years.

DCR/DCF data are in general agreement with the estimates carried out by Romanelli et alet al. (2009) in the last period, showing average landings of less than 20,000 tons in the years 2006-2014.

Figure 4: Yearly landings of C. gallina in the Adriatic Sea. Data from Romanelli et al. (2009) and from Data Collection Program (DCF)




## 4.2. Fishing capacity and effort of hydraulic dredges in the Adriatic sea

The first Adriatic hydraulic dredges came into service in the early 1970s and within a few years outnumbered the traditional hand manoeuvred gears (Gaudenzi, 2008) because catches and economic yields were much higher. Initially, most fishermen simply added a water pump to slightly enlarged versions (1.6- 2.0 m wide) of the traditional dredges but such an “intermediate solution” was soon abandoned for the larger gears still in use nowadays. In turn, this implied more powerful engines and larger boats (Froglia, 1975, 1989a).

In 1974 the hydraulic clam dredges numbered 383 (of which 240 were modified traditional dredges) along the entire Italian Adriatic coast and ten years later they had increased in number to 607 in the same area. In the late 1980s authorised vessels started towing the dredges by inverted propellers so that their operational speed approximately doubled (up to 2.0-2.2 knots; Morello et al., 2005a).

Dredgers peaked at 778 in 1993 and then the fleet started decreasing. Within the EU-funded reduction plans, fishing capacity dropped to 665 in 1998 and 585 in 2002, to subsequently remain nearly unchanged (Romanelli et al., 2009). It should be noted that the fleet reduction greatly affected the maritime districts of Monfalcone and Pescara where a severe scarcity of clams had been recorded for years.

From DCR/DCF data the hydraulic dredges were approximately 640 in the period 2008-2013, with more than 8,000 total GT and 60,000 total kW.

A clear decreasing pattern of dredges effort is observed from the beginning on the period 2000-2013. The mean number of fishing days reported by Romanelli et al. (2009) are comprised between 148 in 2002 and 51 in 2004. According to DCR/DCF data the mean number of fishing days were comprised between approximately 110 in 2008 to less than 80 in 2013.

## 4.3. Spatial distribution of hydraulic dredges effort and assessment of clam stock in Ancona fishing district

### 4.3.1. Fishing effort distribution

There are few available studies in the Adriatic of the spatial distribution of hydraulic dredges fishing effort, which would allow determining the extent of the exploited area with precision.

In a study conducted in 2002 in the Central Adriatic Sea (Ancona district; Marss et al., 2002) data on the spatial distribution of hydraulic dredges were acquired by means of GPS-linked (Global Positioning System) position recording units (PRUs), which provided for the first time a clear definition of the spatial pattern of several fishing parameters, such as effort, landings and catch rate, that are commonly used for fishery management. By recording these data over a long period, namely nine months between the two last closed seasons (summer 2000 and 2001), an indication of the temporal pattern of such parameters was also obtained.

Out of 73 vessels operating in the Ancona Fishing District, 17 previously selected vessels provided data through the GPS data loggers (23% of the whole fleet). Taking into account the vessels characteristics, from a statistical point of view the sample vessels were representative of the whole fleet. The spatial coverage of effort is similarly representative, at least on a yearly basis. Indeed, the total area exploited by the sampled fleet throughout the whole nine-month period was similar to the area of clam distribution estimated for the whole Ancona District.

Throughout a whole fishing season, the seventeen sampled vessels fished all suitable grounds for clams. This activity was carried out through a rotation of the fishing areas decided by the Fishermen's Organisation (Consortium). Fishing effort of the whole fleet (73 vessels) is high on a yearly basis, considering that some small areas (pixels) were fished up to 30 times by 23% of vessels.

As well as clearly defining the actual fishing ground exploited by the fleet, GPS data loggers accurately enabled the seasonal shift of the sampled fleet in different fishing grounds to be followed. This, coupled with data concerning the spatial pattern of removals, allowed the detection of different exploitation strategies between the two sub-areas defined within the Ancona District, that otherwise were hardly detectable (Fig 5).

Figure 5: Spatial pattern of fishing effort of the sampled fleet over the nine-month study period in the south sub-area. The limit of the map is defined by 43º32' - 43º16' N and 13º36' - 13º48' E. Legend values represent the number of times a dredge passed through a 50m by 50m pixel (dredge.px-1)


Two different patterns of fishing activities were identified for the two sub-areas. In the north sub-area, the vessels were spatially scattered and fished on wide areas quite similar in extension and location month by month. This fishing pattern provides a low value of maximum removal per pixel on a monthly basis, but a high value over the whole period studied. Conversely, in the south sub-area the vessels operate more closely to each other, fishing on smaller areas that changed each month; this provides a high value of maximum removal per pixel on a monthly basis, which was sometimes quite similar to that obtained over the whole period. Yearly data for removals of the sampled fleet were very similar in the two sub-areas. Similarly, yearly landings for the whole fleet were equivalent in the two sub-areas. This confirms the sampled fleet was representative of the fleet as a whole. This gives additional support to the decision to separate the two sub-areas, which can be considered as two main fishing grounds inside the Ancona Fishing District, both in terms of fleet utilisation and of geographic location.

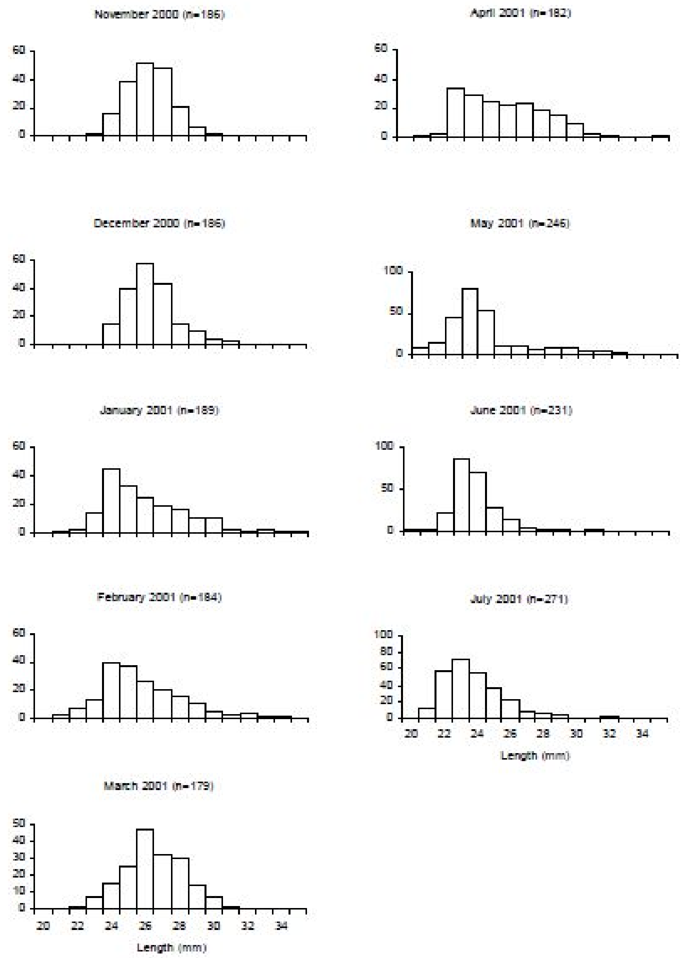
### 4.3.2. Stock assessment

In the framework of the same study two fishery-independent surveys were carried out. The inter-annual variation between the two surveys appears to be very high both in estimated biomass values and in the length structure of the population. This is due to both high fishing pressure and natural mortality. The changes involved often make it difficult to follow the fate of a cohort. For the same reasons analytical models seem difficult to apply and surveys have proved to be a useful tool for the assessment and management of the clam stocks. The occurrence of mass mortalities is difficult to quantify and therefore any estimate of natural mortality is weak. Given the present rotation strategy of the fishing fleet, it would be useful to sample the areas at shorter time intervals and have two surveys a year. This would allow data to be obtained for each sub-area before and after fishing activity and rest periods, and would probably give a reliable quantification of mass mortalities.

Natural, fishing and total mortality estimates are considered to be rather gross approximations and recruitment is known to vary widely from year to year. However, the general impression is that both natural and fishing mortality have rather high values. Under these conditions the usefulness of standard analytical assessment is questionable. The fishery is based mainly on one year-class and therefore is completely subject to year-class strength and to possible mass mortalities. Because of the occurrence of these mass mortalities, natural mortality could greatly vary between different areas and seasons. Given the importance of natural mortality, it would be advisable to concentrate investigation on the estimate of a realistic range of values in time and space for this parameter.

The use of depletion models did not prove to be very successful. It was impossible to obtain a fit with the model in some cases and in others it was possible but only after some exclusion of data (for justifiable reasons). Biomass estimates were in some cases unrealistically high, taking into account that an annual instantaneous mortality rate of 0.6 was applied. This value is surely at the lower limit of the range of possible values, but using higher values led to even higher initial biomass estimates. There are two main facts that hinder the application of this methodology to the clam fisheries in the Adriatic. First of all, fishermen tend to optimise fishing time. This causes them to switch quickly from one clam bank to another as soon as the Catch Per Unit Effort (CPUE) decreases. A second fact is that fishermen modify the selectivity of their gear throughout the fishing season. Because they tend to catch the quota in the shortest time, they prefer areas where the density of clams is high, regardless of the size. This is clearly shown by the trend in monthly length-frequency distribution from commercial catches (Fig. 6) which shows a clear decreasing trend in mean size from October 2000 to July 2001. One of the main assumptions of the depletion model is that the same population is fished through time. A change in selectivity artificially affects the trend in CPUE, which is expected to decrease with time.

Figure 6: Length-frequency distributions of clams from market sampling. The value in parenthesis represents the number of clams in the 1 kg sample




The use of GPS data loggers provided a precise estimation of the intensity of fishing effort over the clam fishing grounds in the Ancona Fishing District. The graphic visualisation of fishing effort allowed the extent of the exploited area to be determined with precision for the first time. Considering the whole period sampled, all the area where clams are distributed is affected by the fishing activities. Raising the fishing effort to the whole fleet, it is estimated that, at the current level of fishing effort, on average every square meter of clam fishing ground has been fished at least once during the fishing season. Therefore, any estimate of the environmental impact of the dredging activity has to be scaled to the whole area where clams are distributed. It should be borne in mind that the present study was carried out in a year of higher than average biomass at sea. Years with lower clam biomass will lead to lower CPUE, and consequently more effort to reach the daily quota. The present estimate of environmental impact could be considered to be at the lower side of the possible range.

As a measure of environmental impact, the total amount of clams and other invertebrates discarded back into the sea was estimated at around 1,000 and 500 tonnes, respectively. This should be considered as a rather rough approximation and more precise and spatially defined estimates could be obtained if the GPS methodology were coupled to an intense sampling of the discard activity.

## 4.4. Hydraulic dredge impact

### 4.4.1. Selectivity

Over 600 vessels commercially exploit bivalve stocks by means of hydraulic dredges in the Adriatic. A study carried out in 2002 (Morello et al., 2005a) highlighted the impact of the hydraulic dredge used to fish clams (C. gallina) but has also revealed a low selectivity of the gear which resulted in considerable quantities of undersized clams and other benthic invertebrates being caught. These are then rapidly returned to sea after passing through the vibrating mechanical sieve used to sort the target species by size on board the vessels. This operation causes additional mortality of fragile organisms such as the heart urchin Echinocardium cordatum and the bivalve Mactra stultorum. An increased width between the bars of the cage would improve the dredges selectivity during the actual towing stage and mortality due to sieving would then decrease. The study did not find dramatic differences in the settlement of C. gallina between undredged grounds and grounds dredged by a single operation.

The impact of a large fleet, however, could be more severe. A the begin of 2000 the Italian law, which applies a precautionary approach, reduced the activity of the clam dredgers to four days per week and imposed a total closure for at least two months in each Maritime District during the spawning and settlement period (April - September).

The annual stock assessment surveys, which have been carried out in the Ancona and S. Benedetto Maritime Districts for the past 15 years, highlighted considerable fluctuations in the recruitment of C. gallina, and for most species within the community. Such natural variation acts at all levels and differences occur from year to year, from District to District and between areas within one District (Froglia, 2000). On some occasions, when the density of ‘yearlings’ was over 1,000 individuals $m^{-2}$, decreased growth rates were observed due to density dependent effects (Caddy, 1989).

### 4.4.2. Seeding or restocking

The high intensity of fishing effort to which the stock is subjected, is such as to ensure the capture of the majority of an annual cohort as soon as it reaches the minimum landing size. This may create serious problems for the resource in years of low recruitment. Should there be huge recruitments in one area, then the seeding of a proportion of the juvenile clams from that area to other areas of low abundance seems worth considering. If all went well, this could result in two areas of medium abundance.

Seeding or restocking is a very useful tool but care has to be taken in carrying out such operations and a detailed knowledge of the resource and conditions in the two areas would be a prerequisite. Seeding would be of no use if the receiving area was not optimal for growth. Of course, the removal of recruits from the dense area would result in a short-term depletion but there might be longer term compensatory increases in growth since intraspecific competition for food resources would have been reduced. Thus, before attempting such interventionist management options, additional surveys in both the donor and receiving areas would be necessary. Restocked areas would have to be closed to fishers until most of the seeded clams had reached marketable size. This implies a rotation of fishing grounds. Such restocking with small clams (15 mm) was attempted in the northern area of the Ancona District during the summer of 1994 and resulted in a profitable fishery the following year.

### 4.4.3. Rotation

Rotational shutdown of previously open fishing areas obviously redirects more fishing effort to the nearby grounds. When the fleet of one District concentrates in any small area then the local resource may be rapidly depleted, unless the daily quota per vessel is not reduced proportionally. Even in the presence of a good recruitment a depleted area will take not less than two years to rebuild a commercial stock.

Closure of fishing areas and ruling on the activity permissible on the remaining grounds would have to be agreed between members of the local management Consortium with the benefit of scientific advice derived from data gathered from periodical surveys.

### 4.4.4. Mass mortality

In recent years mass mortalities, mostly of adult clams (>18 mm in size), have been recorded in all Adriatic Maritime Districts around the end of the spawning season. The origin of these mortality events is still unclear as these phenomena were recorded under normoxic conditions both in areas that were heavily exploited and in areas closed to dredging for several months. These mortalities further aggravated the situation regarding clam availability in some overexploited Districts. The final result has been the total closure of the fishery as, for example, in the S. Benedetto District where dredgers ceased the activity in September 2001.

### 4.4.5. Alternative species

Fishing for alternative clam species could be a solution to some of the problems, both when the C. gallina commercial fraction is depleted and when a particular area is required to lie fallow to allow for growth. The stock of the Venus clam, Paphia aurea, once common on the terrigenous, muddy substrata below 12-13 m in the western Adriatic Sea, at present appears to be considerably reduced and cannot sustain a commercial fishery. Over these grounds, and in the offshore part of the traditional clam grounds, a large stock of the exotic bivalve Anadara inaequivalvis has built-up since the 1970s when it was first recorded in the Adriatic (Rinaldi, 1972). It is not exploited at the moment but its potential for commercial exploitation in the Adriatic is worth investigating. Other species of the same genus, and of similar size, are intensively fished and farmed in the Far East.

### 4.4.6. Control and enforcement

An effective control of fishing effort and active enforcement of existing rules regarding the characteristics of clams dredges and sieving equipment are deemed fundamental to maintain this 'high-tech' fishery in the Adriatic.

It is clear that whatever management regime is put in place concerning the regulation of hydraulic dredge fisheries a key requirement concerns enforcement. The extension of schemes to monitor inshore fisheries activities by placing GPS recorders on fishing boats would be a welcome means of ensuring compliance with regulation.

It is particularly important that exploitation of stocks of long-lived (K-selected) bivalve species be done sensitively. A great potential for long-term damage exists were thoughtless exploitation occur in an unregulated manner. "Boom and bust" fisheries would undoubtedly ensue, with local bivalve populations being fished to near extinction before exploitation moved on to new areas. The likely fact that recruitment in these populations is at best sporadic and unpredictable means that possibly decades would need to pass before any damage to stocks was made good (always, that is, providing a sufficient residual spawning stock remained).

In the case of more short-lived (r-selected) clams, like C. gallina, which are already capable of spawning in their second year of life, high variabilities in stock size and annual production have to be expected and the intensity of exploitation has to be tuned locally (by Consortia or Sea Fisheries Committees) predicated on data gathered from scientific surveys.

# 5. ECONOMIC PERFORMANCE OF THE CLAM SECTOR AND PROPOSAL OF A SMALLER MLS

KEY FINDINGS

- Turkey presents in 2013 the highest production of C. gallina in the Mediterranean, followed by Italy, with half the Turkish production, and Spain. A tendency that has been consolidating since 2005. In Italy the majority of the production originates from the Adriatic Sea.

- Prices fluctuate depending on the scarcity (higher prices) or abundance (lower prices) of the product in the market (dependent on production).

- Italy and Spain are the main markets for clams. Producers from the Adriatic Sea have lost a significant market share due to competition from Gulf of Cadiz (Spain) clams and the possibility of finding clam sizes below the MLS which acts as deterrent for main customer groups. The product has also been partially replaced by the Manila clam from aquaculture.

- In order to recover market share, and according to certain studies interviewing a variety of operators, a reduction of 2-3 mm in the MLS of the clams would be possible if the measure was complemented by a tolerance of at least 5% and management tools such as producer organizations and control the flux of product into the market.

- Given the huge uncertainties on biological parameters of the stock and the factors affecting its evolution, a reduction in 3 mm of the minimum landing size would not be in agreement with the precautionary approach, and it is therefore not advisable.

The bibliographic reference related to the socio-economic aspect of clam fisheries in EU is quite scarce.

## 5.1. Production

The main information gathered on the Adriatic is available from IREPA (Italian Institute for Economic Research in Fishery and Aquaculture) reports (Italian) and FAO-Fishstat database.

Import-export datasets in Italy are available only for the combination of bivalves from several families (Arcidae, Arcticidae, Cardidae, Donacidae, Hiatellidae, Mactridae, Mesodesmatidae, Myidae, Semelidae, Solecurtidae, Solenidae, Tridacnidae and Veneridae), so they are not informative.

Similarly EUMOFA (European Market Observatory for Fisheries and Aquaculture Products) database considers C. gallina under the generic name “Clam”, mixed with other species of Veneridae family.

In the report for MIPAAF (Ministero delle Politiche Agricole Alimentari e Forestali) drafted by Carlucci et al. (2015) data are reported from direct interviews to the main operators of the sector (COPROMO srl – Fano, Co.Pe.Mo. – Ancona, O.P. Vongole Rimini, I.C.I. Industria Conserviera Ittica – Gradara, Adriatica Pesca – Riccione, Eredi Greco Placido Di Greco Domenico, Oscar & C. S.N.C. – Cattolica).

According to FAO-Fishstat (Table 3) Turkey showed the highest production of C. gallina in 2013 with 28,000t, followed by Italy (14,600 t) and Spain (3,900 t), from the northeast Atlantic coast The rest of the production is represented only by less than 1,000 t (including Atlantic production). The time series from 2000 to 2013 indicates a steady increase of Turkish production whilst the Italian production decreased throughout the same period. The production is at a low in 2005 for both series and reaches a peak in 2012 for the Turkish data.

There is no reported data on production of C. gallina for Croatia, where a settlement of C. gallina is present at the Neretva estuary. However there is negligible fishing activity and most of the catches are harvested manually.

In Italy data are available by region (Table 4), showing that the Adriatic presents the highest harvest of the species for the country.

## 5.2. Price

The price trend for the period 2000-2011 can be observed in Table 5. A maximum of 4.32 Euros per kilo was reached in 2002, dropping afterwards to a minimum in 2012 of 1.88 Euros, halving the value in 5 years. These values correspond to a year of scarcity of the product in 2002 with low productions as seen in table 3 and thus higher prices and high Turkish production in 2007 with a drop in the prices due to greater availability of the product in the markets. Unfortunately official statistics are not available for the period 2012-2014, so the data reported were provided by the operators listed before.

Table 3: Production of Chamelea gallina in tonnes (source: Fao Fishstat)

| Country | FAO Area | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Turkey | Mediterranean and Black Sea | 10,000 | 7,500 | 10,000 | 19,700 | 16,899 | 10,847 | 48,344 | 47,215 | 36,896 | 24,574 | 26,931 | 30,176 | 61,225 | 28,030 |
| Italy | Mediterranean and Black Sea | 34,191 | 34,916 | 25,971 | 41,784 | 37,438 | 14,946 | 19,510 | 28,802 | 24,940 | 17,328 | 19,748 | 19,668 | 20,028 | 14,598 |
| Spain | Northeast Atlantic | 4,390 | 4,881 | 2,789 | 2,690 | 3,686 | 3,939 | 3,394 | 3,520 | 2,967 | 3,162 | 2,360 | 1,137 | 2,552 | 3,867 |
| France | Northeast Atlantic | 696 | 627 | 789 | 767 | 829 | 1,016 | 1,165 | 801 | 666 | 712 | 609 | 600 | 659 | 638 |
| Portugal | Northeast Atlantic | 156 | 48 | 865 | 717 | 210 | 840 | 692 | 253 | 83 | 53 | 20 | 132 | 225 | 255 |
| Greece | Mediterranean and Black Sea | | | | | 215 | 248 | 273 | 324 | 304 | 262 | | 138 | 121 | 121 |
| Spain | Mediterranean and Black Sea | 389 | 240 | 105 | 46 | 65 | 148 | 133 | 78 | 111 | 55 | 53 | 24 | 21 | 49 |
| Slovenia | Mediterranean and Black Sea | | 1 | 1 | 1 | 1 | 3 | | | | | | | | |
| Total | | 49,822 | 48,213 | 40,520 | 65,705 | 59,343 | 31,987 | 73,511 | 80,993 | 65,967 | 46,146 | 49,721 | 51,875 | 84,831 | 47,558 |

Table 4: Italian production of Chamelea gallina by region in tonnes (source: MIPAAF, IREPA)

| Region | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abruzzo | 4,868 | 1,835 | 1,153 | | | 1,414 | 2,946 | 1,611 | 3,127 | 3,364 | 3,793 | 3,854 |
| Abruzzo and Molise | | | | 1,137 | 3,573 | | | | | | | |
| Campania | | | 18 | 21 | 11 | 104 | 336 | 2 | 34 | 34 | 26 | 85 |
| Emilia Romagna | 2,092 | 1,894 | 1,245 | 2,184 | 2,622 | 2,441 | 2,117 | 4,389 | 3,526 | 2,466 | 962 | 2,164 |
| Lazio | 175 | 89 | 75 | 139 | 166 | 126 | 63 | 57 | 68 | 107 | 61 | 46 |
| Marche | 14,394 | 14,485 | 4,788 | 14,894 | 8,528 | 4,527 | 6,023 | 13,338 | 11,763 | 7,257 | 11,544 | 9,699 |
| Molise | | | | | | 245 | 146 | 270 | 375 | 129 | 305 | 363 |
| Puglia | 1,238 | 1,713 | 757 | 171 | 272 | 428 | 1,628 | 2,015 | 1,561 | 2,230 | 1,829 | 1,963 |
| Triveneto | 5,185 | 3,874 | | | | | | | | | | |
| Friuli | | | 998 | 1,109 | 924 | 903 | 730 | 578 | 785 | 318 | 187 | 66 |
| Veneto | | | 3,485 | 5,601 | 6,304 | 4,183 | 4,769 | 6,543 | 3,658 | 1,422 | 1,041 | 1,428 |
| Italia | 27,953 | 23,892 | 12,519 | 25,257 | 22,402 | 14,372 | 18,760 | 28,802 | 24,940 | 17,328 | 19,748 | 19,668 |

Table 5: Average price of Chamela gallina per kg (source: MIPAAF, IREPA)

| Region | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | Sector | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abruzzo | € 1.83 | € 2.09 | € 4.69 | | | € 2.96 | € 2.48 | € 1.82 | € 1.97 | € 2.24 | € 2.09 | € 1.98 | | | | |
| Abruzzo e Molise | | | | € 2.83 | € 2.50 | | | | | | | | | | | |
| Campania | | | € 5.68 | € 7.70 | € 6.96 | € 2.64 | € 3.37 | € 8.85 | € 5.68 | € 7.01 | € 4.52 | € 4.20 | | | | |
| Emilia Romagna | € 2.23 | € 2.51 | € 3.55 | € 2.38 | € 3.47 | € 2.84 | € 2.61 | € 2.39 | € 2.75 | € 4.28 | € 3.17 | € 2.77 | Rimini | € 2.24 | € 2.46 | € 2.55 |
| Lazio | € 3.61 | € 6.69 | € 5.97 | € 9.46 | € 9.59 | € 8.92 | € 7.78 | € 8.14 | € 6.10 | € 5.51 | € 5.22 | € 5.57 | | | | |
| Marche | € 2.19 | € 2.90 | € 3.94 | € 3.58 | € 4.08 | € 3.52 | € 2.41 | € 1.67 | € 2.17 | € 2.79 | € 2.70 | € 2.94 | Pesaro | € 2.57 | € 2.76 | € 2.82 |
| Molise | | | | | | € 3.42 | € 3.57 | € 2.57 | € 2.50 | € 2.81 | € 2.79 | € 2.42 | | | | |
| Puglia | € 2.15 | € 3.46 | € 8.61 | € 6.02 | € 4.43 | € 4.85 | € 3.94 | € 2.40 | € 2.87 | € 2.96 | € 2.89 | € 2.88 | | | | |
| Triveneto | € 2.09 | € 3.26 | | | | | | | | | | | | | | |
| Friuli V.-G. | | | € 4.89 | € 2.98 | € 3.57 | € 4.32 | € 4.12 | € 3.05 | € 2.73 | € 4.26 | € 4.52 | € 4.19 | | | | |
| Veneto | | | € 3.85 | € 2.94 | € 2.60 | € 2.64 | € 2.20 | € 1.61 | € 1.80 | € 3.05 | € 3.11 | € 2.21 | | | | |
| Italy | € 2.12 | € 2.92 | € 4.32 | € 3.33 | € 3.36 | € 3.22 | € 2.63 | € 1.88 | € 2.25 | € 2.99 | € 2.67 | € 2.68 | | | | |

## 5.3. Italian market

In Italy, the clam market is represented by a direct relationship between the producer and some major buyers. To ensure a constant supply of product throughout the year, business relationships are established with both boats stationed in the ports closer to the headquarters of the company and located in various Adriatic ports. The number of reference boats depends on the size of the company and the ability to trade.

Currently only three producer organizations are recognized:

- OP Bivalvia Veneto s. c., which operates in Veneto and associates 75 boats belonging to the consortia management of Venice and Chioggia;
- O.P. Clams in Rimini, which associates 12 boats;
- Organization of clams producers of Teramo - Soc. Coop. a r.l., which heads 32 boats operating in the maritime district of Pescara.

In the compartment of San Benedetto del Tronto there is a form of sale by auction. Founded originally as online auction now is made verbally or by telephone. Also 27-28 boats, of a total of 57 belonging to the Consortium of Clams Piceno (Co.Vo.Pi.) participate at the same auction market. The auction system is based on an average price that is calculated at the end of the day on the basis of the quantities sold and the amount obtained.

## 5.4. European clams market

The European market for clams is essentially made up of two countries: Italy and Spain. Although no official figures are available on the export of this mollusc, it is believed that a few years ago, the Spanish market was able to absorb more than 50% of national production, whereas now it imports about 30%. This decrease is determined by two main factors: competition from local product, mainly from the Gulf of Cadiz, and the risk of penalties and disputes due to potential presence of product with size below the legal one.

This factor strongly influences the Italian market. The obligation to market bigger clams according to the legal size clams, as required by the EU Reg. 1967/2006, and the resulting penalties, constitutes in fact a strong deterrent to the purchase by large consumer groups, because the possibility of presenting some specimens of size below the legal one is not to be excluded. This has resulted in a significant loss of market share, primarily to the benefit of the Manila clam (Ruditapes philippinarum) sourced from aquaculture, resulting in a change in eating habits of consumers, who are gradually replacing the clam C. gallina, now less available from major retailers, with the latter species.

## 5.5. Minimum landing size

Given the current situation of the resource, the possibility of being able to freely market clams of a size 2-3 mm below the MLS, is viewed favourably by all operators interviewed in the framework of the study carried out by Carlucci et al., 2015. The authors stated that from the commercial point of view a possible reduction of the minimum legal size of the clams complemented by a tolerance of at least 5% is seen willingly from a fishery perspective. Another prerequisite is that the production sector would be able to handle the

influx on the market and also be equipped with tools, such as, for example, producer organizations.

The same authors reported that there would be no impact of such measure on consumers, as the market has, already dealt with this type of product (Romanelli et al., 2009). It is also believed that this can stimulate recovery in domestic consumption and of new markets, with the ability to differentiate products by size and, consequently, by price.

## 5.6. Impact on stock

The study from Carlucci et al. (2015) provided a series of simulations of the impact on the stock of the reduction in the minimum landing size from 25 to 22 mm.

The main conclusion of such simulations is that the elements in favour of the reduction (socio-economic) are balanced by negative elements (biological) that would require a precaution. In the absence of a clear dominance of one over the other, therefore, the final decision can only be taken on the basis of other factors.

However, as stated also in the report, taking into account the huge uncertainties in the biological parameters of the populations inhabiting the Adriatic Sea as well as the strong decrease in the availability of the resources a reduction in 3 mm of the minimum landing size would not be in agreement with good practices of sustainable exploitation of fishery resources.

From a management perspective the tolerance of not more than 5% in the catches below the minimum landing size would be a practical and reasonable measure. However the introduction of such flexibility should be carefully implemented and an efficient control system need to be cautiously established, taking also in account the newest technologies available, such as automatic measurement tools.

# 6. CONCLUSIONS AND RECOMMENDATIONS

- The Adriatic Sea clam fishery is characterized by high fishing pressure and environmental impact caused by the fishing gear employed.
- The historical trend shows a clear decline in annual landings from 100,000 tonnes in the early 1980s to the current 14,000 tonnes.
- Despite different studies throughout time, the causes of the decline in clam production remain uncertain and negative impacts both by the high exploitation rate and unknown environmental factors have been assumed.
- Considerable year-to-year fluctuations are indicative of a resource and fleet heavily dependent on substantial recruitment events.
- Several management measures have been put in place to sustainably manage the resource. However, control and enforcement needs to be strengthened for the measures to be adhered to and thus be efficient in preserving the resource.
- Seeding or restocking seems a good option for certain areas. However, additional surveys in both the donor and receiving areas would be necessary. Restocked areas would have to be closed to fishers until most of the seeded clams had reached marketable (and also reproduction) size.
- It takes two years for an individual clam to reach the minimum marketable size of 25 mm. Sexual maturity is reached within the second year of life with an average size of 20-25 mm. The minimum landing size (MLS) imposed by the EU Reg. 1967/2006 is thus in line with the sexual maturity to ensure sustainability of resource exploitation.
- High intensity of fishing effort ensures the capture of the majority of an annual cohort when it reaches the MLS, thus reducing considerably the reproduction potential of the resource.
- Adriatic Sea clams are under huge market competition mainly, from Turkish product as well as from other clams of European origin due mainly to penalties on undersized clams that act as deterrent for large customer groups.
- Reducing the MLS would help the Adriatic clam sector recover market share. However, given the uncertainties that characterise the evolution of stock status of Adriatic Sea resources, a reduction in 3 mm of the minimum landing size would not be in agreement with the precautionary approach and it is therefore not advisable.
- A long term monitoring is needed to provide better evaluation of the resource status as well as of the main biological parameters of C. gallina.
- Applicability of other management measures needs to be examined, such as a rotation regime, annual fishing permits, establishment of harvest control rules (catch or effort quota) balanced with the status of the resource and hence based on fishery independent surveys carried out by scientific institutions and, VMS equipment installed in all the vessels using hydraulic dredges to ensure compliance.

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