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A glimpse on the mollusc industry in Europe

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1. European mollusc production: some key values

Nowadays Europe produced per year 800,000 tons of mollusks, representing a turnover of 1,100 million euros and induced 37,000 direct employments, corresponding to 50% of global EU aquaculture production in weight and about 30% in value.

The main farmed species are mussels (*Mytilus galloprovincialis* and *M. edulis*), oysters (*Crassostrea gigas*, *Ostrea edulis*) and clams (*Ruditapes spp*). Cultivated in most of European countries they are however not equally produced, some of them taking advantages of suitable environmental conditions for targeted species.

2. Molluscs farming in France

Several species are produced in France but the cupped oyster dominates clearly the national production. In 2010 France produced ≈194,000 tons with 39% of mussels (*Mytilus edulis* and *M. galloprovincialis*: 76,000 tons of which 60,000 tons were issued from aquaculture), 59% of oyster *Crassostrea gigas* (113,000 tons) and 2% of miscellaneous (3,800 tons) such as cockle *Cerastoderma edule*, clams *Ruditapes philippinarum* and *R. decussatus*), the King scallop *Pecten maximus* and the flat oyster *Ostrea edulis*). It generated a turnover of 360 million euros and 9,300 full time employments (http://agriculture.gouv.fr/les-assises-de-la-concyliculture.

The cupped oyster is produced from the Channel to the Mediterranean Sea, in different locations (seashore, closed bays, pounds) using different techniques. Bretagne (30%) Poitou-Charentes (24%) and Normandie-Mer du Nord (19.5%) are today the three main producing areas; whereas Pays de Loire, Arcachon-Aquitaine and Méditerranée accounted each for 8.5 to 9.5% (Fig. 1). The techniques used are related to the presence (or not) of tide. Coasts with tides (Atlantic and Channel) are devoted to the ground method where oysters are laid on the ground. They can be grown on seashore, or in deep water, in protected shallow bays at 10-15m depth. This technique which used to be very popular for the cultivation of the native flat oyster before the 70s‟ is now replaced by the cultivation of oyster in bags held on trestle (Fig. 2a). In the Mediterranean where low tide occurs the hanging culture technique (Fig. 2b) using cultch or cemented oysters, predominates (Fig. 2c).

Cultivation lasts 2 to 4 years depending on the area, the technique applied and the type of seed used (hatchery/wild; triploid/diploid). 70% of seed come from natural collection in two main spatting areas, Bay of Arcachon and Bay of Marennes-Oléron. Due to global temperature increase, two new oyster collecting areas took place in northern location (Bays of Bourgneuf and Brest). Oyster hatcheries cover more than 30% of the seed demand with 90% of triploids. France accounted 15 oyster hatcheries of which 4 are major producers with yearly supply > 300 millions of spat.

At the beginning of the 1970s, massive importations of spat and genitors were made from Japan and Canada (British Columbia) into France to restart the industry after the principal species *Crassostrea angulata* almost died out. During 20 years no major troubles affected *C. gigas* production in France except its reproduction in Arcachon for five successive years from 1976 to 1981 (His et Robert, 1987) and carrying capacity problems in the bay of Marennes-Oléron (Bacher et al., 1991). Until 1994, *C. gigas* mortality was occasional but some events occurred thereafter, concerning mainly the juveniles (Soletchnik et al., 2001). Because of its geographic extension and occurrence a National Program (MOREST Project) was set up from 2001-2006 to try to understand this phenomena (Samain and Mc Combie, 2008). Despite some sporadic peaks of mortality the yearly mean never exceeded 20%. Situation

has changed suddenly from 2008 due to Oshv1 herpes virus disease with juvenile mortality > 70%. Despite important research efforts and significant results this problem is still a major concern for oyster farming in France today (http://archimer.ifremer.fr/doc/00077/18830/16406.pdf). To counterbalance such disease *C. gigas* breeding programs have been developed for resistance to OsHV-1 from 2010 by two private companies (SFC and Geneocean), and from 2012, by a public–private consortium through SCORE project.

The European mussel (*M. edulis*) is produced along the Channel and Atlantic coasts whereas the Mediterranean mussel cultivation (*M. galloprovincialis*) occurs as far north as northern Brittany (St Brieuc Bay) and hybrids are found from south Brittany to Arcachon Bay. Spat is exclusively collected in the natural environment, by setting, generally on coconut rope, along the Atlantic and Mediterranean coasts. Spat of around 1 cm is dispatched to different mussel production areas where they are kept in a net and will grab on different substrates, including rope (long lines) and wooden posts ("bouchots"). Mussel cultivation until marketing lasts 9-15 months, depending on production areas (Fig. 1), species and culture techniques : on the ground, on "bouchots" in Normandy, Brittany and Poitou-Charentes, under racks in Mediterranean lagoon, in long lines (on surface in Brittany, partially submerged in Poitou-Charentes, submerged in the Mediterranean off shore). Since three years a decrease in *M. edulis* growth performances has been recorded (particularly in 2011) on the Atlantic coast and a survey network named MYTILOBS is in development.

From the 70"s and 80"s two successive diseases affected *O. edulis* production in Brittany (main area in France for its culture) and the population dropped from 20,000 tons to 1,000 – 1,500 tons y^{-1} nowadays. Despite several attempts to control marteiliosis and bonamiosis in natural surroundings the flat oyster population has never recovered. This situation was quite similar for most countries in Europe (Laing et al., 2005) and, in this context flat oyster farming consists in improving oyster growth before the fateful limit of 3 years old or equivalent size. Spatfall, which had been carried out in intertidal areas on clusters of lime-coated tiles since the 19th century, has been developed over the past two decades in offshore areas on suspended mussel shells (Bays of Brest and Quiberon). Since diseases, flat oyster culture has also been moved to marine areas (Cancale and Quiberon) where the oysters are seeded in low densities (100 individuals m-²) and harvested after 2-3 years of rearing. Due to heavy mortality on *C. gigas* juveniles, progress in genetics and a better mastering of *O. edulis* production in hatchery, this species has recently recovered some interest in Brittany with the research and development project PERLE (http://www.pole-mer-bretagne.com/perle-pour-une-reintroduction-durable-de-lhuitre-plate.php).

The King scallop *Pecten maximus* aquaculture is closely linked with fishing (restocking and management of common scallop beds) but aquaculture activity has been developed in the Bay of Brest since 25 years. As in most areas, the King scallop population in Brest declined after the icy winter of 1962-63. A restocking program was settled based on nursery spat production, after previous unsuccessful juvenile collection in the wild. After production in hatchery nursery from 90 µm to 2 mm and on-growing in protected cages from 2 mm to 30 mm, juveniles of 1 year-old are seed offshore on grounds and extensively culture until their market size 2-3 years later. There is only one hatchery in France dedicated to King scallop production, located in Le Tinduff in Bay of Brest, with a yearly production of 8 million of 3 cm spat (the largest hatchery nursery in scallop in Europe) which is also producing, nowadays, the variegated scallop *Chlamys varia*.

The cockles *Cerastoderma edule* are mainly fished along the French coasts, from the Channel to the Mediterranean. Since the 1980s, cockle culture has been developing in Le Croisic Sound, which is the only cockle aquaculture site in France. Spat of around 1 cm is collected by dredging in Bay of Vilaine and is reseeded from mid-September to mid-May at a density of 3-4 kg m^{-2}. After 10 to 15 months cockles are harvested mechanically and graded

on site. Annual cockle yields range from 1,200 to 2,000 tons, and Le Croisic Sound is the second ranking cockle production site in France after Somme Bay (2,000-7,000 t fished).

As the cockles, the abalone *Haliotis tuberculata* is mainly fished in France but its production through Aquaculture is recent but efficient. Three French SMEs produced abalones of which "France Haliotis" is the first sea-based ormer farm in France and the largest in Europe. Production is confidential but targeted to a niche market.

3. Molluscs farming in Spain

According to the Spanish Aquaculture Observatory Foundation (Indicators 2010), the marine aquaculture production in Spain is around 260,000 tons per year. Shellfish production accounts for 81.6%, fish 18.1% and the remaining 0.03% is mostly crustaceans and algae. Cultures of mollusks are mainly concentrated in the Atlantic region, NW Spain (Galicia) and the mussel, *Mytilus galloprovincialis*, is the dominant culture, with an average annual production between 210,000 to 225,000 tons. Mussel farming is more than 80% of all marine aquaculture in Spain and 95% in Galicia. Several species of clams are also grown in Galicia, mainly *Ruditapes phillipinarum* (1,225 tons), *R. decussatus* (200 tons), and *Venerupis pullastra* (150 tons). The other important bivalves are the cockle *Cerastoderma edule* (900 tons), the flat oyster *Ostrea edulis* (862 tons), and the Japanese oyster *Crassostrea gigas* (314 tons). With respect to other regions of Spain fish production is more important than mollusk production. 200 tons of bivalves are produced in Asturias, 300 in Cantabria, 3,000 in Cataluña, 270 in Valencia, 155 in Islas Baleares and 400 in Andalucía. All these regions have developed research programs to support the recovery and development of the production for oysters, clams and mussels.

The production of the mussel, *Mytilus galloprovincialis*, has been stabilized in recent years because of the strict regulation by the authorities (Fig. 3). The number of rafts, the number of ropes per raft, the length of the strings, the places of cultivation (etc.) have been regulated. In Galicia the mussel culture is based on natural seed collection on rocks and the use of collectors in the rafts. Mussels in Galicia have never suffered from parasites (*Mytilicola*, etc.) or other pathogens that have significantly affected the production which, however, faces two current problems. The first difficulty is commercial and refers to the low price in origin, resulting from the trade war with the major Spanish canned food industry. For decades, 70% of production was used in this industry and 30% was sold as fresh product. Now the ratio is roughly 50/50. This implies a decline in prices as a result of the importation of mussels from other countries and the difficulty to sell a lot of fresh mussels in specific periods. The second concern is the proliferation of toxic tides. It seems clear that toxic tides have increased in the last decade originating significant periods of non-marketing and losses for the sector. Probably the future of mussel culture will require technological development that optimizes production and new forms of presentation, processing and marketing. The mussel culture has a social and economic importance because it employs about 15,000 persons in 2,400 familiar micro-companies and generates incomes of 470 million euros per year.

The situation is very different for the other mollusks. The flat oyster, *O. edulis*, is very popular and has a wide potential market but its production has been reduced in the past years; from the presence of almost 900 farming points 40 years ago there are not more than 80 today. Overfishing and massive importation of seed and adult parasitized with *Marteilia refringens* and *Bonamia ostreae* have drastically reduced its production. Small banks with oysters more resistant (or tolerant) to *Bonamia* have been currently detected and research programs have been initiated with those banks with the aim of recovering the culture of flat oyster, as one of the profitable alternatives to the monoculture of mussels. Meanwhile the Japanese oyster (*C. gigas*) cultivation has been authorized in recent years, with an easy adaptation to cultivation

in rafts, with high yields and no apparent problems so far. Several hatcheries are producing seed of both species of oyster, and different lines of research have been developed to optimize its production; there are not however supplying more than 10-15% of the seed market requirements. Hence the culture is based mainly on the import of seed and 12 to 18 month-old oysters from several European countries.

For clams (*R. phillipinarum*, *R. decussatus* and *Venerupis pullastra*) five hatcheries are presently operating. They mainly provide seed for local associations of producers. Most of the production takes place in private parks (concessions for a period of years) and on beaches that are managed by local associations. The problem in clams is the same than in the global shellfish aquaculture: high quality seed availability. This problem has becoming crucial in the past years due mass mortalities caused by various pathogens (as *Perkinsus*), after the massive and continuous importation of small clams to restock the parks. Therefore, there is a growing interest in producing Spanish hatchery seed. To sustain this activity a close collaboration with research centers has been developed recently to master process in hatchery. However, clam farming still depends currently on natural regeneration of parks and imports of foreign juveniles.

Finally, the cockle, *Cerastoderma edule,* is therefore socially and economically important in specific areas. It mainly relied on fishing, although the production of cockle seed from hatchery is in progress.

4. Molluscs farming in Italy

Italian shellfish farming relies almost entirely on two species, the Manila clam *Ruditapes philippinarum* and the Mediterranean mussel *Mytilus galloprovincialis.* The main production areas for both species with landings data are reported in Fig. 4. The production of other mollusk species, such as Pacific oyster *Crassostrea gigas* and carpet shell clam *Ruditapes decussatus* could be considered as marginal, representing less than 1% of both global biomass harvest and economic incomes.

After China, Italy is the second world largest producer of Manila clam with official data reporting 35,700 tons landed in 2010 for a global income of over 90 x 10^6 Euro (Fao, Fishstat 2011). A study recently carried out using other data sources (local farmers cooperatives) reported for Italy a production of 50,600 tons in 2008 (Zentilin et al., 2008). Over 95% of the production belongs to the North-Eastern part of Italy (Venice lagoon, Grado-Marano lagoon and Po delta transitional waters: Fig. 4). *R. philippinarum* is native from subtropical to low boreal part of western Pacific and it was introduced in Venice lagoon in the early „80s. It rapidly spread to all favorable sites of Northern Adriatic transitional systems, characterized by shallow waters, high freshwater inputs rich in nutrients and high natural productivity, where the harvesting of Manila clam soon became the most economically important fishing activity (Pellizzato and Da Ros, 2005). The Italian landings data indicate that clam production rapidly increased peaking at about 64,000 tons in 1999 (Zentilin et al., 2008). However a constant decrease occurred in the last decades, as a consequence of the initial lack of reliable regulation, the adoption of unsustainable regimen of exploitation of natural clams" beds, illegal gathering and the use of high-impacting clam harvesting gears with consequent detrimental effects on benthic compartment (e.g. alteration of groundmass, alteration of benthic communities). The clam production is currently based on managed fishing and farming. Clam fishing is carried out in areas controlled by local Authorities under strict rules concerning size, amounts and fishing gears. Clam farming depends almost entirely on natural recruitment of natural spat that is collected (in specific natural “nursery areas”) and seeded in shallow areas managed by fishermen"s cooperatives (Fig. 5). Only a very small amount of spat is supplied by hatcheries. Local farmers used to seed “large” spat (>10-12

mm) in order to prevent high losses due to predation. The duration of rearing cycle depends on the initial spat size, seasonality and the environmental features of the farmed areas and accordingly commercial size (> 30 mm) is reached in 6-20 months. Different typologies of gears are used to collect Manila clam (hydraulic or vibrating dredges, hydraulic or manual rakes). About 70% of Italian production is consumed internally, whereas the remaining is exported.

Unlike clam culture, the Mediterranean mussel production in Italy is carried out in many different coastal regions (Figure 4). Italy is the third producer in the world of this specie (after China and Spain), with a national production of 64,260 tons and a global income of 41 x 10^6 Euro in 2010 (Fao, Fishstat 2011). Two main culture typologies are commonly used: suspended offshore long-lines in the coastal areas and suspended inland rows in enclosed areas. In both cases the culture methodology is similar. Mussel spat is collected from natural beds or, more generally, on spat collectors. The season of collection is April-May. Clustered mussel (size: 20-30 mm) are twisted round plastic nets and then hung on ropes in the farming installation for further growth. Depending on the location, mussels may also be sorted thereafter and re-socked or otherwise manipulated (e.g., to remove fouling organisms) prior to the final harvest for market. In case of inland culture the mussels‟ bags are directly hung to the row while in case of offshore culture the mussels‟ bags are tied to a series of backlines, single or paired, anchored at both ends and floated in the water by buoys (Fig. 5). In both cases the duration of farming cycle is 12-18 months, depending on initial size and environmental features of the farmed area. About 90% of Italian production is consumed internally, whereas the remaining is exported.

5. Molluscs farming in the Netherlands

In the Netherlands, three species of bivalve shellfish are farmed. The blue mussel *Mytilus edulis* (production of 38,000 tons in 2011), the Pacific oyster *Crassostrea gigas* (production of 19 million in 2009 ≈ 1,500 tons) and the European oyster *Ostrea edulis* (production of 1 million in 2009 ≈ 100 tons). The main production method is farming on bottom plots (Fig. 6). Mussels are produced in the Western part of the Dutch Wadden Sea in the Northwest of the country and in the Oosterschelde estuary in the Southwest. Some rope culture of mussels takes place in old harbors in the Oosterschelde. After ≈ 2 years, mussels are sold through an auction at Yerseke in the Southwest of the Netherlands. Processing takes place after a recovery period of at least 1 week on re-watering plots near Yerseke. Oysters are produced in the Oosterschelde estuary and the nearby saline Lake Grevelingen. They take 3 to 5 years to reach market size.

Production starts with collecting seed and spat in the wild. Mussel seed is fished from seed beds which generally occur in the Wadden Sea. It is then transported to the culture plots in the Wadden Sea and Oosterschelde. The mussel farmers are in a transition process from fishing seed to harvesting seed with suspended collectors. This is a response to pressure from society to reduce bottom dredging and the desire to safeguard a steady supply of seed mussels. A seed collector consists of nets or ropes that are placed in the water column in spring when larvae are present. At the end of summer the seed is harvested from the collectors (Fig. 6) and transferred to the bottom plots A stepwise approach is taken: every two years a decision on reduction of the area open to seed fishing and expansion of the area reserved for seed collection is made based on the annual yield of the collectors. The first tests with seed mussel collectors started in 2000 and the method showed a rapid development. In 2011, the harvest was 9,000 tons. Oyster spat is collected on empty mussel shells. These shells are sown on bottom plots and harvested after spatfall has taken place. Then they are moved to the on-growing plots. Recently trials have started using suspended

collectors for oysters. Nets with empty mussel shells are used, but also collectors from France such as Chinese hats.

Since 2005, two shellfish hatcheries have been established in the Netherlands. They produce seed of mussels (*M. edulis*), oysters (*C. gigas* and *O. edulis*) and clams/cockle (*Ruditapes phillipinarum*, *R. decussatus*, *Cerastoderma edule*). Efforts are put into improving shellfish hatchery technology with recirculation systems and large-scale outdoor continuous algae production to decrease the costs. Still, this production method is more expensive than collection of seed in the wild. However, hatchery production offers opportunities for product improvement through selective breeding. Selection of oyster strains that are tolerant to diseases such as *Bonamia* and herpes virus is currently being carried out. Grow-out of Manila clams takes place at pilot scale in bottom plots. Furthermore, pilots are conducted to grow oysters in cages.

In the Netherlands, the coastal zone where shellfish production takes place is a heavily used area in which many stakeholders interact. As a general trend we see a shift towards other production areas. Since 2009, on-land shellfish production is carried out at three pilot locations in the Southwest of the Netherlands. One pilot cultures mussels and uses naturally growing algae from a pond that is supplied with groundwater. One pilot cultures Manila clams (*R. philippinarum*) and grows algae (*Skeletonema* sp) in aerated ponds to which nutrients are added. And the third pilot grows Manila clams in combination with ragworms (*Nereis diversicolor*) and sole (*Solea solea*). The ragworms and sole supply the nutrients for separate algal ponds. The technical and economic feasibility of on-land culture in these pilots is being studied. In addition, pilots for off-shore mussel production are being developed. The North Sea conditions are rough in comparison to most off-shore culture locations in the world. This concerns both maximum wave height and maximum current speed. However, mussels have been cultured under circumstances comparable to North Sea conditions. Submerged long-lines appear to be the most suitable technique. Off-shore culture can become economically feasible for market size mussels, but not for seed production.

6. Molluscs farming in Ireland

Irish shellfish culture is traditionally located in economically marginalized, peripheral regions of the country. The current value of the shellfish production industry is €47m. Although the majority of production is of the blue mussel and the Pacific oyster, small-scale production of other species such as native oyster, *Ostrea edulis*, King scallop, *Pecten maximus*, clams, *Ruditapes philippinarum* and abalone *Haliotis discus hannai* also takes place and these species make an important contribution to the overall value of the sector. The sector is strategically important to rural communities, employing 480 full-time positions, 340 part-time and almost 700 casual workers.

Irish mussel culture (*Mytilus edulis*) is the country"s largest shellfish production sector with a total production volume of approximately 23,000 tons per annum and value of €16.2m. Production is by means of suspended rope culture and bottom culture. At present production levels, rope cultivation accounts for 80% of the total mussel production (by volume), largely due to a steady decline in the production of bottom cultured mussels in recent years. Cultivation of the Pacific oyster, *Crassostrea gigas*, has steadily increased in the last decade and the current production volume is almost 8,000 tons per annum with a value of approximately €28.5m. Pacific oysters are cultivated using the traditional bag and trestle technique. Much of the blue mussel production is concentrated along the Western seaboard whereas the primary regions for Pacific oyster cultivation are in Dungarvan Bay, County Waterford and Carlingford Lough (Fig. 7). The supply of seed/spat and the threat of biotoxins and disease are the major biological issues concerning these sectors.

Although the shellfish production industry has considerable scope to expand in the future, the industry is presently faced with a number of challenges that must be carefully managed in order to allow the industry to achieve its full potential. Of foremost importance, the sector is currently embroiled in a prolonged restructuring of the licensing and regulatory arrangements that govern the multiple-users of the foreshore and, with 80% of the industry located in the vicinity of the Natura 2000 network of protected sites, progress in granting or renewing licenses has been stymied whilst the regulatory bodies ensure compliance with the EU Birds and Habitats Directives. This issue has also created confounding problems along the production chain because the capacity and continuity of supply does not exist to address other issues that constrain the industry such as improving efficiency in production and processing, gaining a competitive advantage in international markets and improvement of the marketing and quality assurance frameworks that support the industry.

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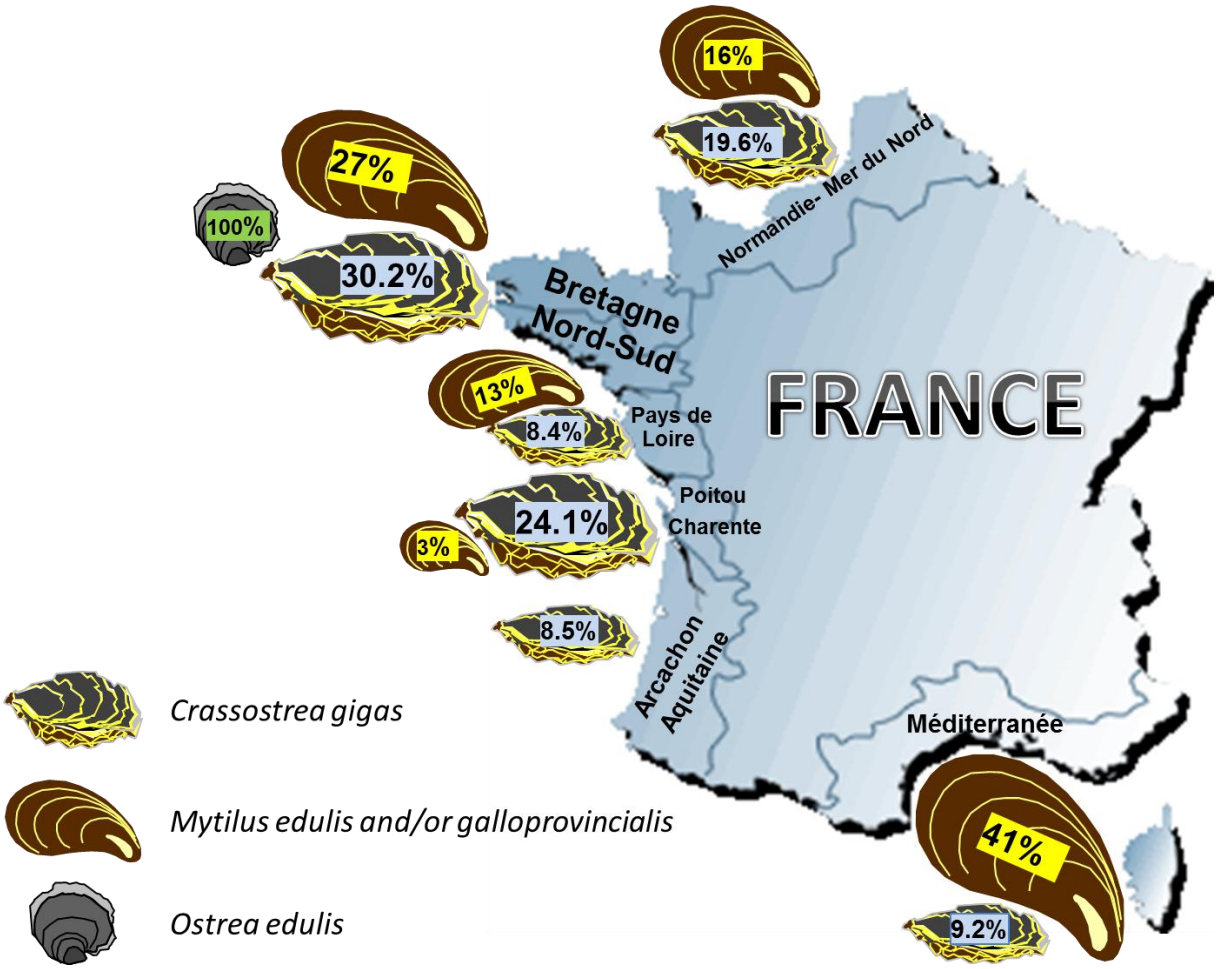

Figure 1: Repartition of oyster and mussel productions in France.

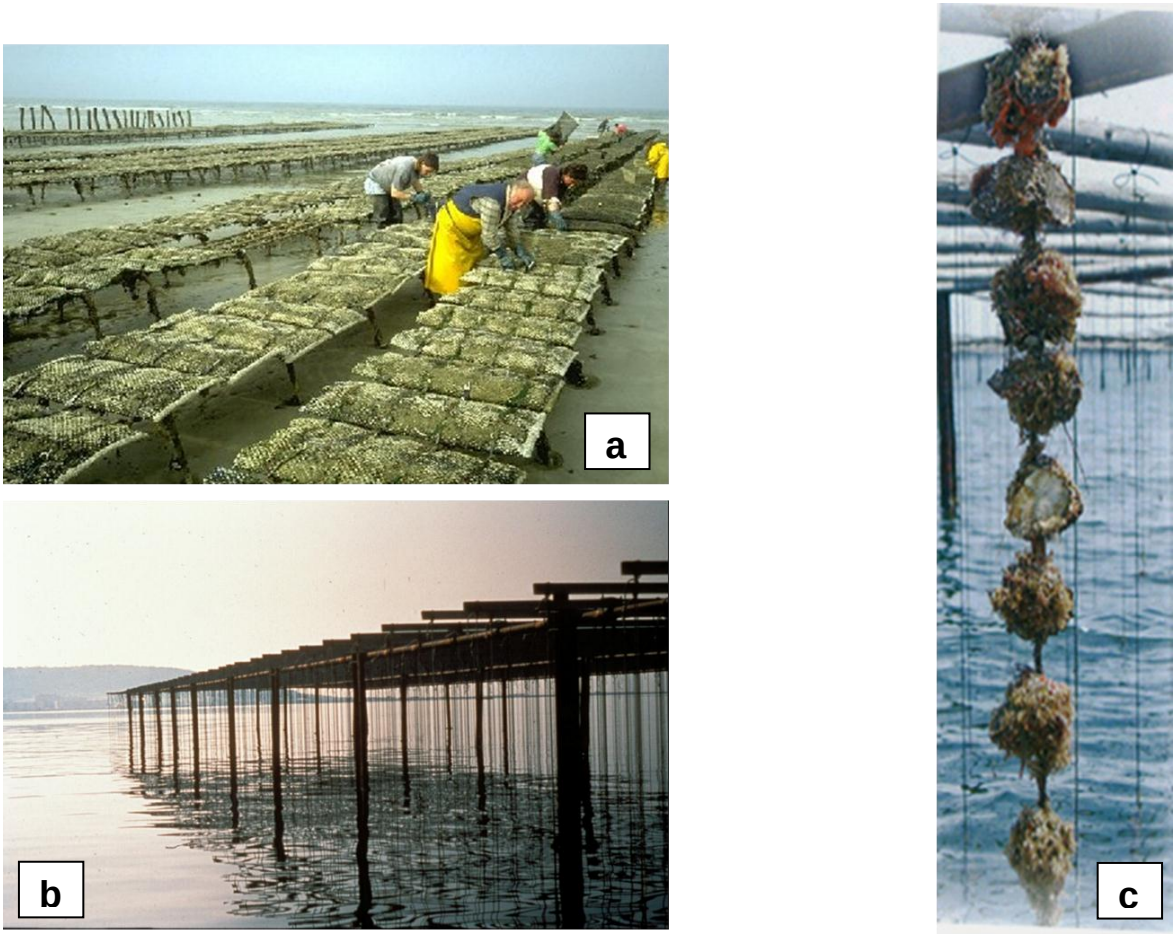

Figure 2: Oyster rearing techniques: bags on trestles (**a**), raft (**b**) and details of hanging culture (**c**), France (Brittany and Thau lagoon).

Figure 3: Mussel rearing techniques: raft and boat (**a**) and details of hanging culture (**b**), Spain (Galicia).

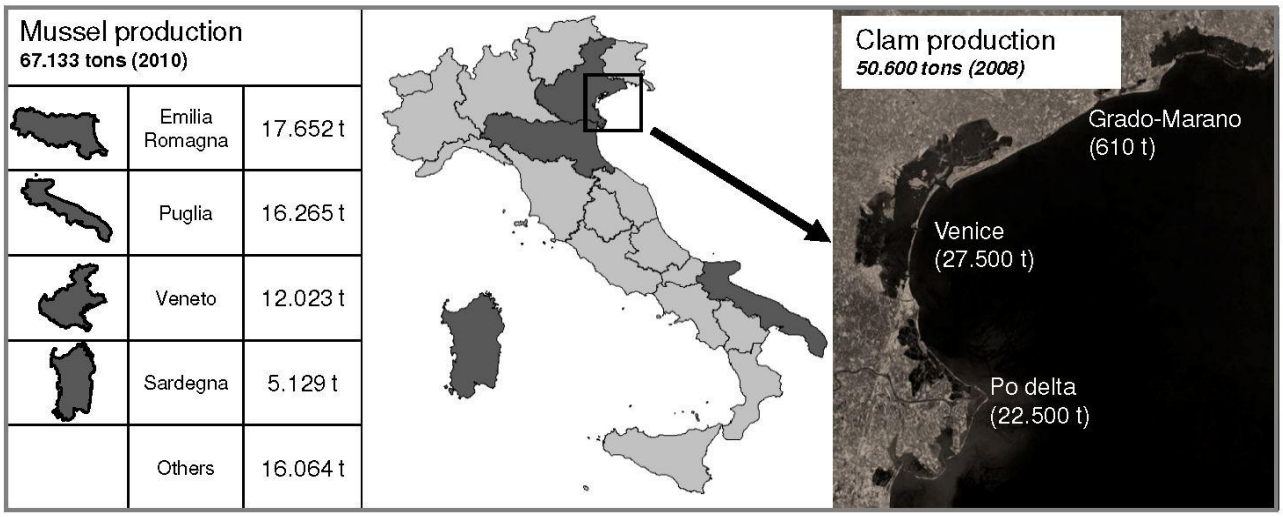

Figure 4: Italian mollusc production sites and landings data. Manila clam data (right panel) from Zentilin et al., 2008; Mussel data (left panel) from Prioli, elaboration of institutional data (Ministry of Agricultural, Food and Forestry Policies).

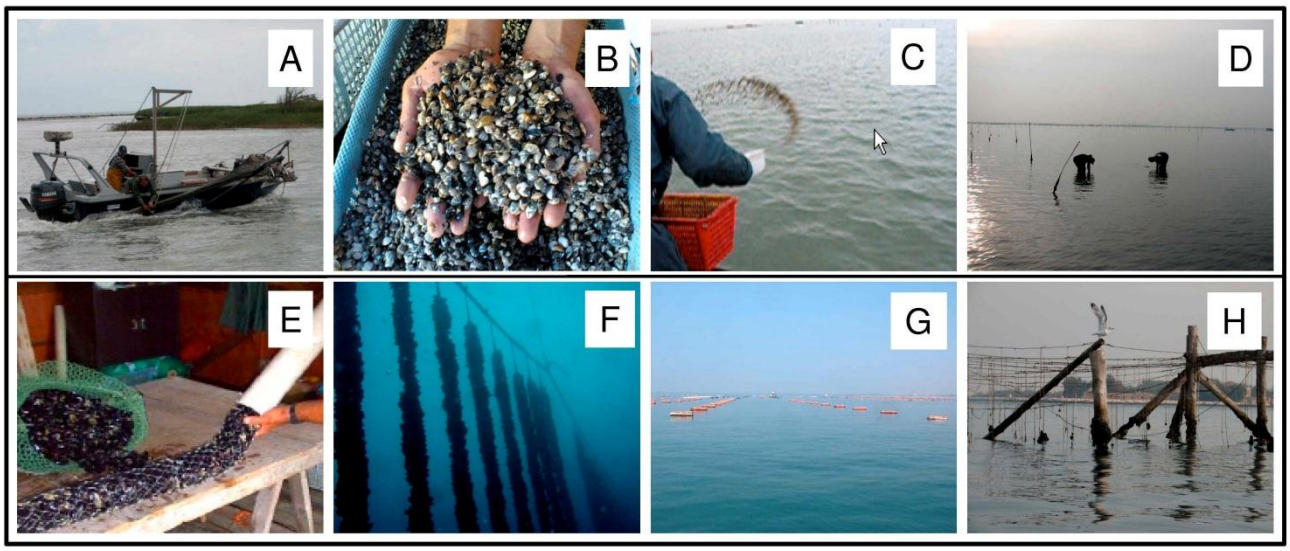

Figure 5: Upper panel: Manila clam (*R. philippinarum*) culture in Italy: A and B) wild spat collection; C) seeding of spat in areas managed by farmers; D) maintenance activity in the areas and survey to verify growth and densities. Lower panel: Mediterranean mussel (*M. galloprovincialis*) culture in Italy: E) set-up of mussel net bags using collected wild spat; F) arrangement of bags onto backlines; G) mussel culture in suspended offshore long-lines; H) mussel culture in suspended inland rows**.**

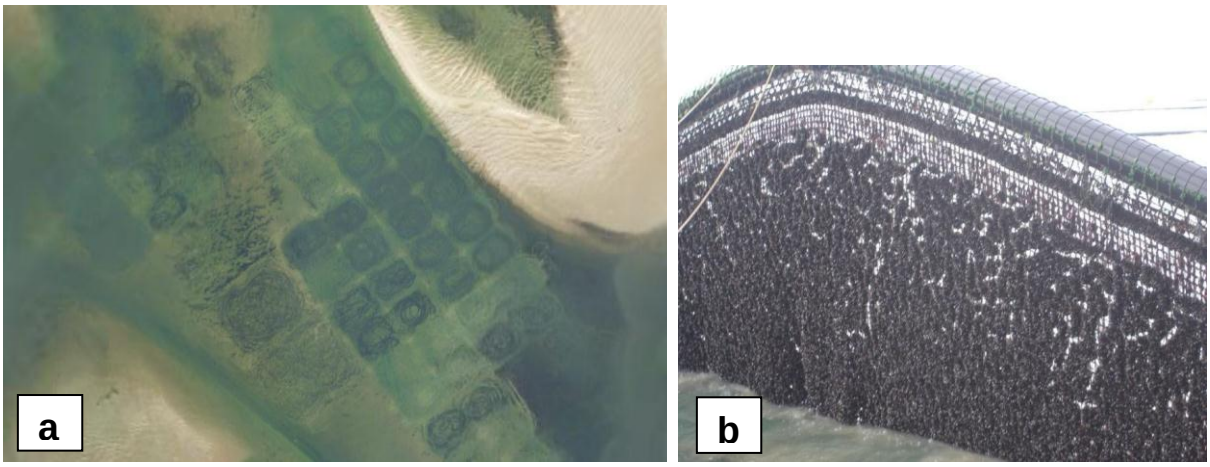

Figure 6: Mussel bottom plots in the Oosterschelde estuary, SW Netherlands (a) and a net with mussel seed (b) in Holland.

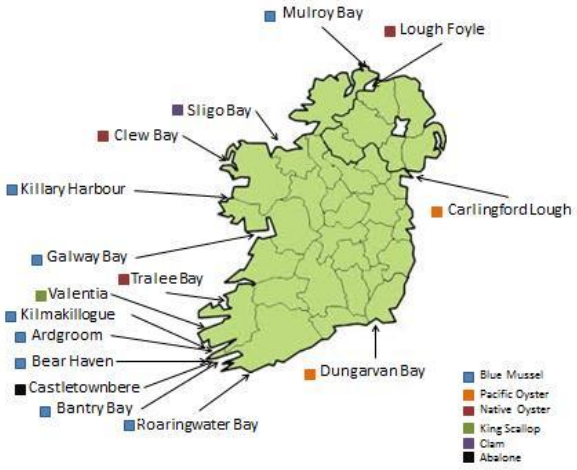

Figure 7: Main shellfish production sites in Ireland