4

Manila Clam (*Tapes philippinarum* Adams & Reeve, 1852) in the Lagoon of Marano and Grado (Northern Adriatic Sea, Italy): Socio-Economic and Environmental Pathway of a Shell Farm

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1. Introduction

Manila clam is a subtropical to low boreal species of the western Pacific, distributed in temperate areas of Europe. The natural populations are distributed in the Philippines, the South China and China Seas, Yellow Sea, Sea of Japan, the Sea of Okhotsk, and around the Southern Kuril Island (Scarlato, 1981). Its culture was initiated in those areas from the initial traditional fishing activities by the collection of wild seeds.

As a species of commercial value, Manila clam has been introduced to several parts of the world, to become permanently established in several areas. The species was accidentally introduced the 1930's to the Pacific coast of North America along Pacific oyster *Crassostrea gigas* seed import (Chew, 1989). The species naturally spread the Pacific coast from California to British Colombia (Magoon & Vining, 1981). Besides public fisheries, hatchery production has facilitated Japanese carpet shell culture along the Pacific coastline. Manila clam was also transferred from Japan to Hawaiian waters early in the 20th century, where wild populations still occur. Overfishing and irregular yields of the native (European) grooved carpet shell, *Ruditapes decussatus*, led to imports of *R. philippinarum* into European waters.

In 1972, the species was introduced into France by a commercial hatchery where they cultivated since the early 1980's (Goulletquer, 1997). The aquaculture development was facilitated by commercial hatcheries and additional imports from the United Kingdom using broodstock from Oregon (USA), resulted with numerous transfers within the European Union borders (Portugal, Italy, Ireland, Spain). Moreover, aquaculture experiments resulted in seed imports into Belgium, Germany, Israel, Tahiti, Tunisia, (Cesari & Pelizzato, 1985; Shpigel & Friedman, 1990).

In March 1983 the species was introduced in Italy in the Venice Lagoon (South Basin) by purchasing the seed from an English hatchery (Breber, 1985) (Fig. 1).

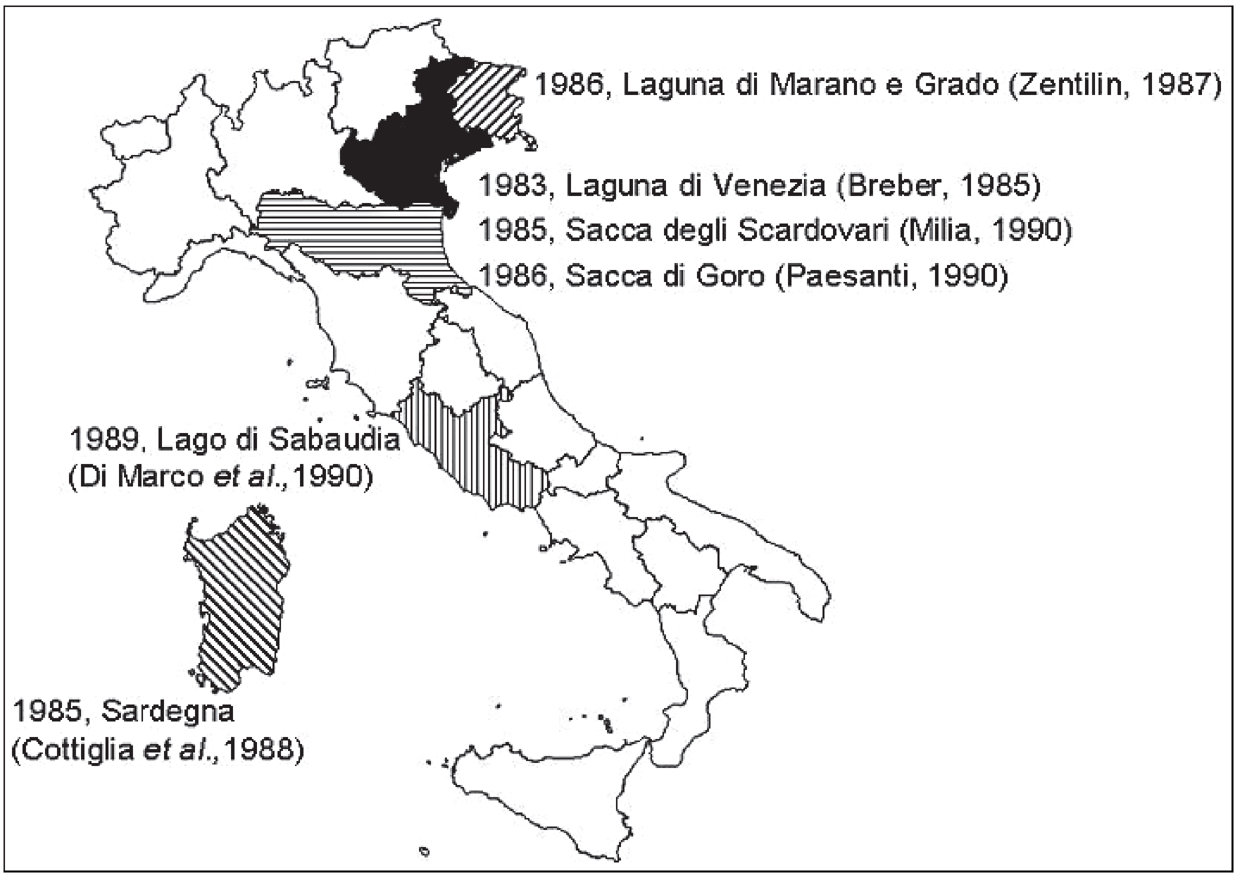

Fig. 1. Introduction of Manila clam (*Tapes philippinarum*) in Italy (Zentilin et al., 2007)

The promising results and the interest shown by many in this new zooculture, led to the spread of sowing in many transitional environments of Veneto (Lagoon of Venice, Lagoon of Caorle and the Po River Delta) (Breber, 1985; Giorgiutti et al., 1999), Emilia Romagna (Sacca di Goro and Sacca di Scardovari) (Paesanti, 1990; Milia, 1990), Friuli Venezia Giulia (Lagoon of Marano and Grado) (Zentilin, 1987), Sardinia (Cottiglia et al.,1988), and Lazio (Lake Sabaudia) (Di Marco et al., 1990). Following the large aquaculture hatchery based on developments in Europe over the 1980s, natural reproduction resulted in a geographical expansion of wild populations, particularly in Italy, France, and Ireland, where Japanese carpet shells have proved to be hardier and faster growing than the endemic *R. decussatus*. Consequently, *R. philippinarum* populations are now the major contributor to clam landings in Europe, and are the focus of intensive public fisheries, competing with aquaculture products in several rearing areas.

In these areas the species has acclimatized, reproduced and distributed at all sites, more environmentally favorable. The colonization of new environments has been fast and that makes the Manila clam the most economically important species.

The Manila clam (*Tapes philippinarum*) culture was preferred to that of the indigenous, *Tapes decussates* due to high growth rate, less difficult in obtaining seed from controlled reproduction and for better tolerance to variations of temperature, salinity and quality substrate that it presents with respect to local species.

2. Biological features and life cycle of Manila clam

Manila clam *(Tapes philippinarum* or *Venerupis philippinarum*) is an edible species of saltwater clam, a marine bivalve mollusk in the family *Veneridae*, the Venus clams. The common names of the species include "Manila clam", "Japanese littleneck", "steamer clam", "Filipino Venus", "Japanese cockle", and "Japanese carpet shell". Its shell is solid, equivalve, inequilateral, beaks in the anterior half, somewhat broadly oval in outline. Ligament inset, not concealed, a thick brown elliptical arched body extending almost half-way back to the posterior margin. Lunule elongate heart-shaped, clear though not particularly well defined, with light and dark brown fine radiating ridges. Escutcheon reduced to a mere border of the posterior region of the ligament. Sculpture of radiating ribs and concentric grooves, the latter becoming particularly sharp over the anterior and posterior parts of the shell, making the surface pronounced decussate. It has three cardinal teeth in each valve; centre tooth in left valve and centre and posterior in right, bifid. No lateral teeth. Pallial sinus relatively deep though not extending beyond the centre of the shell; it leaves a wedge-shaped space between its lower limb and the pallial line. Margins are smooth. Extremely variable in color and pattern, white, yellow or light brown, sometimes with rays, steaks, blotches or zig-zags of a darker brown, slightly polished; inside of shell polished white with an orange tint, sometimes with purple over a wide area below the umbones. The features most diagnostic for the identification of this species are the following: the inner ventral margin of the shell is smooth; the ligament is prominent and elevated above the dorsal margin. In the living animal, the siphons are separated at the tips. Water is drawn in and out of a clam by siphons that protrude from the posterior end of the shell. In this species, the siphons are mostly fused, and are only separate at the tips. The siphons are short relative to some other clams, which means that the clam lives burrowed only a shallow distance under the surface of the substrate. Short siphons are what inspire the common name “littleneck clam” (Bourne, 1982).

T. philippinarum is a dioecious animal (Bardach et al., 1972; Chew, 1989; Eversole, 1989; Devauchelle, 1990). In natural populations *T. philippinarum* becomes sexually mature in the first to the third year of age. *T. philippinarum* are strictly gonochoric and their gonads are represented by a diffused tissue closely linked to the digestive system. The period of reproduction varies, according to the geographical area; spawning usually occurs between 20-25 °C. A period of sexual rest is observed from late autumn to early winter. Gametogenesis in the wild lasts 2-5 months, followed by the spawning. A second spawning event may occur in the same season, 2-3 months later. The pre-winter recovery phase facilitates energy build up, by filtering seawater still rich in organic matter and phytoplankton. Temperature and feeding are the two main parameters affecting gametogenesis, which can be initiated at 8-10 °C and is accelerated by rising seawater temperature. Its duration decreases from 5 to 2 months between 14 and 24 °C. Within this temperature range, *T. philippinarum* are ready to spawn. Although the optimal temperature is between 20 and 22 °C, 12 °C is the minimum threshold below which this species cannot spawn efficiently. Food availability influences the amount of gametes produced. Larval development lasts 2 to 4 weeks before spatfall. Settlement size is between 190 and 235 μm in shell length. Many external factors regulate spatfall success in the wild, such as temperature, salinity and currents. Larval movement mainly depends on wind driven and tidal currents. Adding pea gravel and small rocks can facilitate species recruitment in natural setting areas. The larvae settle by attaching a byssus to a pebble or piece of shell. Regarding the *Tapes* longevity, Ponurovski (2008) has reported that the maximum recorded age of *T. philippinarum* was 7 years, but the maximum longevity of this species that has ever been reported for Melkovodnaya Bay (Russia) is 25 years.

The reproductive cycle in the northern Adriatic lagoons is quite similar (Da Ros et al., 2005): the period of sexual rest lasts from October to January, when first specimens start the gametogenesis. Sexual maturity is observed from April and the first spawning occurs already in May, the last in September. The theoretical growth curves depend on the period of larval settlement. When it occurs during the spring, Manila clam can reach about 47 mm in length after two years (Pellizzato et al., 2005). The maximum length recorded was 78 mm in Sacca di Goro (Po River Delta), whereas in the Lagoon of Marano the record was 71 mm, 136 g in total weight and about 7 years old.

3. Statistics

3.1 Main producer countries and production statistics

Cultivation of Manila clam, with the world production of 3 million tons/year makes it economically the most important shell species. In fact, its production represents the 20% of global world shell market (FAO, 2011).

At the global level, since 1991, global Japanese carpet shell production has shown a huge expansion, by a factor of nearly six times. China is by far the leading producer (97.4 % in 2002). Disease factors have impacted production in some other countries, notably in the Republic of Korea. In the decade 1993–2002, production in that country varied between 10,000 and 19,000 tones.

Production in Italy, following its introduction, the development of wild populations, and the consequential increase in seed supply, is the second highest in the world, followed by United States of America, Spain and France. Extensive production also occurs in Japan but is not reported within this specific statistical category, being included within clams (FAO, 2011).

In Europe, 90% (50,000 tons /year) of production derives from Italy, 6-8% from Spain (4,000 tons/year) and 2% from France (1,000 tons/year) (Turolla, 2008).

Italian clam production is mostly concentrated in the lagoons of the North Adriatic. Northern Adriatic production contributes to overall Italian production by up to 95% (Orel et al., 2000; Zentilin et al., 2008). This species is one of the most popular and profitable molluscs of lagoon and coastal sites in the Mediterranean. Production areas in the northern Adriatic (Lagoon of Venice, Lagoon of Marano and Grado, River Po mouth in the Region Emilia Romagna, River Po mouth in the Region of Veneto) reached its peak in 1998 and 1999 with over 60,000 tons. In the Lagoon of Marano and Grado the highest production was registered in 1996 with over 1,500 tons. In 2010 the production in the Lagoon of Marano was 1,042 tons, of which 74% derives from aquaculture in about 130 hectares of lagoon. Approximately 20 persons are employed in the two main shell farm business operators: ALMAR Society founded in 1995 and Molluschicoltura Maranese Society (begin of ‘90th), which took over the shell farm plants of the previous Aquamar Society, founded in 1988.

3.2 Market and trade

About 70% of Italian production is consumed internally, while the remaining is exported, mostly towards European countries, Spain primarily. Due to increased consumption during summer months, in just two months (August and December), 20-25% of all Italian production is collected and commercialized (Turolla, 2008). Consumption is almost exclusively directed to live product trade, only in the last years product processing is starting to take part on the market.

4. Lagoon of Marano and Grado

The Marano and Grado Lagoon is located in the northern Adriatic Sea covering an area of about 160 km^2 with a length of nearly 32 km and an average width of 5 km (Fig. 2).

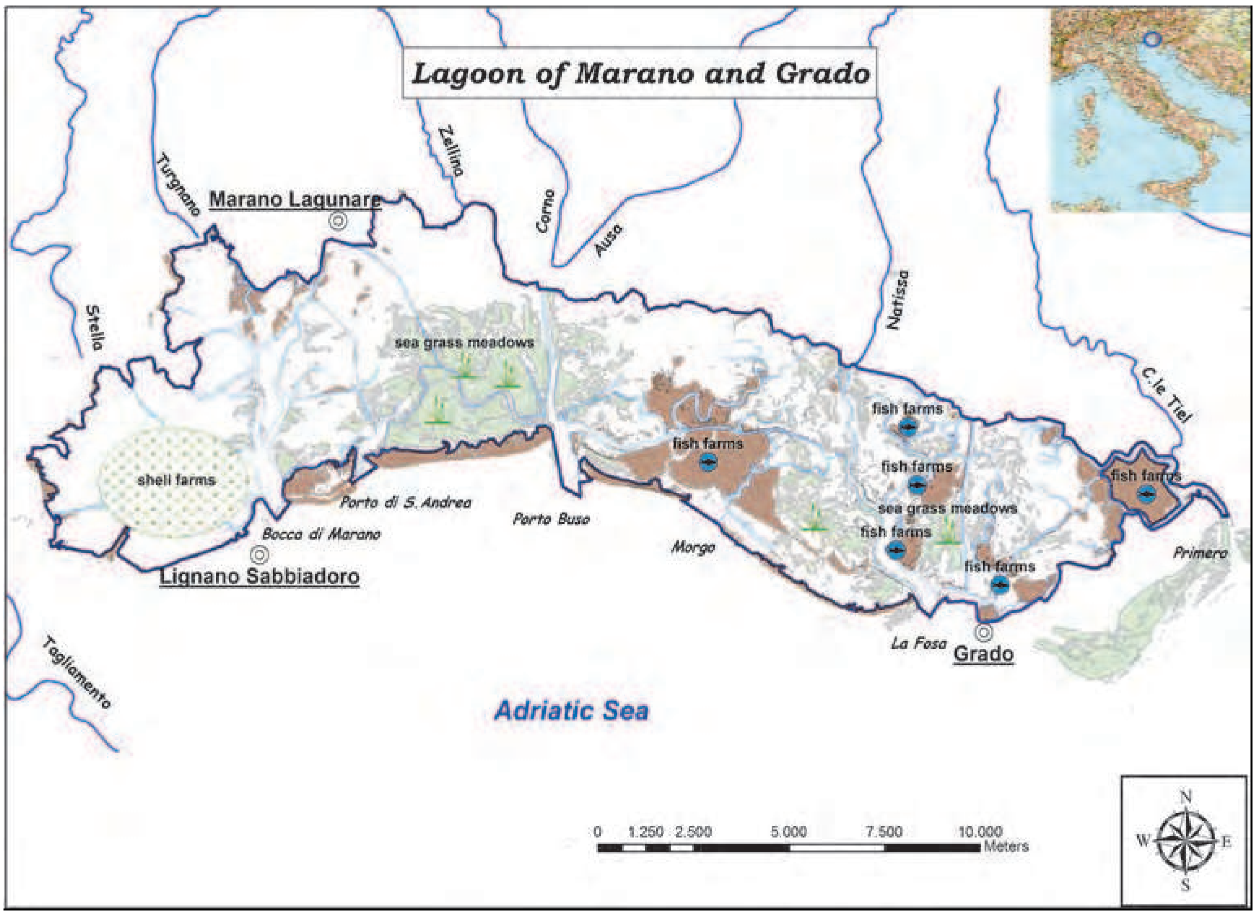

Fig. 2. The Lagoon of Marano and Grado

It is the more eastern among all the delta and lagoon systems on the Adriatic coast (Po River Delta, Lagoon of Venice and Lagoon of Caorle). This wetland system is delimited, moving westward, by the Isonzo and Tagliamento Rivers deltas, and is separated from the Adriatic Sea by the presence of six barrier islands (1.6 to 6 km long, for a total length of 20 km; 1-2 km wide). These latter roughly subdivide the lagoon in hydraulic sub-basins (Marano, S. Andrea, Porto Buso, Morgo, Grado and Primero; ARPA-FVG, 2006).

The whole catchments area of the lagoon covers about 1880 km^2 with 65 municipalities and a rivers network of 743 km. Rivers flow into the lagoon mainly in the western sector (Marano) draining waters coming from the spring line. The estimated overall amount of average freshwater discharge is about 70-84 m^3 s^{-1} (ARPA-FVG, 2006; Ret, 2006) and is mostly due to the Stella River, particularly important for its peculiar estuarine habitats, the Cormor River and the Corno River, that receives the water of the Aussa River before entering the lagoon. Salinity is strongly influenced in the areas close to the river mouths where very low values (from 2 to 7) are often recorded. Conversely, a sudden increase is observed moving towards the tidal inlets, where values between 24 and 36 (typically marine) were recorded (Brambati, 2001). Temperature gradients and other biogeochemical parameters (i.e., dissolved oxygen, nutrients, chlorophyll) are characterized by high spatial and temporal variability (Acquavita et al., 2010a), with some extreme phenomena such as ipoxic/anoxic conditions recorded in the more confined areas especially in case of a high organic carbon content coupled to a scarce water renewal.

The sedimentary input of small rivers consists mostly of fine suspended material washed out from the groundwater table (Brambati, 1972), whereas the most important source of sediments comes from the sea, through the tidal inlets, as a contribution of the two river deltas (silty and clayey particles) and from erosion of the barrier islands (sands) (Brambati, 1970). Grain-size distribution observed for the whole lagoon is characterized by medium to fine sands prevailing along the both main and secondary channels. The fine pelitic fraction is widely dispersed in the basin and varies from 52% to 100%. The silty fraction (62.5-3.9 µm) normally comprises a higher percentage than the clay fraction (<3.9 µm) in the pelitic component. Generally, the ratio fine-silt/clay (2–16/<2 µm) identifies areas affected by freshwater inputs into the lagoon: a high ratio indicates an area of fresh water input and vice versa (Piani & Covelli, 2000; Piani et al., 2005).

The main sub-basins identified in the past are characterized by several morphologies. The presence of barriers, sandbanks, saltmarshes, channels, intertidal/subtidal flats and tidal creeks are strictly dependent from both tidal and hydraulic regimes. The Marano Lagoon is a semi-enclosed shallow tidal basin, with a few marshes and several channels, receiving freshwaters from several adjacent rivers. The Grado Lagoon is shallower, has a series of morphological relieves (islands) and marshes, and receives freshwater from a single tributary, the Natissa river (Marocco, 1995).

As already reported for other lagoon environments this system is clearly dynamic, being the morphology subjected to relevant changes derived from both natural and human influences. Fontolan et al. (2009) observed a remarkable decrease of saltmarshes surface, which occurred especially in the last decades (1954-1990), in the central-western areas (i.e. S. Andrea, Grado and Porto Buso sub-basins), probably due to relative sea level rise, erosive processes and land reclamation. Actually, the main salt marshes are located between Marano and S. Andrea sub-basins and in Morgo. Fringing marshes are also located in the inner parts of the Marano sub-basin.

However, the influence of human activities on lagoon morphology cannot be neglected. In order to protect the main inlets breakwaters were constructed, along with the creation of the Porto Nogaro harbor, which is connected by means of a lagoon channel (Aussa Mare), up to 7.5 m of depth, with the open sea for shipping purposes. In addition, stabilization of the barrier islands and several docks for marinas were realized.

Lagoon channels actually represent a 100 km network, partly navigable, connecting the lagoon to the northern Adriatic Sea, with waterways close to the main industrial and tourist areas.

4.1 Hydraulic regime

Hydraulic circulation and diffusive processes in lagoon environments exert a pivotal role in most of the physical and biogeochemical processes. Interannual and interseasonal variations of hydraulic forcing greatly contribute to biogeochemical processes through dispersion of nutrients and pollutants (Rigollet et al., 2004) and changing basic physico-chemical parameters (i.e., turbulence, dissolved oxygen, pH, salinity). During the first half of the last century some investigations concerning hydrodynamic of the lagoon were conducted; however, variation in both physical and chemical parameters were firstly described in order to define water circulation pattern by Dorigo only in 1965. Recently, more sophisticated 2D models were applied by Bosa & Petti (2004) and Petti & Bosa (2004) for clarifying the sediment transport and the dispersion of a dissolved pollutant in the lagoon environment. Ferrarin et al. (2010) employed a finite element modelling system (named SHYFEM, http://www.ve.ismar.cnr.it/shyfem) developed at ISMAR-CNR (Umgiesser et al., 2003; 2004) to describe the water circulation taking into account different forces such as tides, wind, rivers and sea-lagoon exchanges. One of the main outputs of this work was the comparison of the simulation against water levels, salinity and temperature data collected in several stations inside the lagoons. The lagoon has a strong tidal influence with several basins separated by the watersheds where exchange of water between neighboring basins occurs (Umgiesser, 1997). In a simulation proposed following Solidoro et al. (2004) employing different tracers, the lagoon can be roughly divided in three subbasins. Taking into consideration areas influenced by riverine inputs, a clear west-east salinity gradient was found (from ~20 to~ 34 in western and eastern region, respectively) with a narrow band (1-2 km width) where a rapid change from mesohaline to euhaline conditions occur. The eastern part of the lagoon presents a physical division due to the bridge connecting the main land to the city of Grado.

4.2 Conflicts in coastal areas

The Marano and Grado Lagoon is one of the most important ecological systems of the North Adriatic Sea, assuring connectivity with some psammophile and halophile habitats of the coast. Nowadays, most of the natural areas are included in the Regional System of Protected Areas (S.A.R.A.), as Communitary Importance Sites (CIS) and Special Protection Zones (SPZ). The area includes some historical sites designed to protect wildlife migration submitted to the Ramsar Convention in 1971, and, following the implementation of the Habitats Directive (92/43/EEC transposed in Italy by DPR Sept. 8, 1997 No 357), concerning the protection of biodiversity, the entire basin has been identified in the survey sponsored by the state called "Natura 2000 "as a site to be included among the sites of Community importance (SCIs - IT3320037). Moreover, the lagoon is an economical important source for the inhabitants.

Fishing involves actually 245 fishermen and 200 persons in charge of marketing in Marano Lagunare, whereas in Grado tourism represents the leading sector (over 1,700 persons), and is almost exclusively carried out from April to October. Aquaculture (lagoon fish farming) is a common historical practice for the upper Adriatic. Within the lagoon system 17 fish rearing ponds (320 hectares in Marano) and 38 (1,088 hectares in Grado) are still active. Due to the shallow depth of the basins, arise of temperature and salinity linked to hypoxia may occur during summer periods, whereas occasionally frosts occur during winter.

On the other hand, the lagoon has been declared one of the polluted sites of national interest (SIN; Ministerial Decree 468/01) because of its high level of sanitary and environmental risk due to several factors. In this context one of the main concerns is represented by the high concentration of mercury (Hg) in sediments and its related neurotoxicity whenever it is in the food chain. SIN covers about 13,500 ha partially overlaps the SCI, and is actually subject to environmental characterization, emergency safety measures, restoration, rehabilitation plans and monitoring activity.

The Environmental Protection Agency of Friuli Venezia Giulia (ARPA FVG) is involved in a monitoring network according to Directive 2000/60/CE (European Union, 2000), which is applied in Italy following the Legislative Decree 152/2006. The WFD aiming to monitor and solve the problems connected with quality of the water, to protect and to enhance the restore of all the water bodies (inland surface waters, transitional waters, coastal waters and ground waters in Europe). The final goal is to achieve a “good ecological and chemical status” by the year 2015.

The data obtained represent an implementation of the past investigations (since the end of the 80s) conducted by the Region FVG in a monitoring system of superficial water, where physical, chemical and bacteriological data were recorded. GIS based analysis of data collected from about 20 monitoring stations for the period 2000 – 2005 show that the lagoons is characterized by a good diurnal oxygenation. On the other hand, a significant nutrient supply pose a risk of distrophy close to river mouths with the induction of algal blooms and possible oxygen falls during the night. Moreover, these areas are subject to high nitrogen concentrations, which go beyond the limits stated into the Nitrate Directive.

4.2.1 Agriculture

Agriculture and breeding are activities connected to the quality of the Marano and Grado Lagoon mainly through the related drainage basin of cultivated land. Rural economy of Friuli Venezia Giulia is almost placed in the Lower Friulan Plan, where, during the last century, 50,000 hectares of wetlands have been reclamed into cultivated areas. Nowadays, 70% of the agricultural land is arable and mostly planted with soybean, Indian corn, beetroot and cereals (wheat and barley). There are also several vineyards or specialized fruit farming.

The main risks posed by agricultural activities are pesticides and fungicides releases into the lagoon system. The irrigation of the plantations, especially during the summer periods, implies a serious water withdrawal, and the lack of vegetation enhances the problem of erosion. In the considered territory, there are several breeding farming. The wastes of this activity are used as fertiliser and, as a consequence, part is carried into the lagoon (Friuli Venezia Giulia Region, 3th Interim Report “S.A.R.A. Regional System of Protected Areas”).

The main river courses of the area are loaded with the discharge of the channels belonging to the agricultural drainage system. Thus, it results in a close relationship between agriculture activities and the quality of waterways and lagoon ecosystem. The release of nutrients from agriculture are closely linked to hydrological processes as they are conveyed during rainfall in the catchment and load significant amounts of nitrogen and phosphorus supplied to the soil with fertilizers. Due to their patterns of adsorption and release from the soil nitrogen is mainly present as $N\text{-}NO_3^-$ ion when reach the lagoon system, whereas P is tied to the particle in suspension.

4.2.2 Industry

Besides its environmental and natural significance, the lagoon hosts some important socio-economic activities. Two industrial sites are located in San Giorgio di Nogaro and Torviscosa, whereas a commercial harbour sited in "Porto Nogaro" is connected to the lagoon by mean of channel along the Ausa-Corno River. The industrial plants of the Aussa-Corno (ZIAC) industrial includes 87 factories and about 2500 persons are actually employed. Two separate districts are placed in the whole area. The largest area (498 ha) extends in San Giorgio di Nogaro municipality along 6,5 km of the Aussa river up to Marano and Grado lagoon. An area lies at the confluence between Aussa and Corno rivers; a part is located near the Ausa river. A second area is in Torviscosa municipality and is occupied by "Caffaro" industries (130 ha). There are 320 ha not yet occupied. The "Porto Nogaro" serves the industrial area and moves about 1,500,000 tons/year. Categories, employees and area of the factories in the ZIAC are reported in the following table (from: http://www.dest.uniud.it/dest/eventi/watergeography/lagoon_of_marano_tesis.pdf).

Category	N° employees	Area (m^2)
Mechanical engineering	176	93,297
Iron and steel (production)	41	164,269
Iron and steel (manufacturing)	554	890,238
Chemical (production)	508	1,255,359
Chemical (articles)	555	674,056
Textile	66	45,340
Food	141	148,457
Naval/nautical	116	336,821
Wood	20	17,240
Stone processing	41	32,570
Total	2218	3,657,647

Table 1. Categories, employees and area of the factories in the ZIAC

The Torviscosa site still represents the main source of pollutants in the area. The consequent contamination regards both soils (manly the upper meter) and groundwater (Menchini et al., 2009). The main concern is mercury (Hg), due to the chlor-alkali plant that became operative in 1949 and that actually is not-operative. Moreover, the occurrence of other contaminants cannot be neglected. The presence of heavy metals (Cd, Zn, As, Pb, Cu), polychlorinated dibenzodioxins (PCDDs) and furans (PCDFs), hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), is closely related to the location of the different chemical productions that took place in the industrial site. San Giorgio di Nogaro shows a less critical situation with soil contamination related to waste disposal and industrial processes, mainly heavy metals and to a lesser extent PAHs and PCBs. In a similar manner, the environmental quality of the Corno River seems better than the Aussa one, both in terms of contaminants and measured concentrations.

4.2.3 Exploitation of aquatic resources

The Lagoon of Marano and Grado hosts the two most important fishery ports of the Region Friuli Venezia Giulia: Marano Lagunare and Grado. Together they represent almost 80% of the fishery fleet of the region as number of vessels. Fishermen operate at sea by trawling, seine, hydraulic dredge for bivalves (mainly *Chamelea gallina*, *Callista chione* and *Ensis minor*), trammel and gill nets, longlines, fish traps adapted to catch cuttlefishes (*Sepia officinalis*) and mantis (*Squilla mantis*). Most of fishermen in Marano Lagunare work both at sea and lagoon; in the latter case they use prevalently a very old method to catch fish in the northern Adriatic lagoons: a barriers system ending in the fyke nets (locally named *cogolli*). This very ancient method is tightly linked to the tide regime. Moreover in the lagoon there is a so much ancient tradition (arising to 16th century in the Lagoon of Grado) to farm fishes inside pools such as sea bream (*Sparus aurata*), sea bass (*Dicentrarchus labrax*), eel (*Anguilla anguilla*) and mullet (*Mugil* sp.).

The spreading of Manila clam in the Adriatic lagoons led to a consistent abandonment of traditional fishery, because of the massive abundance of this species, its easiness of harvesting and overall the considerable market of this resource. In this way at the beginning of 90th almost 50% of fishermen in Marano Lagunare started to harvest these clams. In the first time they were harvested by hand from spring to autumn and a maximal daily quota per person of about 50 kg was established. In 1992 a special dredge was introduced to collect clams during the winter in the Lagoon of Marano. This gear was studied and built in Marano Lagunare and it is locally known as "maranese rake" (Fig. 3.). This method permitted to harvest Manila clams in the cold season and these gears were hauled on the shallow lagoon bottoms by boats with a power engine ranging between 80 and 120 Hp. A quota of 50 kg/day was established for each boat, excepting for about twenty days during the Christmas celebrations when a quota of 70 kg/day was permitted (Zentilin & Orel, 2009). No specific limitations were established to access the Manila clam natural banks with this method of fishery. Thus until December 2006 almost 150 fishermen could harvest freely this resource from October to March using this mechanical gear in the most part of the Lagoon of Marano. In the Lagoon of Grado Manila clam had not a massive spreading such as Marano basin and this species is manually harvested only by local or leisure fishermen; although an illegal harvesting and sale occur nowadays in both lagoons.

The Table 2. shows how the exploitation with "maranese rake" increased enormously since 1995, when the contribution of farm to the total production in the market of Marano Lagunare was only 3%, whereas the biggest production was recorded in 1996. In those years each natural bank of Manila clams was freely overexploited until the biomass dropped below 0.01 or even 0.005 kg/m^2. This impulsive and uncontrolled exploitation of the resource, accompanied to mobilization of sediments and potential contaminants, led the authority to stop definitively this free practice with the rake in January 2007, after many years of tacit assent. This sudden decision caused social disorders and resentments between the citizens of Marano Lagunare where, due to the general crisis of marine resources too, half of fishermen community was employed till then to this kind of harvesting. This occurs

Fig. 3. The "maranese rake"

Year	Shell farm (tons)	Fishery (tons)	Total Manila clam production (tons)	%Shell farm
1988	3		3	100
1989	0.9		0.9	100
1990	9		9	100
1991	16		16	100
1992	35		35	100
1993	80	70	150	53
1994	70	150	220	32
1995	30	1,000	1,030	3
1996	60	1,560	1,620	4
1997	25	1,230	1,255	2
1998	140	800	940	15
1999	310	760	1,070	29
2000	911	463	1,374	66
2001	647	641	1,288	50
2002	535	468	1,003	53
2003	595	378	973	61
2004	417	602	1,019	41
2005	680	531	1,211	56
2006	368	300	668	55
2007	375	193	568	66
2008	204	169	373	55
2009	699	145	844	83
2010	772	270	1,042	74

Table 2. Production of Manila clam in tons in the Lagoon of Marano and percentage contribute of shell farm to the total production

especially during the winter when Manila clam represents one of few resources accessible and capable to ensure a profit to the families.

In such a climate the pioneers of the cultivation of Manila clam had to operate for the development of their activity. From the beginning they embraced the principle on which the lagoon must be cultivated, to ensure a profitable activity for the fishermen community in the long time, thus minimizing the impact in the environment. Of course a lot of fishermen fell in contrast against farmers and now a minority of them sustains to be entitled for the free use of the "maranese rake" in their lagoon. In fact they adduce the principle on which only the local fishermen know how to manage their lagoon, on the basis of old knowledge inherited by fathers and concessions got in the ancient times for their exclusive utilization of the lagoon resources.

The challenge today is to promote a cultural revolution inside the Maranese community in order to gradually convert the clam fishermen toward the sustainable aquaculture, thus introducing the new conceptions of the shell farm business operator. In any case the free harvesting by hands is nowadays authorized, although most of the production derives from aquaculture. However the farmers must maintain continuously a vigilance staff to prevent the frequent illegal harvesting, inside the areas devoted to the Manila clam cultivation.

4.3 Heavy metals in the Lagoon environment

Natural processes such as leaching of the rocks, erosion and geothermal activity, and human activities such as fuel use fossil, mineral fusion, industrial and oil contribute to the diffusion of heavy metals in the atmosphere, water, soils, river and coastal sediments (Solomons & Föerstner, 1984). Sediments are known to be one of the most important site of deposition and a secondary source of trace elements to the marine environment (Leoni & Sartori, 1997).

The distribution of heavy metals in sediments of the Marano and Grado Lagoon was investigated since '70s (Stefanini, 1971), but only recently an evaluation of the anthropogenic influence on contamination levels was considered (Mattassi et al., 1991). The Authors pointed out the huge amount of Hg, with values very high (from 0.61 to 14.01 $\mu g\ g^{-1}$) if compared with other Mediterranean systems. On the other hand, Cd, Cr, Cu, Ni, Pb and Zn showed no significative enrichment and an homogenous distribution in the whole system. Due to this, Hg distribution, speciation and mobility is the main concern in the whole lagoon environment. The element can exert neurotoxic effects on humans and can be transformed in the more toxic and potentially bioaccumulable organometallic form monomethylmercury (MeHg). The huge amount of Hg found is mainly due to the particulate inputs from the Soca/Isonzo drainage basin. The River is responsible for the presence of Hg into the northern Adriatic Sea since the 16th century, due to its transport of cinnabar rich tailings from the Idrija mining district (North-West of Slovenia; Covelli et al., 2001; 2008), which Hg production was second only to Almaden (Spain). The Idrija Hg mine operated for nearly 500 years, until it definitively closed in 1996. Nevertheless, Hg is still being delivered through river flow to the Gulf of Trieste and the adjacent Marano and Grado Lagoon (Covelli et al., 2007). Within the lagoon Hg contents range from 2.34 to 10.6 $\mu g\ g^{-1}$ and progressively decrease westwards. Moreover, the Marano and Grado Lagoon experienced the input from the chlor-alkali plant (CAP) sited in Torviscosa. Here, Hg was employed for electrolytic production of Cl_2. The plant became active in 1949 and it was estimated that a total amount of 186,000 kg of Hg (with a maximum of about 20 kg day^{-1}) was deliberately discharged into the

Ausa–Corno River system in connection with the lagoon (Piani et al., 2005). In 1984, due to application of law rules, a modern wastewater system treatment was installed; hence no more inputs of Hg should have been released into the environment.

Covelli et al. (2009) stated that although uncontrolled Hg discharge from the CAP stopped, the artificial channel connecting the industrial area to the upper river course is still an active Hg source for the Marano lagoon environment.

During the application of the WFD 2000/60/EC, ARPA FVG investigated the distribution of ten elements (Al, As, Cd, Cr, Fe, Hg, Ni, Pb, V and Zn) and of MeHg in surface sediment (0-5 cm) collected in 28 stations distributed throughout the lagoon ecosystem.

In this monitoring plan some critical rose. However, where some elements exceed the environmental quality standards (EQS) set by the WFD it should be stressed that these represent, similarly to what reported for the adjacent Gulf of Trieste (Acquavita et al., 2010b), the values underlying the region's natural lagoon geochemistry.

Previous data for As in the Gulf of Trieste showed a mean value of 7.4 µg g^{-1}. In the lagoon an average of value 8.9±1.7 µg g^{-1} confirm that sediments can be considered as uncontaminated (Francesconi & Edmonds, 1997). Moreover, only one site with 12.5 µg g^{-1} exceeded the EQS (12.0 µg g^{-1}) fixed by the law. For cadmium, the mean concentration detected was equal to 0.17±0.04 µg g^{-1}, with the whole set of data <0.30 µg g^{-1} (EQS). The element was significantly correlated with Fe (r=0.7940, $p<0.05$) and with Cr, Ni, Pb and Zn, thus suggesting a common origin among these elements. Cr exceeds the EQS (50 µg g^{-1}) only in some stations (mean value 45.6±12.3 µg g^{-1}. The Pearson matrix correlation showed a distribution mainly influenced by mineralogy (Cr vs. Al, r=0.9255, $p<0.05$) rather than the textural characteristics. A good correlation was also found with Zn and Pb. This latter showed values quite low (16.9±4.7 µg g^{-1}) if compared with those reported by Covelli & Fontolan (1997) mean 55 µg g^{-1} with a maximum of 144 µg g^{-1}. Zn exhibits an extreme variability also in uncontaminated sediments. In the Gulf of Trieste a wide range of values from 8 to 213 µg g^{-1}) is reported (Stefanini, 1971; Ministero dell'Ambiente, Servizio Difesa Mare, 2005). Sediments of the lagoon showed a mean value of 68.5±19.4 µg g^{-1} and the significant correlation with Al (r=0.9003, $p<0.05$) suggest that there no significant anthropogenic contribution. Ni always exceeds the EQS (30 µg g^{-1}) proposed, thus ARPA FVG will pose particular attention in the future monitoring. The data collected for Hg confirms a range between 0.5 to 8.1 µg g^{-1}, and clearly that Grado is more heavily polluted than Marano. However, some spikes were detected at the Ausa-Corno River mouth (5.9 µg g^{-1}). MeHg contents were similar (2.0±0.9 ng g^{-1}) to those already observed by Covelli et al. (2008). Since the production of methylated Hg species depends on several factors (i. e., redox state of the system, presence and quality of organic carbon, presence/absence of specific bacteria solforiduttori) but not on total Hg contents, no correlation was found between the two species (r=0.4343, $p<0.5$).

The concentration of Hg, Cd, Pb and benzo(a)pyrene are semiannually detected in bivalves (*T. philippinarum*, *C. gallina*, *C. chione* and *M. galloprovincialis*) on the basis of Regulation (EC) 1881/2006, setting maximum levels for certain contaminants in foodstuffs. During the ten years monitoring conducted by ARPA FVG (2001-2010), concentrations of these heavy metals were always below the maximum level. In addition, benzo(a)pyrene levels were always under limit of detection. The maximum level of MeHg in Manila clam from shell farm in the Lagoon of Marano was 0.089 mg/kg wet weight. (Rampazzo et al., 2009).

5. Cultivation of *T. philippinarum* in the Lagoon of Marano and Grado

5.1 Production cycle

The cultivation of *T. philippinarum* in the Lagoon of Marano and Grado is characterized by three phases: production of larvae and seed, pre fattening and fattening. The production of larvae and seed take place in the hatchery and in this phase the conditioning of broodstock occurs through acclimation with controlled temperature and a balanced diet. The emission of gametes is induced by thermal shock and after the fertilization the true phase of cultivation takes place with the growth of larvae up to metamorphosis stage (220 µm). The subsequent growth of the seed occurs in tanks with controlled temperature and by intake of phytoplankton cultures. When the seed reaches a size of 1.5-3 mm the next phase of pre fattening starts. This is a very delicate step and an unsuccessful of the pre fattening could seriously affect the entire cycle of production. The techniques used in the Lagoon of Marano and Grado are carried out in plastic or fiberglass tanks at ground (Fig. 3), on floating upweller or directly on the lagoon bottom, where juveniles are protected by laying of plastic nets (Fig. 4). These plastic nets protect the juvenile clams from predators such as crabs and birds. This step ends when Manila clams reach a size of about 12-15 mm, after this the product is collected, selected, counted and prepared for the next phase called fattening.

Fig. 3. Pre fattening in plastic tanks

The fattening is conducted on the lagoon bottom with pelitic sand sediment and some of the culture areas are periodically emerged during low tide (–40 cm to +10 cm). In this phase the seed of about 15 mm is placed with a density of about 150 individuals/m^2, for a period of 24 to 36 months. Normally 50% of the juveniles survive until the commercial size (35-40 mm, 15 g)

Fig. 4. Laying of plastic nets to protect the juvenile clams from predators

after about three years. In particular during a production cycle the areas devoted to fattening of Manila clams are seeded in an alternate mode; in the second year the growth of molluscs, sanitary and environmental conditions are tested, during the third year mature clams are harvested. Before the subsequent cycle of production the culture beds have to spend a rest period (Zentilin & Orel, 2009).

5.2 Production system

All further steps of the cultivation in the lagoon are conducted with specific equipments and boats: lagoon bottom treatment, seeding, laying and removing of plastic nets (if necessary), cleaning of nets, harvesting. In the past all operations were manually conducted and only after specific experiments, an accurate planning and a lot of experience, peculiar mechanized systems were employed for each phase of the processing in this intertidal environment. Many requirements had to be performed to realize the ideal prototype of operating machine: the choice of resistant materials adapted to operate in the marine environment, the choice of the dimension and a correct distribution of weights, the estimation of the pressure applied to the lagoon sediments and the operating security. These requirements led to perform three models of operating machine: a model of seeder machine combined to remove oyster shells from lagoon bottom and a system to lay plastic nets (Fig. 5); a model for the cleaning and removing of plastic nets and finally a model of shallow hydraulic escalator harvester. The impact of these prototypes, in particular on sediment texture and benthic community, was accurately studied to verify the environmental sustainability of each operation system.

Since 2004 a new multifunctional vessel (M/S ADA) is employed in areas with depth up to -40 cm (Fig. 6). ADA has the following characteristics: 19.34 GT, steel hull, total length 21 m, 7 m in wide and 1.25 m in height. ADA is equipped with a diesel engine of 347 HP and is

Fig. 5. Seeder machine combined to remove oyster shells

Fig. 6. Multifunctional vessel

powered by three feet hydraulic power plants; the two feet aft side also act as a rudder. This vessel is also provided by two winches at the bow and one aft, and both bear anchor mooring. The winch-system has the function to advance or retreat the vessel during harvesting operations without the aid of the propellers. This system permits the elimination of sediment resuspension caused by turbulence of propeller on the shallow water. The studies conducted on this kind of vessel, fully demonstrated that such production system constitutes the best compromise for environmental sustainability and economic yield achievement (Zentilin & Orel, 2009).

5.3 Control measures

Regulations (EC) No 853/2004 and No 854/2004 of the European Parliament and of the Council, establish specific rules for the hygiene of foodstuffs and for the organisation of official controls on products of animal origin intended for human consumption respectively. In this way clam farmers may only harvest living bivalve molluscs from production areas with fixed locations and boundaries that the competent authority has classified. The competent authority in fact must fix the location and boundaries of production and relaying areas that it classifies and it may, where appropriate, do so in cooperation with the food business operators. In addition the competent authority must classify production areas from which it authorises the harvesting of living bivalve molluscs as being of one of three categories according to the level of faecal contamination, as following: Class A areas from which living bivalve molluscs may be collected for direct human consumption; Class B areas from which living bivalve molluscs may be collected, but placed on the market for human consumption only after treatment in a purification centre or after relaying so as to meet the health standards, molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (MPN) test of 4,600 *Escherichia coli* per 100 g of flesh and intervalvular liquid; finally Class C areas from which living bivalve molluscs may be collected but placed on the market only after relaying over a long period so as to meet the health standards, molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN test of 46,000 *E. coli* per 100 g of flesh and intervalvular liquid.

If the competent authority decides in principle to classify a production or relaying area, it must make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production area; examines the quantities of organic pollutants which are released during the different periods of the year; determines the characteristics of the circulation of pollutants by virtue of current patterns, bathymetry and the tidal cycle in the production area; establishes a sampling programme of bivalve molluscs in the production area which is based on the examination of established data, and with a number of samples, a geographical distribution of the sampling points and a sampling frequency which must ensure that the results of the analysis are as representative as possible for the area considered. Classified relaying and production areas must be periodically monitored to check: there is no malpractice with regard to the origin, provenance and destination of living bivalve molluscs; the microbiological quality of bivalves in relation to the production and relaying areas; the presence of toxin-producing plankton in production and relaying waters and biotoxins in living bivalves and for the presence of chemical contaminants in molluscs. Sampling plans must be drawn up providing for such checks to take place at regular intervals, or on a case-by-case basis if harvesting periods are irregular. The geographical distribution of the sampling points and the sampling frequency must ensure that the results of the analysis are as representative as possible for the area considered. Where the results of sampling show that the health standards for molluscs are exceeded, or that there may be otherwise a risk to human health, the authority must close the production area concerned, preventing the harvesting. The same may re-open a closed production area only if the health standards for molluscs once again comply with Community legislation. To decide on the classification, opening or closure of production areas, the authority may take into account the results of controls that food business operators or organisations representing them have carried out. In that event, the authority must have designated the laboratory carrying out the analysis and, if necessary, sampling and analysis must have taken place in accordance with a protocol that the authority and the operators or organisation concerned have agreed.

The Decision of the Regional Government of Friuli Venezia Giulia (DGR No 124/2010) applies the above mentioned EC Regulations in the marine coastal and transitional waters, in term of classification of harvesting areas and the guidelines for the monitoring protocol of these. In particular Fig. 7 shows that the harvesting areas in the Marano and Grado Lagoon are identified as Class B. In this way the harvested Manila clams need to be treat in a purification centre so as to meet the health standards of three dilution Most Probable Number (MPN) test of <230 *E. coli* per 100 g of flesh and intervalvular liquid.

Fig. 7. Classification of bivalve harvesting areas according to the level of faecal contamination

6. Impact of *T. philippinarum* cultivation on marine ecosystem

The minimization of negative effects, both direct and indirect, of fishing and aquaculture activities is perceived to be an important component of management plans in heavily exploited ecosystems (Benaka, 1999). Demersal resources, such as Manila clam, need to be harvested by use of mobile gears (mainly trawl nets and dredges), producing disturbances which may exceed any other natural and anthropogenic disturbance on the lagoon or the marine ecosystem (Watling & Norse, 1998). Bottom gear may cause widespread physical disturbance in sediments affecting benthic communities, removing both target and non-target species, and altering habitats. Many studies have been carried out to assess the impact of fishing gear used for harvesting molluscs, particularly dredges, on bycatch species and benthic communities (e.g. Pranovi et al., 2001; Hauton et al., 2003; Gaspar et al., 2009; Leitão et al., 2009). The few studies available on the effects of commercial fishing on target species focus mainly on the qualitative/quantitative assessment of the discarded clams and on the selectivity of the fishing gear (Gaspar et al., 2003; Morello et al., 2005; Kraan et al., 2007). In addition the effects of dredging on habitats include changes in the physical structure and chemistry of the environment, sediment suspension and its redistribution (Gaspar & Chicharo, 2007). The alteration of sediment features may influence the colonization and presence of benthic species, including target ones, leading to long-term changes in community structure (Pranovi & Giovanardi, 1994; Pranovi et al., 1998). In this way, there has been increasing recent interest in evaluating the collateral effects of commercial cultivation of bivalves on the marine environment (Sorokin et al., 1999; Bartoli et al., 2001; Jie et al., 2001; Dame et al., 2002), especially on macrobenthic communities (Kaiser et al., 1996; Drake & Arias, 1997; Spencer et al., 1997; Gaspar et al., 2002; 2003). The main effect on non-target species is a reduction in species richness and abundance (Commito, 1987; Dittman, 1990; Guenther, 1996; Ragnarsson & Raffaelli, 1999; Beadman et al., 2004; Pranovi et al., 2004), although in some cases the opposite effect has been recorded (Mantovani et al., 2006). This latter may be caused by the use of plastic nets to protect juvenile clams from predation by shorebirds and crabs (Spencer et al., 1992), which increased sedimentation rates and consequently the density of some species of infaunal deposit-feeding worms (Spencer et al., 1997).

In the Venice Lagoon the harvesting by "rusca" produces a V-shaped furrow (about 60 cm wide and 7 cm deep) and a plume of resuspended sediment with a significant increase (up to two orders of magnitude greater than undisturbed areas) of suspended particulate matter and increased C_{tot}, C_{org}, N_{tot} and sulphide concentrations in the water column. During experiments "rusca" hauls significantly reduced macrofauna density, whereas no significant effect on meiofauna was detected (Pranovi et al., 2004). The resuspension caused by "rusca" fishing activity could be an important factor in determining food quality and quantity available to filter feeders as described by De Jonge & Van Beusekom (1992), for other resuspension sources. All this could explain the "*Tapes paradox*", which is the apparent benefit of *Tapes* populations to exploitation. As reported by Pranovi et al. (2003), to sustain the huge clam biomass an external energetic input is required, because the concentration of the suspended food in the Venice Lagoon is occasionally below the threshold demanded by Manila clams (Pranovi et al., 2004).

One of the main effects of the resuspension activity is an increase in water turbidity (Black & Parry, 1994), which could profoundly affect primary production (both in the water column and on the bottom). In the Venice Lagoon a significant increase in water turbidity has been recorded since the beginning of the 1990s (Sfriso & Marcomini, 1996). In this way, the resuspended sediment could be transported by natural hydrodynamics, e.g. tidal currents, and eventually reach deeper channels and be driven outside the lagoon. Even if the resuspended sediment is redeposited in other shallow areas, it would not be well stabilized and would therefore be more exposed to erosion processes. So in the Venice Lagoon, resuspension due to mechanical clam harvesting could produce an additional effect on the natural erosion of the shallow bottoms, which is at present one of the major points in the safeguard policy of the Venice Lagoon (Pranovi et al., 2004).

Experimental studies were conducted also in the Lagoon of Marano to test the impact of the "maranese rake", the shallow hydraulic escalator harvester and the hand harvesting on benthic communities and sediment texture and to estimate the regeneration times of macrozoobenthos after the employ of these harvester methods (Orel et al., 2001; 2002; 2005). Everyone leads to a drop of richness and abundance of macrozoobenthos and a loss of fine sediments after the haul of harvesters or the hand method. Nevertheless, after 4-5 months from the experimental harvesting, sedimentary and biological conditions were restored. In this way we could assume that harvesting of Manila clam in the Lagoon of Marano and Grado not involve any relevant environmental modification in the short term and space, but on the contrary the reiteration of the activities in term of space and time could induce long term negative impacts, by progressive reduction of sediment thickness (Orel et al., 2001; 2002).

7. Future approaches and production sustainability

7.1 Trends

Given forecasts of increasing air and sea temperatures (Hulme et al., 2002) it might be expected that the Manila clam will spread to more sites around the coasts of Britain and Europe. The magnitude of the environmental consequences of the naturalisation of the Manila clam at these sites is likely to depend upon the density that the species attains. This in turn is likely to depend upon the future environmental conditions and the intensity of any fishery for this commercially valuable resource. Thank to Regulation (EC) No 708/2007, concerning use of alien and locally absent species in aquaculture, the risk assessment to cultivate Manila clam in the EU is no more necessary. After 25 years from its introduction, this species has never threatened the original ecosystem of the Lagoon of Marano and Grado. On the contrary the development of its sustainable culture could represent a benefit to the local fisheries economy.

7.2 Responsible practices toward sustainable production

In the Lagoon of Marano and Grado a temporary association among business operators was constituted in 2009. This association includes ALMAR Society, Molluschicoltura Maranese Society and the Cooperative of fishermen St. Vito of Marano Lagunare. The goal of this historical cooperation is to start together a pathway towards the sustainable aquaculture of Manila clam in the Lagoon of Marano. After many years of conflicts, the results, the prestige and the reliability got by ALMAR and Molluschicoltura Maranese in the shell farm business, the Cooperative St. Vito, grouping the major part of the fishermen in Marano Lagunare, perceived the necessity to enter the way of the cultivation in the lagoon. Anyway before the constitution of the temporary association, the cooperative already got in 2005 a financial support from EU to realize an hatchery plant sited close to the town. This hatchery has a theoretical production of 200,000,000 ind/year, whereas that in ALMAR is 400,000,000 ind/year. The new hatchery equipped itself of biologists able to follow the entire productive process.

In 2006 a Decision of the Regional Government of Friuli Venezia Giulia approved the new lagoon areas suitable for the fattening of Manila clam, thank to a research conducted by the Department of biology of the University in Trieste in collaboration with ALMAR Society. The study took into consideration: sediment texture, depth profile, hydrology, primary production, macrozoobenthic communities, presence or absence of seagrass and macroalgae, growth rates of clams for each considered zone, microbial suitability in agreement to UE rules, chemical conditions of sediments, anthropogenic pressures, potential disturbs to wild birds, closeness to navigation channels and so on.

At present the total area devoted to Manila clam farming amounts to about 800 hectares (Fig. 8) of which 130 are in full regime of production.

Fig. 8. Areas devoted to Manila clam farm in the Lagoon of Marano and locations of sampling stations for the environmental monitoring

In 2010 a new harvesting gear was introduced in Lagoon of Marano to operate inside the assigned area to Cooperative St. Vito (see ATI – COOP San Vito in Fig. 8). This gear is a small hydraulic clam dredge (Fig. 9), called "*idrorasca*", originally designed and constructed to be used in the Manila clam natural banks located in the transitional waters of Po River Delta. The use of this new harvesting method was authorized in 2004 after a series of researches inherent the environmental sustainability of this gear in the delta area (Turolla, 2008).

Fig. 9. Hydraulic clam dredge "idrorasca"

In 2008 the use of idrorasca was authorized and tested in the Lagoon of Grado too, but the experiment failed because of the high mortality of Manila clam juveniles in that area. Thus the fishermen of Grado had to give up the first attempt of cultivation in their lagoon. Vice versa the area entrusted to maranese fishermen seems to be very suitable to the growth of clams. In winter 2011 the cooperative has granted to fishermen the use of 30 idrorasca to treat the bottom before the seeding, whereas a plot was already seeded in 2010. Before starting the new gear, a monitoring program was established with the regional agency for the protection of the environment (ARPA FVG), in order to evaluate the sustainability of this new method of harvesting in the Lagoon of Marano during a whole production cycle. In this way seven monitoring stations were selected (Fig. 8) to check the status of macrozoobenthos, sediment texture, chemical pollutants in clam tissues, both inside and around farm areas. Of course in this initial phase the fishermen are strictly watched to prevent any accident or illegal harvesting out of areas. They have to use the gear strictly following the procedures established by the regional authority: max speed of tow 1 km/h, pressure of water flux must not exceed 3.5 atm, no more than two hauls in each pathway and over all they must operate during the high slack tide, to prevent as much as possible the loss of fine sediments.

The environmental and socio economic vicissitudes of the Manila clam in the Lagoon of Marano and Grado could represent a case study: after more than 20 years of fights, farmers, fishermen and environmental policy seem to have found the pathway toward a sustainable shell farm. *T. philippinarum* arrived in the northern Adriatic lagoons as an alien species in '80th, leading to a total derangement of socio economic and environmental conditions. Now after almost 30 years, thanks to the model of shell farming in the Lagoon of Marano, this acclimated species could constitute strength for the fisheries economy of the lagoons and the northern Adriatic too.

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