Program: FP7 Cooperation

Short synopsis of each thematic area

Project acronym:	EUROSHELL
Project title:	Bridging the gap between science and producers to support the European marine mollusc production sector
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Synopses of European and National RTDI projects classified under the EATIP Thematic Areas

Overview

This series of synopses summarises the outputs of the 171 EU and national projects in the EUROSHELL Knowledge database. It should be noted that these do not represent all of the research effort over recent years, but were selected by EUROSHELL partners (scientists and producers) as being the most relevant basis for a knowledge database that supports a European extension network.

These projects have been assigned to the Thematic Areas (TA) of the European Aquaculture Technology and Innovation Platform (EATIP) based on keywords and the nature of the outputs. In some cases, projects have been assigned to more than one of the EATIP TAs. Under each TA, a further sub-division has been made to group projects and this is outlined below.

TA 1. Product quality, Consumer Safety & Health

- Quality and safety of shellfish products
- Biotoxins and HABs
- Nutritional benefits of shellfish products
- Shellfish markets

TA 2. Technology & Systems

- Production systems
- Depuration and purification systems
- Integrated species production

TA 3. Managing the Biological Lifecycle

- Reproduction and breeding
- Larvae and spat
- Genetic improvement of productive traits
- Managing the lifecycle of 'new' species

TA 4. Sustainable Feed Production

- Shellfish nutrition
- Algae and algal replacements

TA 5. Integration with the Environment

- Carrying capacity
- Interactions between farmed and wild stocks
- Tools for environmental governance
- Exotic species
- Ecosystem services

TA 6. Knowledge Management

- The benefits of the shellfish sector for society and the environment

TA 7. Aquatic Animal Health & Welfare

- Shellfish diseases
- Treatments and prevention methods

TA 8. Socio-economics, Management & Governance

- Status and management of shellfish stocks
- Social and economic dimensions of shellfish cultivation

For each Thematic Area, a synopsis of research, where possible with a focus on the outputs, has been provided. In all cases, the source of the research (EU, or country codes FR-France, IE-Ireland, IT-Italy, NL- Netherlands, ES-Spain, UK-United Kingdom) is also indicated.

TA 1. Product quality, Consumer Safety & Health

Significant research has been done over the years on the quality and safety of shellfish products, and including diagnostics, hygiene and risk assessments. Listed separately below is a section on toxicity and harmful algal blooms, where special emphasis has also been placed on better understanding and the development of early warning systems for producers.

More recently, research has shifted slightly to underline the nutritional benefits of eating shellfish and studies on markets and consumption.

Quality and safety of shellfish products

Diagnostic tools (with a focus on rapidity, sensitivity and non-destructiveness) have been a focus in for *Perkinsus atlanticus*, the most important pathogen in both cultured and wild stocks of clams (ES and EU), *Marteilia refringens* in oysters and mussels (ES), *Vibrio tapetis*, the etiological agent of the brown ring disease in clams (ES)

Quality issues include the bringing together of information on virological quality (ES). A study in Italy looked to deepen the knowledge on the epidemiological spread of Vibrio and to evaluate the correlation between the presence of these vibrios with the presence of microorganisms of faecal origin.

A publicly available database monitoring the concentrations of faecal coliforms, *E. coli*, heavy metals and flame retardants in shellfish flesh is available in NL and trends in the levels of *E. coli* in commercially harvested bivalve shellfish from England and Wales were also developed for the period 1999–2008.

On hygiene issues, a practical handbook for Italian producers was developed, containing useful information on legislation, causes and risks of dietary hazards in shellfish production and hygienic practices to prevent hazards.

Many shellfish production areas are periodically vulnerable to contamination of the water body. Research efforts on this are mainly summarised under TA5 (Environment), but there are several case studies and examples of risk assessment in this subsection, with examples of Manila clam cultivation in the Venice Laggon (IT) and norovirus in oysters in FR. A 2-year study (UK) sought to provide a baseline analysis of norovirus contamination in commercial oyster production areas in the United Kingdom and compared norovirus levels with risk factors in order to assist risk managers in developing control strategies to reduce the risk of human illness.

In the Vendée area of France, 9% of batches analysed were positive for the detection of noroviruses, mainly NoVGII in winter. The level of this viral contamination is directly related to the scale of the winter gastroenteritis epidemic in the population and with environmental events. Prevention measures to limit the risks of viral contamination (NoV GII) must take into account the winter risk period, the scale of the gastroenteritis epidemic, the contribution of NoV in coastal waters, and producers' practices.

On transport and seed quality, one study (IE) developed a behavioural indicator (% re-attachment) to evaluate the viability of seed mussel following various transport times. Extended transport times and protracted periods out of water do not decrease the viability of seed.

Biotoxins and HABs

There are four forms of poisoning caused by consumption of contaminated seafood, which differ in symptoms and duration: Paralytic shellfish poisoning (PSP), Neurotoxic shellfish poisoning (NSP), Amnesic shellfish poisoning (ASP) and Diarrhetic shellfish poisoning (DSP).

Monitoring of potentially toxic phytoplankton species, according to national standards and guidelines of the European Community has been the focus of several projects, resulting in a mapping and real-time monitoring system for the Adriatic Sea (IT) accompanied by the development of a handbook for producers that brings together in simple language information on the identification of species, the distribution of the potentially toxic species in the Adriatic region and information on the toxicology of the species.

EU research has developed fast, simple and cost-effective marine biotoxin detection methods for seafood and patient sera and successfully raised antibodies against okadaic acid, a diarrhetic shellfish poisoning (DSP) toxin.

However, the time delay from receipt of samples to identification of species does not allow for the main purpose of monitoring- which is taking preventive measures when coastal areas are threatened by HABs and monitoring costs represent a major economic outlay for the European industry. EU projects have looked into this, with the development of an automated, species specific and cost effective biological sensor for a rapid detection of toxic algae *in situ*.

More recently, another EU project has produced HAB advisory and forecasting capability as a service to the European aquaculture industry. The early warning of severe blooms allows fish and shellfish farmers to adapt their culture and harvesting practices in time, in order to reduce potential losses. A web portal delivers the data in a standardised and easy to access format (based on GIS) providing forecast bulletins for producers. A pilot biotoxin risk database for scallop producers was also tested in Scotland (UK).

Eliminating PSP (Paralytic Shellfish Poison) biotoxins , which is commonly accumulated in rough cockles (*Acanthocardia tuberculata*) and scallops (*Pecten maximus*) in natural banks of the Mediterranean coast, has been addressed in Spain, although no clear outputs of this national research have been communicated. In the UK, identification and toxicity of *Alexandrium Tamarense* (Dinophyceae) sub-types In Scottish Waters was investigated, so as to identify sub-types of *Alexandrium tamarense* that do and do not cause PSP in shellfish.

Nutritional benefits of shellfish products

In the UL, as technical report on the nutritional benefits of shellfish has been produced, that compiles literature on shellfish consumption and human health and provides an overview of the known/perceived health benefits in eating shellfish. Categories covered include cardiovascular disease, brain health and physiological conditions, joint health, stroke and cancer.

Shellfish markets

Market based approaches to culture have been looked at in Italy for clams *Tapes philippinarum* and mussels with the objectives of quality labels for production and certification of origin. These have shown the importance of the purification process and chill chain management and evaluate the quality of shellfish at different times of the year.

In France, studies have evaluated the impact of processing and social representation on perception of oyster-based products by French consumers. 5 products with different degrees of processing were presented within focus groups and consumer tests and results showed that social representation had a strong impact and that behaviours were contrasted according to the initial profile of the consumer (traditional raw oyster consumers or non-consumers) and their age distribution (younger and older people). The degree of processing needs to be adapted to each segment.

The market share of the Dutch oyster sector is decreased over the last years. This is due to increased competition, reduced market conditions and decreased oyster quality. A competition analysis is being done to get more insight in the current situation and potential new markets for the Dutch oyster.

TA 2. Technology & Systems

Production systems

An extensive review of production practices for mussel production in France looked into their dependence on meteorological factors, biological constraints (predators...) and farming practices (densities...), following a drop in production in 2010/2011.

In Spain, a comparison of raft and bag culture of oysters showed that success is dependent on seed size, culture density and the season. The growth obtained in the culture in bags was very similar to that obtained in a culture suspended in raft, but with lower mortality. With optimal densities and good husbandry practices, off bottom culture system of oysters could provide commercial size before the second summer.

Better management of natural beds has also featured in research on oysters (IT).

Validation of technology and the production of best practice for clam production has been performed in IT and ES.

Spat settlement and capture systems for mussels were tested in Spain, where long-line systems were found to be a good alternative to traditional methods. A new technique for harvesting mussel seed has been under construction in NL since 2000. They are called Mussel Seed Capture Installations (or MZIs). Scaling up MZIs has possible effects on the bottom structure and benthic organisms due to deposition of mussel- and pseudo faeces and hence the identification of most suitable locations is crucial to optimise their use.

On fouling issues, control of the spread of slipper limpets with movements of wild settled mussel spat (UK) assessed brine rinsing treatment protocols as a solution. Mussel farmers spread bleach over the ropes of mussel spat so as to limit the proliferation of *Enteromorpha* that invades the mussel-growing areas (FR). This may represent a danger to many species, including sea urchins, although the study did not demonstrate such effects on microalgae.

Finally, offshore shellfish production systems are being focussed upon, both in oysters and in mussels (UK and ES). The combination of offshore production with (for example) renewable energy of other marine structures is also receiving attention.

Depuration and purification systems

The main challenge is to find technical and biological processes that can safeguard and detoxify bivalves of commercial interest at harvest, and particularly during toxic algal blooms.

In France, research looked to identify the best rearing conditions for bivalve survival and quality preservation during safe-storage and detoxification processes. Safe storage: oysters can be kept for 3 weeks undamaged whatever process is used (dry or wet storage), whereas mussels need a storage device including algal food supply. Detoxification: a 60% drop in PSP toxin content can easily be obtained within 5 days with Pacific oyster fed non-toxic algae, whereas additional trials are needed for DSP detoxification of mussels. Technico-economic analysis: a public and private decision-making tool was developed and successfully validated.

Investigative trials on the purification of oysters to identify ways of reducing norovirus (UK) assessed the effects of depuration time and temperature in addition to two water sterilisation techniques (UV and ozone treatment) to reduce norovirus, FRNA bacteriophage and *E.coli* from experimentally contaminated *Crassostrea gigas*. Best practice was developed.

Integrated species production

Integrated Multi-trophic Aquaculture (IMTA) has recently been identified as a way forward for the European aquaculture sector. In simple words, it looks to use by-products, including waste, from one aquatic species as inputs (fertilizers, food) for another.

National research projects have looked at land-based pond algae and IMTA production (NL), combining the cultivation of sole with that of shellfish, rag worm, algae, seaweed and sea vegetables in a closed cycle without the use of fish feed.

Offshore production of octopus and mussels was also reported (ES).

TA 3. Managing the Biological Lifecycle

Reproduction and breeding

Several key EU programmes (Aquafirst, Aquabreeding, Aquagenet, Aquagenome) have dramatically enhanced our knowledge on breeding techniques and practices in European aquaculture. These initiatives have helped us to make an appraisal of existing knowledge throughout Europe and prioritise research needs. Genetic maps have been used to detect desired Qualitative Trait Loci (QTL) - regions of DNA of which the expression is associated with disease and stress resistance and these QTL's were analysed to identify genes associated with stress specific traits and disease resistance traits. This has resulted in the development of operational genetic protocols as a basis of selective breeding programmes. Next Generation Sequencing (NGS), is producing new genomic resources for shellfish species above and has created a transnational network for cooperation in biotechnology in aquaculture.

This work has been reflected in national research efforts on *C. gigas* (FR), as well as flat oyster and clam species (ES).

Larvae and spat

Collection of bivalve mollusc spat from the wild has been shown to be highly variable year on year.

Considerable work has been done on early development of mussels, including the development of a viable production method for (a) sterile triploid mussel seed and (b) tetraploid broodstock that will enable year-round marketing of high quality mussels (EU).The effects of endogenous and environmental factors on the byssus (ES) have also been elaborated.

On clams, efforts are focussing on early growth comparison between species; spat quality and basis of differences and the handling and transport of spat (ES).

For pectinids, environmental effects (temperature, salinity, depth….) considerably influence the success and quality of natural spat collection (ES). In the Malaga area, April to June is the best period, although the material used for collectors, their placement and the depth at which they are anchored are the main factors that influence the quantity of seed that is obtained. However, year-on-year results show a high variation and hence hatchery methods to produce spat are now being investigated.

For flat oysters, pond production of spat (UK) has been identified as a key way to progress and this extensive, low-technology technique could also be used for restoring natural oyster beds using local broodstock oysters. Development of these extensive pond systems in managed retreat schemes will undoubtedly lead to the establishment of collaborative projects and partnerships between industry and other organisations involved in creating these areas.

The origin of the extreme variability in natural collection of Pacific oyster in Mediterranean lagoons has been investigated in the Thau lagoon (FR). Software modelling and monitoring of the major ecological factors (including the potential biological barriers) and adaptation of cultural practices will allow more reliable natural collection in the lagoon.

Genetic improvement of productive traits

With significant production of triploid spat in hatcheries in France using tetraploid broodstock, there is a potential risk exists that tetraploid oysters escape into the environment. A network (FR) was created to monitor the possible appearance of polyploid oysters in the principal Pacific oyster spat production (collection) zones. The network has been in operation since 2002 and 1814 analyses collected in ten sites in 2010 (three in the bassin d'Arcachon, five in Marennes-Oléron and one in baie de Bourgneuf) found no polyploids, triploids or tetraploids in any of the three areas.

But which is better (i.e. less susceptible to mass mortality?) In separate conditions, diploid or triploid hatchery spat put for pre-growing in laboratory tanks or in oyster ponds, suffered hardly any mortality (0-3%) between April and October, while the same batches were strongly affected when grown in mixtures (82-100%). In all cases the wild spat showed 39 to 82% mortality.

It appears that the naturally collected wild spat could be the source of contamination for the spat produced in the hatchery.

A study (IE) investigated the growth of sibling diploid and triploid oysters under varying environmental conditions at three ecologically different sites on the south coast of Ireland and found no significant differences in the growth performance of diploid and triploid oysters at the 3 different sites over the 4-month duration of the study.

In the Bassin d'Arcachon (FR) spat supply has become an issue and producers have looked for resistant oyster stains from hatcheries (genetic selection), or from elsewhere (naturally resistant wild oyster populations). Restocking procedures were therefore defined: where to place the introduced

oysters, the optimal quantity to place and how to disperse the larvae. Descendants of the introduced oysters were genetically traced, so as to differentiate them from natural populations to estimate the success of these operations.

In looking at the genetic basis of selection against oyster mortality (FR), a new generation (6th generation of reproduction) was produced in 2009 and oysters (aged 6 months) were tested on the foreshore at one site and tested for infectious agents (OsHV-1, *Vibrio splendidus* and *V. aestuarianus*) in comparison to unselected oysters (control units) of the same age. Resistance to the phenomenon of summer mortality of juvenile oysters of 6 months showed high heritability; the performance of generations 2 and 3 were similar to that of generation 1. Selection on survival had a positive effect on production performance and no impact on growth was found.

In 2013, a program of inter-regional monitoring (FR) was initiated between four technical centres to compare rearing performances of *C.gigas* between the different rearing areas using common pools of spat. This will provide valuable information to producers on the evolution of stocks over an entire rearing cycle; compare rearing performances with a batch of common natural control spat placed at the same sites and observe the evolution over the medium term, though the use of common spat over several years.

The mortalities of oyster spat are caused by a virus and are contagious. Healthy individuals isolated from involved pathogens do not develop the disease. Zootechnical management of the disease epizootic was thus proposed based on the isolation of batches. This seems particularly suitable in the context of Normandy where the scarcity of wild stocks eliminates a potential source of contamination. Observations suggest that spat issued from collection early in the season could be less sensitive to the mass mortality phenomenon than spat collected later.

In Spain, research has identified and evaluated different DNA molecular markers on the economically important queen scallop *Aequipecten opercularis* looking to characterise Galician populations and establish genetic relationships with other Spanish (Fuengirola, Malaga) and European banks.

Similar work (several project summaries) has also been done on various clam species (*Ruditapes spp*), to study the variability and genetic differentiation of wild beds along the coasts of the Iberian Peninsula and to determine parent-offspring relationships in a batch of hatchery-produced clams, so as to look for genetic variation for quantitative traits of commercial importance.

Managing the lifecycle of 'new' species

The principles of continuous, controlled reproduction are now being applied to 'new' shellfish species –including horse mussels *Modiolus barbatus* (IT), sea snails *Nassarius mutabilis* (IT), razor shells *Ensis spp.* (ES and NL), and abalone (*Haliotis spp.*), where hatchery protocols have been published in IE and FR.

TA 4. Sustainable Feed Production

Shellfish nutrition

Increasing knowledge on the nutrition of clams (ES) has focussed on studying the pathways and processes of assimilation of carbohydrates in two clam species *R.decussatus* and *V. pullastra,* so as to establish minimal nutritive requirements of each component of the diet and to look into the use of stored reserves in both species during nutritive stress.

This has been complemented by further work (also in ES) on the same species to study digestive process (enzymatic biochemistry) in order to develop *in vitro* assays for the design and nutritive evaluation of diets for the culture of clam spat.

Algae and algal replacements

Algal production and replacement, has been on the research agenda for many years.

The development of gelatine microcapsules of different sizes for the larvae, post-larvae and brood stock (ES) is reported with a focus on digestion and assimilation of fatty acids and other nutritional elements.

An EU project has also tested microencapsulation as a way of delivering probiotic bacteria to degrade toxins, out-compete pathogens or aid host virulence (see TA7).

Various alternative diets for feeding 1-2mm oyster spat were compared (UK) alone or in combination with a standard live microalgae diet. The diets tested included algae pastes, compounded rotifer feeds and yeast. In all trials the best overall growth performance was always achieved with live algae. However, when algae supply is limited, its partial replacement (25% of the diet dry weight) with yeast is possible without severely compromising production cycle time and thus overall hatchery productivity.

TA 5. Integration with the Environment

Carrying capacity

Under the project “Carrying capacity: Possibilities and limitations of the ecosystems for oyster culture”, a study (NL) is being done to assess the reduction in growth of cultured oysters in the Eastern Scheldt and address the question if more nutrient rich freshwater or the capture of wild oysters will have a positive effect on the culture plots.

A regional project (FR) focused on Baie de Bourgneuf (10% of French oyster production) is orientated around three axes, of which the third is intended to integrate the first two. The axes are bio-production and marine resources and identification and analysis for sustainable management - that will lead to the creation of a decision-making tool for Integrated Coastal Zone Management.

Another study (FR) has developed a monitoring protocol for the natural Pacific oyster population and its evolution on the coasts of Normandy by monitoring colonisation density and recruitment to predict future populations and better understand the recruitment mechanism.

Interactions between farmed and wild stocks

A sub-project of the EU Interreg programme addressed the genetic variability between wild and hatchery based stock of the European flat oyster, *O. edulis*. Genetic mapping showed that hatchery produced populations show a loss of diversity relative to natural spat-fall and hatchery restocking could therefore be detrimental to wild flat oyster populations. However, pond production could be a valuable alternative, as it is more efficient in maintaining genetic diversity. New microsatellite markers (8 for *M.edulis* and 27 for *O.edulis*) developed during the project can help marker assisted genetic selection in these two species.

Tools for environmental governance

An interdisciplinary analysis of the clam sector in the Venice lagoon (IT) includes social, cultural, economic, environmental, biological and legal information for producers and policy makers. A separate publication describes the fisheries of the lagoon and policy recommendations.

A similar approach (IT) gave rise to the production of an environmental management model for shellfish activities in the north Adriatic for the preparation of integrated management plans for coastal areas in that region.

In the Netherlands, as study was prepared in the impacts of seed fishing for mussels. The Wadden Sea is a protected nature reserve, so a permit is required under the terms of the Nature Conservation Act (NCA). According to these terms, it must be demonstrated that the fishing has no negative effects on the designated conservation objectives for the habitat type in which the fishing takes place.

Spatial self-organization is the main theoretical explanation for the global occurrence of regular or otherwise coherent spatial patterns in ecosystems. Using mussel beds as a model ecosystem (NL), an experimental demonstration of spatial self-organization was developed. Provision of information to policy makers was used (NL) to develop recovery programs by identifying the factors that affect the disappearance of young mussel beds.

Spatial management planning has also been developed in various regions of France for the various shellfish species of economic importance.

The environmental sustainability of sub-tidal oyster structures in Southern Brittany (FR) used novel sampling methods (scuba diving and net catch) to compare and analyse benthic and demersal communities and their food web. In the UK, a review of the evidence base related to the economic, legal and environmental issues pertaining to the growth of the Pacific oyster culture industry in the UK was prepared for policy makers and coastal management authorities.

A long term study (IE) brought together experts from a wide range of disciplines, including shellfish biology, ecology, physical oceanography and economics to produce guidelines for future fisheries management and policy of the shellfish industry in Ireland & Wales for the next 50-100 years. This was achieved by assessing the effects of climate change, via oceanographic models, on shellfish productivity in the Irish Sea and determining adaptation or mitigation strategies for the industry.

An overarching study (ES) addressed the minimization, treatment and sewage use from aquaculture activities.

Exotic species

Historically, some shellfish culture has been responsible for the introduction of exotic species that can sometimes out-compete native species for natural resources. Invasive exotic (alien) species have

not been taken into enough consideration concerning the European Water Framework Directive (WFD) and other European directives until recently. The Dutch ministry responsible for water management is looking for ways to establish the impacts that invasive exotic species may have on specified water types. This new approach focusses on the system where the alien species are introduced into rather than only on the exotic species themselves.

The physiological responses of native and invasive mussel species were the focus of studies in Spain.

Ecosystem services

A trial (NL) on the use of constructed banks of oyster shells in gabion mattresses to restrict wave action and catch silt is being conducted in the Eastern Scheldt as part of the "Building with Nature" innovation programme.

TA 6. Knowledge Management

The benefits of the shellfish sector for society and the environment

The 'Choose Mussels' web portal (IT) looks to enhance regional mussel production in Puglia through product diversification, the search for new markets, the development of advertising campaigns at regional and national level and the development of networking among the operators.

The web portal has a forum for stakeholders, links to information for producers/retailers/consumers and a calendar of events organized in the region.

TA 7. Aquatic Animal Health & Welfare

Shellfish diseases

The EU Bivalife project provided knowledge on the pathogens infecting oysters and mussels and developed practical approaches for the control of infectious diseases and resulting mortality outbreaks on *Crassostrea gigas*, *Mytilus edulis* and *M. galloprovincialis*. The targeted pathogens were the virus OsHV-1, vibrio species including *V. splendidus* and *V. aestuarianus*, as well as the parasite *Marteilia refringens* and the bacterium *Nocardia crassostreae*. Screening of brood stock, larvae and spat allows the selection of batches without pathogen detection or improved immune resistance to pathogens.

The molecular tracing of viral pathogens in aquaculture was the subject of another EU project, where models to assess effects of different control strategies were developed through collection of isolates of specific important aquatic animal viruses and their respective epidemiological data; characterisation of the isolates by phylogenetic and expression analyses and constructing scenario simulation models to assess effects of different control strategies.

Since 1992, France has a mollusc pathology network, and a national reference laboratory was created to centralise information, including the establishment of inter-regional monitoring of infectious agents. The first epidemiological map in Catalonia (ES) showed zones that could be declared 'disease-free'.

A lot of research effort has been directed towards elucidating the factors contributing to severe mortality of Pacific oysters.

Studies in France to increase knowledge on mortalities of cupped oysters associated with the bacterium *Vibrio aestuarianus* looked at oyster sensitivity at different ages, ploidies, origins, genetic and historic backgrounds and compared the health status of batches with contrasting sensitivity. It also compared strain virulence of *V. aestuarianus* isolated in 2012 and earlier years through experimental pathology trials and tudied strain diversity using new methods for typing and sequencing the complete genome.

The role of juvenile and adult asymptomatic carrier oysters in the propagation of viral disease was also addressed (FR) and several projects looked much deeper at spat physiology during mortality events.

At these times, an increase in the abundance of microbiota with a decrease in its diversity, and increase in Vibrio representation concomitant with *V. splendidus* and herpes virus was also noted (FR). The host-pathogen interaction was studies based on recognition of *V. splendidus* as a pathogen, mechanisms by which the Vibrio resists the antimicrobial response of its host and if resistance to oyster antimicrobials contributes to the virulence of Vibrio for its host.

The EU project, Oysterecover produced a toolbox for flat oyster natural beds management, comprising protocols for best management of stocks with recommendations on location choices, seed supply alternatives and transfer between different locations to avoid the spread of the disease. The toolbox also includes GIS (Geographic Information System) on flat oyster beds, including limits of the oyster beds, biomass, oyster density, bathymetry, type of bottom, water temperature, salinity, chlorophyll a, nutrients, *Bonamia* status and evolution of the prevalence level of the infection, as well as markers for bonamiosis tolerance that could be used for population screening.

This was reflected in national programmes, where histopathological data from annual shellfish disease monitoring from 1988 to 2006 (NL) quantified its prevalence and factors that could lead to the introduction and/or spread of the disease (UK) were assessed.

Identified for many years by the mussel and oyster farmers, predatory drilling gastropods, *mytilicola* and birds are major predators or parasites of mussels and oysters. The economic impact is significant, exceeding 10% of the shellfish yield in some areas (FR). Methods aimed to reduce predation and parasites were evaluated.

Treatments and prevention methods

Research efforts have focused on further knowledge of immune response and the identification of gene networks involved during infection.

In Spain, the modulation of immune response produced by external stimuli was assessed, to determine if this immunomodulation has effects on diseases resistance in the carpet shell clam (*Ruditapes decussatus*).

The function of antimicobial peptides and their potential implication in the immune response of bivalves was also investigated (ES).

Other studies identified and characterised genes that are expressed and proteins that are induced during the immune response of clams against perkinsosis (ES – several projects) and oysters to vibrio (FR).

A recent study (FR) showed that oyster spat previously infected with herpes virus OsHV-1 µVar, and maintained at 13.0 °C for 40 days, eliminated the viral DNA in their tissues, showed no mortality and did not transmit the disease to healthy oysters placed in cohabitation. In addition, when these animals, acclimated to 13.0 °C, were subjected to a sudden increase in temperature to 20.6 °C in the laboratory DNA of OsHV-1 µVar was still not detected, oysters showed no mortality, and the disease was not transmitted to healthy oysters placed in cohabitation. Exposing spat to low temperature (13.0 ° C) would therefore provide a way of limiting oyster mortalities.

Delivering active agents to bivalve molluscs through micro-encapsulation was the objective of the EU Beads project that sought to develop 'probiotic diets' that could be directly filtered by shellfish.

Although not really a treatment, the French safeguard plan for oysters showed that notable improvements in survival could be obtained through selection. Selected triploid spat (Eclo-3nR) showed a mean survival rate of 48.5%, which was significantly higher than for classic triploid oysters (22.5%) or non-selected diploids (11.5%).

TA 8. Socio-economics, Management & Governance

It is often commented that socio-economic research does not figure sufficiently in EU and national programmes. There is also potential overlap in this TA and the market aspects of TA1. However, several national projects have addressed these issues, as well as the status and management of shellfish stocks.

Status and management of shellfish stocks

Clam fishing in the Venice lagoon has developed spontaneously and with fishing methods based on open access, where exploitation of the resource has been without limits. To establish a system of shared rules and self-governance, an interdisciplinary analysis of the sector was made, including social, cultural, economic, environmental, biological and legal information. This approach was also made for mussel areas in the north Adriatic, complimented by a study to assess the possibility of application of the standard of certification proposed by MSC (Marine Stewardship Council) to fishery and aquaculture activities in Italy.

These and other studies lead to the recommendation to create a Producer Organisation (PO) that would allow greater economic stability, the ability to interpret market trends, increase bargaining power and attain a consistent product quality in strongly competitive markets.

In the Netherlands, a survey on the tidal flats and in the channels is determining the biomass and distribution of shellfish populations. The same approach was made in UK to clarify the composition of *Mytilus* species in cultivation at Scottish mussel farms.

A long term regional network (FR) is assessing annual performances of Pacific oysters in terms of mortality, growth and quality. The protocol aims to monitor individuals of two age groups ("adult" = 2 years and "juvenile" = 1 year) at 10 stations representing the major shellfish growing areas in Normandy. With oyster mortalities since 2008, a national network with standardised methods and data is recording growth and survival in sentinel batches reared across the diverse production sites.

An economic assessment of the Dutch cutter fishery in 2009 has also been reported.

Social and economic dimensions of shellfish cultivation

A study of the natural *Ostrea edulis* beds (IT) showed the viability of ongrowing flat oysters caught on these periodically-forming beds along the Adriatic coast. Survival was >95% and microbiological and toxicological levels were lower than legislative norms. Product quality was high. This also highlighted the need to safeguard wild oyster stocks from being overfished, while encouraging a management policy and collaboration between fishermen and farmers.

Mussels seed capture installations (MZI) have been assessed economically in NL so as to assess investment cost, positive effects on the local and regional economy and potential negative economic effects on other fishing activities as a consequence of the loss of fishing grounds.

The potential for conflict between shellfish aquaculture and recreational use for yachting of a loch in Western Scotland was assessed (UK) in consultation with a local environmental forum and a small reference group of public officials.

In Spain, a Real Options approach was used to clearly document investment and risks in aquaculture. This approach helps to facilitate the management of strategic investments in aquaculture; to allow decision making with a higher flexibility on scale and loss reduction and to hence add value to the company.