SEACASE

SUSTAINABLE EXTENSIVE AND SEMI-INTENSIVE COASTAL AQUACULTURE IN SOUTHERN EUROPE

PROJECT NO. **044483**

INSTRUMENT: **SPECIFIC TARGETED PROJECT**

THEMATIC PRIORITY: **FP6-2005-SSP5A**

FINAL PUBLISHABLE ACTIVITY REPORT

PERIOD COVERED: from **01.01.2007** to **31.01.2010** DATE OF PREPARATION: **31.01.2010**

START DATE OF PROJECT: **01.01.2007** DURATION: **37 MONTHS**

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REVISION V0

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SUMMARY

The main goal of the SEACASE project was to **develop effective tools** for maintenance of **competitiveness, productivity, profitability** and thus sustainability **of extensive and semi-intensive aquaculture** production in **Southern Europe,** while minimizing its environmental impacts and improving the quality and public image of its products.

Extensive and semi-intensive aquaculture systems in Southern Europe are responsible for a significant production, at least 100 000 tons/year, and for using a large area, at least 92 000 ha, along the southern European coastal zone (e.g., confined areas of coastal lagoons, natural and managed deltas, and semi-closed bays and estuaries, encompassing polders with earthen ponds). Nevertheless, further geographical studies are required to better estimate the evolution of land use by farmers, and wetland abandonment.

Six independent **case studies were developed to demonstrate the feasibility for productivity enhancement** in coastal extensive or/and semi-intensive aquaculture in Southern Europe under sound environmental conditions. These included production of juveniles in extensive or semi-extensive conditions, extensive and semi-intensive polyculture in earthen ponds, an intensive-extensive integrated land-based system, extensive production in valliculture, and integrated management of marine extensive ponds and lagoons for a sustainable eel fishery.

Technical improvements within the SEACASE project aimed to **add value** in extensive and semi-intensive systems aquaculture while increasing **sustainable production, improving management practices and resources conservation.** These improvements included development of innovative eco-friendly diets, optimisation of slaughter procedures and the identification of genes that confer a higher adaptability to low temperature allowing the selection of best performing strains in extensive aquaculture.

The project investigated **quality criteria as potential markers** to differentiate fish (seabream) reared in different systems. Sanitary and nutritional quality, yields and body traits, colour, sensory quality and muscle structure were followed. In addition, an artificial intelligence application was developed in order to distinguish between fish juveniles reared in intensive and non-intensive systems.

After a review of **certification procedures** at national level, six specific **Codes of Conduct** for each of the SEACASE case studies were developed. These Codes of Conduct were used as a starting point to build up a proposal for a Joint European Certification System for Products of Non-Intensive Sustainable Aquaculture.

The **socio-economic patrimonial value** of aquaculture was assessed over the case study of integrated eel fisheries and oyster refinement, through a patrimonial audit approach. This illustrated the **importance** of non-intensive aquaculture **in maintaining ecosystems functionalities and services** supported by the ecosystems in confined and intertidal areas. It also pleaded in favour of maintaining such systems beyond farms' private profitability alone.

CONTRACTORS INVOLVED

PORTUGAL

CCMAR – CENTRO DE CIÊNCIAS DO MAR DO ALGARVE

INRB,I.P. – IPIMAR – INSTITUTO NACIONAL DE RECURSOS BIOLÓGICOS – IPIMAR

SPAIN

ICMAN-CSIC – INSTITUTO DE CIENCIAS MARINAS DE ANDALUCÍA – AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

FRANCE

IFREMER – INSTITUT FRANÇAIS DE RECHERCHE POUR L'EXPLOITATION DE LA MER

CREAA – CENTRE RÉGIONAL D'EXPÉRIMENTATION ET D'APPLICATION AQUACOLE

FMA – SYNDICAT MIXTE "FORUM DES MARAIS ATLANTIQUES"

CEDEM-UBO – CENTRE DE DROIT ET D'ECONOMIE DE LA MER - UNIVERSITÉ DE BRETAGNE OCCIDENTALE

ITALY

ISPRA – ISTITUTO SUPERIORE PER LA PROTEZIONE E LA RICERCA AMBIENTALE

UTV – UNIVERSITÀ DEGLI STUDI DI ROMA 'TOR VERGATA'

UNIPD – DEPARTMENT OF PUBLIC HEALTH, COMPARATIVE PATHOLOGY, AND VETERINARY HYGIENE – UNIVERSITÀ DEGLI STUDI DI PADOVA

GREECE

HCMR – HELLENIC CENTER FOR MARINE RESEARCH

UoC – UNIVERSITY OF CRETE

BACKGROUND

Traditional coastal extensive and semi-intensive aquaculture systems in Southern Europe are facing difficulties, especially due to increased competition for coastal areas by other candidate users and to market competition, due to low-price products from intensive aquaculture. However, the positive effects of extensive and semi-intensive aquaculture in coastal areas – including environmental protection and restoration in areas of particular ecological interest, employment opportunity and development in rural and coastal areas - have been clearly recognised within EU policy. Optimisation of existing protocols, and developing of new farming protocols, to enhance productivity of ponds and lagoons, or using certification processes allowing an add-value to products from extensive and semi-intensive systems, could render these activities more economically effective and attractive for new generations of farmers.

SEACASE – "Sustainable extensive and semi-intensive coastal aquaculture in Southern Europe" is a specific targeted research project, supported by the European Commission within the Sixth Framework programme under contract no. 044483. The main goal of SEACASE was to develop effective tools for the maintenance of competitiveness, productivity and profitability of extensive and semi-intensive Aquaculture production in Southern Europe, and, at the same time, minimize its environmental impacts and improve the quality and public image of its products. The project was based on case studies covering a wide variety of production systems and geographical locations (Portugal, Spain, France, Italy and Greece).

PROJECT OBJECTIVES

QUALITY

- Development of environmentally-friendly farming protocols for certification opportunities;
- Promotion of codes of conduct in European aquaculture;
- Promotion of product safety and animal welfare.

COMPETITIVENESS

- Development of technological improvements for optimizing the production of extensive and semi-intensive aquaculture systems;
- Better dissemination of knowledge on production processes in Southern Europe;
- Promote the diversification of aquaculture products;
- Promote income diversification strategies.

ENVIRONMENT AND SOCIETY

- Preservation of wetlands and coastal areas of particular ecological interest;
- Develop innovative diets to reduce waste output;
- Assess socio-economical relevance of the sector;
- Promote employment opportunities through more sustainable systems.

Fulfilling these objectives should also provide support to national and European authorities in defining their policies.

WORK PERFORMED AND RESULTS ACHIEVED

Current status of extensive and semi-intensive systems

Extensive and semi-intensive systems are responsible for a significant production (at least over 100 000 tons/year) and for using a large area (at least 92 000 ha) along the southern European coastal zone (e.g., confined areas of coastal lagoons, natural and managed deltas, and semi-closed bays and estuaries, encompassing polders with earthen ponds). Nevertheless, further geographical studies are required to better estimate the evolution of land use by farmers (e.g., abandonment).

Productivity is one of the main concerns of modern semi-intensive farming, where good production values can be obtained. The situation is very different for extensive production systems, which display different levels of productivity depending on management levels, natural and administrative constraints, and technical capacity, among others. Reliability gain could be technically reached in many cases, but socio, administrative and economic issues are often the bottleneck. The various systems that were inventoried within the SEACASE project display similarities between countries, where similar modern techniques have been integrated by farmers for mass production of shellfish (oysters, clams), as well as for semi-intensive fish and shrimp rearing. On the contrary, traditional practices display more differences regarding technical protocols and water management. Further improvements in traditional systems would need a stronger commitment from farmers, governmental agencies and other stakeholders, which is often difficult to obtain.

Successful stories of improvement of traditional extensive systems are oyster and mussel monocultures in France. Shellfish aquaculture provides massive volumes of production in lagoons (over 100 000 tons/year). Lagoon use for shellfish and fish rearing is high in many places (over 100 000 ha in Southern Europe), but expansion is often limited by the threats posed by pollution and eutrophication processes, and by competition with other human activities (e.g., tourism). In many cases, marshlands with earthen ponds/saltworks display abandonment (France, Spain), and could recuperated for shellfish and fish extensive or semi-intensive farming.

Ancient practices of extensive fish aquaculture still go on because of the traditional background of local populations. Except in Italy (e.g., valli's and confined areas of coastal lagoons), these activities only benefit from limited improvements. They produce small amounts of high quality fish, but suffer from a lack of traceability and public recognition. Only Italy with its different types of lagoons displays an optimized use of their potential for extensive fish production, with probably a large production despite the lack of statistical data.

Semi-intensive fish productions have reached a mature level. Several successful trials during the last 15 years are now converted into reliable farming systems (Spain, Portugal). Fish production statistics, which are not complete due to the lack of data, reached a minimum of 4200 tons/year in all the countries studied. Real

production values of semi-intensive and extensive fish rearing are probably higher, but non-official trade practices and barter still persist what prevents from getting more reliable information.

Shrimps' rearing in earthen ponds relies on modern techniques (rather the same in all countries), but these productions are very limited, probably due to profitability constrains. At least 160 tons of high quality products are produced in Spain, France and Greece. After a slow growing period, the production may increase, looking at niche markets, driven by the need for diversification by the earthen pond farmers submitted to strong difficulties during the last three years on the western European coasts.

Technical improvements in extensive and semi-intensive systems

The study of technical improvements within the SEACASE project aimed to add value to the extensive and semi-intensive aquaculture while increasing sustainable production, management practices and resources conservation.

Innovative diets, replacing 40% and 60% of fishmeal and 35% of fish oil with vegetable ingredients, were formulated to reduce the pressure on natural resources and minimize farm waste and nutrient output in semi-intensive farming. The experimental diets, produced and tested under pilot and commercial scale, have no detrimental effects on growth performance and flesh quality in gilthead seabream, reduce soluble phosphorus levels in effluent waters, and reduce the susceptibility of fillets to lipid and protein oxidation.

Slaughter is one of the most critical points in fish farming management, as it may influence the quality of the final product and affect fish welfare. An enquiry launched by SEACASE project partners in several countries concluded that live chilling in ice/water slurry is the more common slaughter method used in semi-intensive and extensive aquaculture (see Figure 1). However, as recommended by EFSA (2009)[1], this method needs to be improved to avoid negative effects on fish welfare. Within several pilot trials carried out on seabass and seabream, improvements to the ice slurry method were developed and resulted in reduced time to death (generally accepted as resulting in higher welfare), improved general sensory attributes, and not detectable or significative differences in physical and microbial measurements of fish quality.

[1] Scientific Opinion of the Panel on Animal Health and Welfare on a request from the European Commission on welfare aspect of the main systems of stunning and killing of farmed seabass and seabream. The EFSA Journal (2009) 1010, 1-52

Figure 1. Operation of transfer of seabass and seabream from the net in the pond to slaughter tanks with ice slurry at Aqualvor aquaculture facilities, Portugal.

Winter temperature represents a major limiting factor for semi-intensive and extensive coastal aquaculture in northern Mediterranean areas. Stress response and adaptability to severe low temperature was investigated in gilthead seabream through a physiological and functional genomics approach (see Figure 2 and Figure 3). Under experimental conditions (6°C for 21 days), changes of physiological parameters reflect changes of several molecular pathways, mainly lipid metabolism, protein degradation and repair, regulation of cell death, oxidative stress and innate immune depression. The obtained results allowed to formulate preliminary recommendations to improve fish performance at low temperature. A large genomic data set was also acquired by microarray technology. The integration of molecular and biochemical tools may allow the identification of genes that confer a higher adaptability to low temperature and the selection of best performing strains in extensive aquaculture.

Case studies

Six independent case studies were developed to demonstrate the feasibility for productivity enhancement in coastal extensive or/and semi-intensive aquaculture in Southern Europe under sound environmental conditions.

1) To optimise the initial rearing stage of marine fish under extensive or semi-extensive conditions, different experiments were performed in France, Portugal, Italy and Greece. Results showed that larvae reared in mesocosm tanks/ponds had higher performance than those reared in intensive systems, and that the use of artificial substrates enhanced the natural production of

plankton, benthos and periphyton communities, leading to a higher juvenile production in mesocosm systems. Seeding the ponds with cheaper highly performing juveniles resulting from larvae reared in mesoscosm systems may be one way to increase profitability of extensive and semi-intensive systems.

2) Possibilities for improving the production protocols in earthen ponds currently used to ongrowing gilthead seabream and European seabass were assessed. Polyculture of seabream and sole was tested in Portugal at two different fish stocking densities and with two feeds, regular and eco-friendly feed. The feed trial confirmed that suspended particulate matter levels reflect mostly the effect of fish density rather than feed quality, since no significant differences were found between the ponds supplied with standard- and eco-feeds. Nevertheless, the use of eco-feeds seemed to reduce the amount of dissolved organic phosphorus released into the environment while maintaining an optimal fish growth. Ongrowing sole in ponds in polyculture with seabream can bring added value, but recovery of stocked sole is variable. It depends on maintaining good pond bottom conditions and is viable only at moderate sole and seabream densities. Higher fish densities tested (up to 3 Kg/m^3 at harvest) lead to macrobenthos depletion, explaining thereby the poor results with sole at such densities, but do not seem to have a negative impact on water effluent quality.

3) To test a potential remediation treatment of intensive aquaculture effluents, an integrating land-based extensive aquaculture system was evaluated in France. The best results in nutrient removal from effluents coming from a hatchery/nursery were obtained when combining macroalgae (*Ulva*) production and harvesting. However the combination of *Ulva* and fish in the same pond is not recommendable because *Ulva* population induces occasional severe oxygen deficits.

4) To provide 'added-value' to valliculture in Italy, several optimizing farming protocols were performed for gilthead seabream in three different valli. This study performed differently according to the considered valle. However, when wild and reared juveniles are stocked in the same valle the origin of seed (wild vs hatchery-reared juveniles) did not significantly influence the recapture rate of seabream after one year rearing, nor did it influence physiological parameters, nor health status. DNA fingerprinting (see Figure 2 and Figure 3) provides effective and reliable molecular tools to trace fish origin in valliculture. In the other two valli, where experimental activities were carried out, a significant relevant impact of ichthyophagous birds was noted on recapture rate, both of wild and reared stocked fishes. The impact caused by piscivorous birds limits traditional valli management, particularly in those oriented towards gilthead seabream production. In these valli, a drop of 30% in the annual production of stocked seabream can be inputted to predation by ichthyophagous birds. This impact can be direct, when fish are captured, or indirect, due to the development of secondary infections of injuries or to the general decrease in fish performance. Furthermore, they disrupt fish migration toward fish barriers, scattering fish on their way toward summer pasture zones and provoking death for cold during wintertime. The shifting of seabream production towards large-size instead of 'portion-size' fishes can

bring added value to production (higher market price; higher survival rates) and offers larger market size fish that are very rarely available from capture fisheries. Morphological evaluation (shape analysis and skeletal anomalies) evidenced that large-size gilthead seabream from valliculture also exhibit 'wild-like' phenotype, making them undistinguishable from wild fishes of similar size.

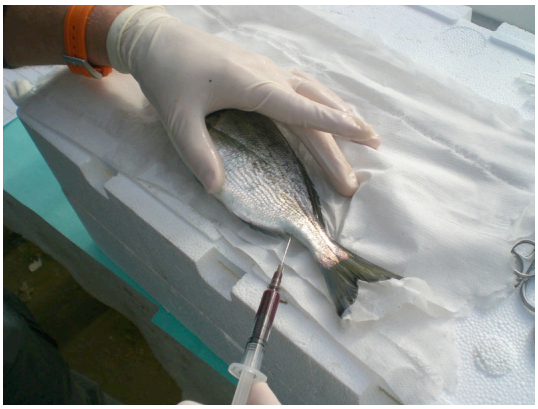

Figure 2. Seabream blood sampling – Valle Bonello, Italy.

Figure 3. Tissue sampling for genomic analysis - Valle Bonello, Italy.

5) To assess the role of coastal wetlands in the sustainability of the endangered eel fishery and to promote the extensive eel production in these systems, a study was carried out in ponds in France. Results demonstrated that traditional fish ponds in coastal wetlands in the French Atlantic Coast as well as in the Spanish South Atlantic coast are still being colonised by the natural entry of eels. The coastal fish ponds seem to work as a trap and growing place for juvenile eels, having a relevant role in maintaining the eel life cycle and the fishery of this species.

6) To evaluate the potential of extensive fish polyculture in abandoned pond/saltwork areas in the South West coast of Spain, a case study was performed to compare the production of polycultured fish between ancient and recent restored ponds in a traditional farm (see Figure 4). The study also evaluated the importance of additional harvesting of high valued species, such as eel and crab. Results demonstrated that new-built ponds connected to a network of channels and tidal marshes have the capacity for a quick regeneration of benthos and plankton communities, as well as for the regular fish production in extensive system since the first working season.

Figure 4. Aerial view showing marshes and fish farms in transformed and untransformed old saltpands (*esteros*) in the Bay of Cádiz, Spain.

Quality markers

The project allowed to investigate some quality criteria as potential markers to differentiate fish (seabream) reared in different systems. Sanitary and nutritional quality, yields and body traits, colour, sensory quality and muscle structure were followed. The same methods of analysis were performed firstly on a large number of samples from intensive production systems coming from different farms at different seasons, and then were applied to case studies developed in different countries and illustrating a specific rearing system: extensive, semi-intensive or integrated system based on effluent treatment of an intensive hatchery. The number of repetitions or locations tested for each case study does not allow generalization, nevertheless some tendencies can be highlighted:

- All the samples analysed from intensive or semi-intensive system are safe for human consumption (low levels in PCB's and heavy metals, well under the EU limits),

- The lipid content of the flesh is often higher in seabream from intensive system (*not always, some variations exist according to the farm and the season*) and therefore the trimming loss after filleting can be higher in this case.

- Compared to intensive production, integrated systems, semi-intensive systems, and to a lesser extent extensive systems, lead to products with a better nutritional balance, with a higher level of polyunsaturated w3 and a lower level of w6, which means a better w3/w6 ratio for human consumption. Some intensive samples can present also a good ratio but in our study only

21% of the 24 samples from intensive production reach a ratio of 1 and 8% a ratio of 2, whereas for case studies samples, 6 out of 8 (75%) reach at least a ratio of 1 and 2 out of 8 (25%) exceed 2.

- Sensory characteristics discriminate the kind of rearing system. For extensive systems, samples are generally perceived less firm and less dense during chewing, with higher moisture in flesh and less fatty characteristics in odour, taste and texture. Some quality characteristics of seabream from integrated systems seem to be a consequence of the environmental conditions in earth ponds. Appearance (golden line between eyes and orange colour in gill area), odour and taste are a sort of fingerprint of these conditions. Moreover, the rearing system seems to modulate the muscle structure, since the muscle of seabream from intensive system had a higher number of small fibres and a higher density of fibres.

- Environmental conditions have been identified as an influent factor on odour and taste characteristics of fish reared in earth pond or estuaries. Products from intensive farming have more constant sensory characteristics and present a generally whiter fillet colour, after cooking; on the other hand, the characteristics of the products from the other systems reflect the influence of natural conditions, in terms of external appearance and sensory properties.

Another task in the project was dedicated to setting up an evaluation system for reared seabream juveniles on the base of similarity to wild phenotype. At least 60% of the actual production of reared seabream juveniles is affected by skeletal anomalies that have to be culled out during the production cycle. Furthermore, deformed individuals show lower growth rates and higher sensitivity to pathogens. Deformed commercial size fishes induce reserves in consumers regarding aquaculture products. In order to identify which larval rearing methodology was able to produce wild-like seabream, data from skeletal anomalies inspection carried out on a total of 5200 seabream from different rearing methodologies and at different sizes were analysed by means of Self Organizing Maps (SOM), an artificial intelligence application. The obtained results evidenced:

- semi-intensive rearing methodologies (large volume, mesocosms) are able to guarantee wild-like juveniles with a certain regularity both in seabream and in Senegalese sole; this was observed for skeletal pattern, external shape and lateral line morphology in gilthead seabream and for skeletal pattern in Senegalese sole;

- seabream (≈150 g) recaptured after 5-7 months in extensive conditions (valliculture) resulted of better quality than before stocking and undistinguishable from wild fish of similar size;

- large-size (>500 g) seabream from valliculture showed skeletal pattern and shape undistinguishable from wild capture fishery seabream.

Codes of conduct and certification

From internal and external discussions, general collection of bibliographical data and national reports on the review of certification procedures, a common structure was defined for the writing of specific Codes of Conduct for each of the SEACASE case studies. Six Codes of Conduct were thereby developed, focusing the non-intensive farming realities of each participating country. These systems could be either highly representative of national contexts or under development with good future perspectives within extensive and semi-intensive aquaculture. These Codes of Conduct were used as a starting point to build up a proposal for a Joint European Certification System for Products of Non-Intensive Sustainable Aquaculture. The proposed Certification System includes, among others, the following main suggestions:

- A central Certification initiative and organization should be EU-based;

- National, regional or local entities should be created, to support directly geographical realities;

- Already-existent Certification systems and labels should be respected, and stakeholders' experience and expertise should be valued and used to refine the new system, in which everyone involved must feel part of the process;

- Farmers' associative capacity should be reinforced towards the establishment of an effective certification system. The contribution and participation of farmers' associations is fundamental to build a better understanding of local, regional and/or national realities, specific needs and interests, and to unify and concentrate efforts, as these organizations facilitate communication within the aquaculture sector;

- Recent and reliable statistical data (e.g., on farm locations, aquaculture facilities, farmed species, production financial and technical details, actual needs and general concerns) are missing and are necessary to increase the scope of any initiative carried out by the non-intensive farming sector;

- Specific scientific and technical data on how to define and measure welfare, stress and pain; on efficacy and improvement of slaughtering methods; on improvements on more immediate pre-slaughter conditions (like starving or withdrawal, net crowding and exposure to air), but also on all general pre-slaughter welfare-related parameters (like available space, water quality, feed quality, predation and cannibalism, etc.) are necessary to achieve more quantitative and precise Codes and Certification rules;

- Already available Certification systems (like Organic Farming), are very useful sources of inspiration, but some rules seem to be difficult to apply directly to non-intensive systems (as they were designed mainly to intensive systems). Non-intensive farmers can also join the organic certification system, although they should benefit from a specific and independent Certification system, due to the specificities and characteristics of these farming systems;

- Like any other Quality-related approaches, Codes of Conduct or Certification systems for aquaculture can only be effective if they comprehend and are applied to all the stages of the production chain, from the fry / seed suppliers and feeds manufacturers to the distributors, wholesalers, retailers and consumers. The whole aquaculture production chain must be covered when applying these new certification systems, as their main objective - the visibility of the advantages offered by non-intensive farming products and their consequent added-value, can only be achieved when consumers perceive that the whole chain is being covered by the certification system, resulting in the indispensable confidence in labels and claims.

Socio-economic assessment

The socio-economic assessment was implemented with two main objectives. The first one aimed at assessing the current status of production systems from a technical-economic point of view: profitability, dependency from inputs, characterization and comparison of systems, structural difficulties, marketing outputs, etc. It was based both on the work achieved through the task on current status of extensive and semi-intensive aquaculture, and SEACASE case studies. The work over case studies was implemented through surveys and interviews. In case studies where the data collection was implemented by non economists – valliculture and Greek lagoon nurseries, the information was quite difficult to analyse and did not allow for robust results. But an opinion survey attached to the economic one and dealing with issues regarding the future of aquaculture underlines that both extensive and semi-intensive systems are rather benefiting from an environmental and location rent that cannot be reproduced elsewhere in Europe.

From other case studies – extensive aquaculture and semi-intensive aquaculture in earthen ponds (see Figure 5), integrated eel fisheries, oyster refinement in wetlands, the analysis underlines the difficulties faced by such systems in confined or transitional areas. If the most extensive systems are less sensitive to crisis, their lower productivity aggravated by decreasing environmental quality often do not allow for a sufficient level of income. Intermediate systems in terms of intensification (semi-intensive) are the ones facing the most important difficulties. Barely profitable, production cost of many farms do not allow anymore to compete with more intensive systems and more and more farms turn to bankruptcy, trapped into a vicious circle of intensification. Most semi-intensive systems were able until now to meet some specific demands in terms of volume but their situation is more and more difficult and their capital intensity makes them far more sensitive to crisis on the short-term. Farms that are still benefiting from the activity are those able to run longer production cycles (3 years long versus 2 years long) in order to target premium price for large-size first grade products. This strategy claiming for more important cash flow is often supported by additional activities or benefiting from shared facilities in processing and marketing.

Figure 5. Fishing in an *estero* (Spain). The pond was partially emptied and the fish were brought and encircled with a net to a small area to be fished.

Main reasons to difficulties are a complete disconnection between demand and supply as usually observed in the European aquaculture. Driven by and developed on high value species, farmers use to be solely producers, ignoring and not anticipating demand characteristics. The lack of real understanding of costs and benefits induced by a multiannual activity also contributes to an obscure situation that yearly farms' accounting is not able to clarify. This is particularly well illustrated by a number of farmers requesting to get access to their individual farm's data within the project, in order to know whether they are profitable or not.

The second and more innovative objective of the socioeconomic assessment was the patrimonial assessment of traditional extensive and improved extensive systems. Instead of implementing a non market valuation method, the patrimonial value of aquaculture was assessed in a more qualitative way through the patrimonial audit approach. Implemented over the case study of integrated eel fisheries and oyster refinement, this method illustrated particularly well the importance of aquaculture in maintaining ecosystems functionalities and services supported by the ecosystems in confined and intertidal areas. It also pleaded in favour of maintaining such systems beyond farms' private profitability alone. Monetary valuation of aquaculture's patrimonial value will not influence the society in the decision of supporting coastal extensive and semi-intensive aquaculture. Non market methods are rather useful in the implementation of support tools by exploring different options of alternative management once the society decides to act.

SEACASE IMPACT

Strategic impact of the project

1. *Increasing environmentally sound aquaculture practices and resources conservation*

   Extensive and semi-intensive aquaculture systems in coastal areas in Southern Europe are known to preserve the landscape, wetlands functionality and increase biodiversity. To maintain and support these systems as an economic activity in protected wetlands will, in the long term, be more valuable for the society and the environment, when compared to abandoned coastal areas. Such abandonment leads to eutrophication or siltation, bringing up the risk of disappearance to ancestral wetlands.

   In particular, Valliculture needs an effort to expand its knowledge basis, including the relation between the Valli ecosystem dynamics, eco-geography, production output and environment quality (see Figure 6). It is therefore essential to guarantee the development of a system of indicators to allow evaluation of the role of this activity, including environmental/cultural/social service functions performed in the coastal environment.

Figure 6. Vale Bonello, Italy – Valliculture.

The preservation of the ecological functionality of extensive basins is closely linked to specific management planning. Conservationist approaches aim at leaving lagoons or marshlands to their natural dynamics. But they are submitted to processes leading to silting up and erosion, leading to a continuous moving landscape and eventually to declining of functional performances of general interest to the marshlands. It is well known that managed wetlands have expressed a continuous potential that satisfied production needs for ages and patrimonial amenities more recently. Farmers have been stabilizing the landscape and held the natural functionalities to a satisfying level, in general for sustainable cost. Since farmers still sustain today well-balanced ecosystems and contribute to their good health, the related costs (between 1000 and 2500 €/ha/year) cannot be held by farmers alone anymore.

Wetlands morphology management and restoration are the base of land production potential. But as many areas suffer from a lack of hydraulic intervention this potential is diminishing every day, as well as ecologic functionalities (containments, dystrophy, etc.). Further ability to reuse such aquatic ecosystems would induce extra costs to get back to appropriate design and hydrology regimes. Natural infrastructures management to avoid silting, channel restoration to ensure appropriate hydrodynamism, hydraulic interventions based on lagoon and earthponds ecological functions and functionality, and landscape features are the basic tools required to orient a productive strategy, and ensure well balanced hydrosystems. A legislative framework should be devised to allow hydraulic and other works in coastal lagoons to be rapidly evaluated, regulated and implemented, according to a logic of shared costs between fish farmers and the society.

The possibility of combining aquaculture with multifunctional (e.g., tourist, educational, recreational) activities involving new generations of stakeholders and land managers represents a focal issue for management continuity and the conservation of a traditional husbandry, both of which are essential for ecosystem protection.

Several technical improvements studied within the project SEACASE scope were shown to be effective in non-intensive systems, allowing reduced environmental impacts, or increased productivity without major effects to the environment.

Several Mediterranean farmed species, such as the gilthead seabream, European seabass or the Senegalese sole, are currently fed diets rich in protein and fats, derived from ingredients of marine origin, such as fishmeal and fish oil. A shift towards a lower usage of these finite marine-harvest resources is a major sustainability challenge faced by the aquaculture industry. Data generated in several SEACASE trials with seabream and sole showed that growth performance during the juvenile and grow-out phases can be sustained by a practical dietary formulation containing as little as a 13% level of marine-derived proteins.

In extensive aquaculture and valliculture the seeding of wild juveniles is generally preferred by fish farmers. However, an experimental protocol carried out in valliculture provided the first objective evidence that seed origin does not necessarily influence survival rates or performances in gilthead seabream. When stocking of wild and reared juveniles was carried out in the same small valle (50 ha), the obtained recapture rates were not influenced by the origin of the juveniles. However, when stocking actions were carried out separately in two larger valli (300 ha and 200 ha) for wild and reared juveniles, there were differences between wild and reared seabream recapture rates, possibly due to the differences between the two valli. Additionally, a high pressure of piscivorous birds was found, causing the death of about 30% of the stocked fish in the first summer and injuries and scars on as many as 42% of the larger seabream (64 – 1350 g). These results contribute to promote the replacement of wild seed resources with hatchery ones, with a positive effect on recruitment and resources conservation, and suggest that the recapture of fish should be anticipated to September to face both cold temperatures and the presence of birds, which increases during the winter (see Figure 7).

Figure 7. Fish recapturing and transfer to wintering basins (Valliculture, Italy).

Periphyton-based systems in extensive nursery ponds are more efficient for herbivorous-omnivorous species, such as the grey mullet (*Liza aurata*), than for seabream (*Sparus aurata*). Carrying capacities at the end of the trials in France did not exceed 13-17g/m² for carnivorous species, but probably exceeded the 100 g/m² observed for golden grey mullet.

Use of self-feeders could be valuable in the case of nursery units in lagoons and ponds. Such devices were applied successfully in the case of seabream juveniles in Greece resulting in high survival and growth.

Ulva, produced in treatment ponds to remove nutrients in fish farm effluents, appeared as an interesting feed complement to improve the final quality of fish (external coloration of seabream, higher levels of w3 PUFA). *Ulva* could be included fresh in fish feeding (or probably also in dry powder included in the feed pellets), in the last two months of growth, with positive results on the fish quality as observed in the French integrated system.

2. *Increasing aquaculture production by promoting traditional aquaculture activities*

New/improved farming techniques will increase economic viability of extensive and semi-intensive aquaculture, thus assisting in developing the rural communities in these coastal areas. Coastal territories, where traditional extensive and semi-intensive aquaculture developed in confined areas, are strongly identified through aquaculture activities. This contributes to structure coastal and rural communities and acts in an attractive way for other economic activities such as tourism, which should not be seen as opposed activities but rather as complementary ones. Sustaining the economic viability of traditional aquaculture will then sustain other activities and will contribute to maintain the patrimonial assets attached to such aquaculture. Beyond fish organoleptic properties, it is also the economic and patrimonial properties of aquaculture products that are under question. Even if the future of aquaculture in southern Europe is not at stake, its development should not be made at the expense of traditional aquaculture systems.

The socio-economic assessment underlined a stronger economic impact per kg of fish produced under traditional systems rather than through intensive systems. What is important is not only the added value generated by the activity but also the distribution of this added value, especially in rural and remote areas where maintaining coastal communities is also a societal objective. But if technological innovation such as nutrition improvement can benefit traditional aquaculture, it will also benefit open intensive systems and the increase in profit margins will be certainly used in selling products at lower price in a context where supply is over meeting demand. In that way, technological innovations such as integrated systems have to be linked to economic reality.

3. *Increasing multifunctionality*

According with a socio-economic evaluation of the different case studies, the SEACASE project identified several opportunities for multiple use of coastal wetland areas in order to explore their potential and diversification of the present activities. The social and political recognition of non market ecological services is as important as its economical role. But the simple acknowledgement of non market benefits attached to extensive aquaculture is not sufficient in itself to ensure the improvement of the economic viability of these productions. The provision of not only regulatory but also incentive mechanisms to improve sustainability (e.g., compensation of conservation

services, public-private partnerships) is a key element to drive coastal extensive and improved extensive aquaculture in confined areas to a sustainable path. Looking for incentive mechanisms such as an increase of added value or a diversification of income are other complementary options. These can be complementary activities developed in order to generate an income through added value or through activities benefiting from the environment and aquaculture's image: ecotourism, activities related to education and environmental awareness. The interest of urban populations for nature and coastal areas could help develop fish farms designed to accommodate summer tourists, show extensive aquaculture methods in marine ponds and give them the opportunity to taste the quality of the products (aquatourism). But this would also require an investment in communication and in education (support and training material) and the development of stronger collective actions to meet such requirements.

4. *Increasing the availability of healthy, safe and high quality aquaculture products and improving the image of aquaculture industry*

   a. *Quality markers* for aquaculture products coming from extensive and semi-intensive systems were studied in the SEACASE project. It should be noted that the products from extensive and semi-intensive systems tested in the project (seabream) are safe for human consumption as are products from intensive systems. A common characteristic of these products is the external appearance with an orange colour in the gill area and a golden yellow line between the eyes. These colours remind us of the wild specimens' appearance and could contribute to confer a better image of aquaculture products among consumers. Moreover, the good nutritional quality, observed in these products in term of fatty acids profile and w3/w6 ratio, could allow farmers to promote the quality of their products and obtain higher prices for them. Sensory properties as odour and taste are clearly influenced by environmental and seasonal conditions and natural feeding, which can lead to a large range of characteristics from marine/iodine note to earthy note. The texture of these products tends to be slightly different (less firm and dense but juicier). The nutritional quality of these products associated with specific sensory characteristics could allow their promotion in local markets as regional aquaculture products with different qualities. This market development is based on the assumption that environmental conditions allow to deliver the same fish characteristics from one year to the other, and supposes actions of promotion from farmer to consumers to highlight the specificity of his product. The integrated system based on effluent treatment of an intensive hatchery showed that it was possible to obtain the same product characteristics when the same location and conditions of rearing were used.

   b. *Slaughtering improvements* for safer and high quality products were studied in the SEACASE project. Farmed fish welfare is increasingly important nowadays, both from a production and the consumers' point

of view. Pre-slaughter conditions and slaughter methods were evaluated and some improvements in the method of immersion in ice slurry, the most generalized slaughtering method, were tested and proved to be feasible and effective. These simple improvements, if applied by the industry, can lead to a reduction in the time before death, reducing suffering and increasing the welfare level, especially if combined with more careful and rapid pre-slaughter operations. SEACASE adopted the recent view of pre-slaughter operation as including not only the operations immediately before slaughtering (e.g., starving, confinement, catching, transferring, stunning) but also all farming operations along the whole production cycle, from egg to death. A slight improvement in the pre-slaughter phase is recognized to have a considerable beneficial effect on fish welfare and, consequently, on the quality of the products and on their corresponding image to final users and consumers. The quality improvement promoted by the reduction of slaughtering time is scientifically proven (EFSA, 2009)[1], since less stress induces slower fish degradation, allowing these food resources to be available for longer periods of time without compromising consumers' health.

c. The development of high quality farming procedures and high quality products from extensive and semi-intensive aquaculture were also studied. Mesocosmos units were shown to offer the possibility to rear high quality juveniles in systems with low labour intensity, avoiding the use of intensive systems with high impact on the environment. The morphological quality (based on skeletal anomalies and shape analyses) of semi-intensively reared seabream and Senegalese sole is much more similar to the wild counterpart than to intensively reared juveniles. Extensive rearing conditions exert a selective pressure on mostly deformed fishes, returning fish of whatever size undistinguishable on a morphological basis from wild phenotype.

Reinforcing competitiveness

1. *A range of case studies developed protocols* aimed to increase productivity of extensive and semi-intensive systems, maintaining high quality standards and minimal environmental impact.

   a. High quality fish fry with morphometric characteristics similar to the wild were obtained by feeding larvae with natural plankton produced in mesocosms tanks. The natural productivity of such systems can be enhanced with fertilizers and by adding vertical surfaces to increase the settling area of the tanks. Rearing larval densities should be low. The use of natural productivity of the water from earthen ponds in smaller mesocosms tanks to rear high quality fish fry may permit the fish farmer to produce its own seed either for extensive or semi-intensive aquaculture. Such fry production may be easily adjusted to comply with organic farming requirements.

b. Valliculture was proved to be able to produce wild-like, large-size gilthead seabream with sizes (500 g>BWg> 1,350) not available from capture fishery. Further, survival rate and market prices are higher for fish weighing over 350g. DNA fingerprinting was shown to be a reliable tool to trace fish origin in valliculture, and may lead to selection of the best strains for farming in Valli.

c. Semi-intensive polyculture of seabream with sole was shown to be a possible avenue to bring added value to traditional semi-intensive monoculture of seabream, making semi-intensive farming in earth ponds a more sustainable activity. Success of such polyculture depends on maintaining good pond bottom conditions and is viable only at moderate sole and seabream densities. Supply of artificial feeds does not seem to have a negative impact on water effluent quality, and this was shown to be further reduced when optimized feed formulations are used.

d. The SEACASE project demonstrated that traditional fish ponds in coastal wetlands in the French Atlantic Coast as well as in the Spanish South Atlantic coast are still being colonized by the natural entry of eels. These ponds may be a valuable tool for the endangered eel fishery, and extensive eel production in these systems may bring added value to these patrimonial wetlands.

e. A system integrating land-based extensive aquaculture was shown to be a viable remediation treatment of intensive aquaculture effluents. A significant removal of effluent nutrients was accomplished combining macroalgae (*Ulva*) production and harvesting. *Ulva* may be used in fish feeding and as raw material for parapharmaceutical applications.

f. Extensive fish polyculture in abandoned pond/saltwork areas was shown to be a viable option, even in recently restored ponds, which have the capacity for a quick regeneration of benthos and plankton communities, as well as for regular fish production.

2. *Particular characteristics of extensive and semi-intensive products, such as high quality and size diversification of fish product*, may open new niche markets, which will reinforce extensive and semi-intensive systems competitiveness with regard to intensive systems

The substitution of production for non-market services to the environment is still insufficiently acknowledged and remains a difficult way to improve sustainability. Nevertheless, product differentiation is a way to bring an increase of added value and to generate niche markets for extensive and semi-intensive aquaculture. If the development of niche markets is a way to sustain traditional fish farming in confined areas through size diversification (which should target also premium grades rather than solely volume of small grade), the intrinsic quality of the product should also act for a segmented market compared to products from intensive production systems. Although difficult, collective work to value conservation benefits in the price of the commercial products from these areas (certification) is another key action to be taken into account. Results of SEACASE on quality of the final product

show that total lipid content was generally lower in extensive systems compared to intensive ones, and some sensory characteristics have also been identified as different. The texture was slightly less firm and juicier, and odour and taste were often related to particular environmental characteristics. In addition, the non-intensive products show an attractive external appearance, offering different products to consumers and therefore a possibility to enlarge the market. The Identification of different products according to the aquaculture system used could contribute to improve the image of aquaculture showing the possibility to produce premium nutritional quality fish while maintaining sustainable environmental conditions.

3. *Slaughtering methods may* be optimized in order to improve flesh quality, increase product shelf life and respect for fish welfare issues.

   It is well known that the future of highly competitive global markets foresees the creation of small niche markets for high quality-demanding consumers. Welfare, associated with pre-slaughter and slaughter conditions in fish farming, is nowadays one of the most important concepts and concerns of those involved in all kinds of animal production chains. The SEACASE project suggests general and specific improvements that can be put into practice, leading to lower stress, higher welfare and better quality and product image.

4. *Codes of conduct may pave the way to certification of non-intensive fish production*

   Codes of Conduct developed and proposed by SEACASE focused on the specific realities and farming systems of each participating country. In these Codes were included references to other existent Certification systems (good sources of information) and also to Traceability actual needs. This information was used to build a Joint European Certification System for Non-Intensive Sustainable Aquaculture, which reflects and covers these concepts, concerns and legal requirements.

Innovation-related activities

1. *A synthesis of existing pond management techniques was performed, and improvements proposed*

   a. The management of aquatic weeds and algae blooms relies on physical, mechanical, chemical and biological techniques. A technical note is available to farmers “Limitation du développement des végétaux aquatiques en marais salé: macro algues et Ruppias” (2009 Guide technique CREAA:

   http://pagesperso-orange.fr/creaa/doc/09_guide%20algues.pdf

   b. Concerning the removal of mud, a better understanding of mud drying natural processes provides an optimization of earthponds and basins survey techniques.

c. Prevention against bird predation is better managed with the use of nets and/or raptors like scarecrows.

d. The use of traps for crabs' removal is recommended.

e. Unexpected competitors can be removed by filtering the incoming water with meshes and/or gates. Manual removing and destruction can also be used by drying the mud to remove spores, mollusks, and anemones.

f. Nutrient stimulation can be conducted by adding a special mix of nutrients to pond water to enhance primary productivity and stimulate feeders of the second level, like shellfish (oysters).

g. The enhancement of epibiotic production, available for fish grazers, can be obtained by the disposal of adapted devices in the ponds.

2. *Formulation of innovative sustainable fish diets*

The move towards a lower usage of finite marine-harvested resources in fish feeds is a major sustainability drive, both environmental and economical, in the aquaculture industry. Following an intense research effort throughout the last two decades, it is now clear that plant protein and oil sources are valid alternative ingredients in fish feeds. Regarding fishmeal replacement, provided that essential amino acid requirements are met, the palatability of the feed is guaranteed and the levels of anti-nutritional factors are low, plant proteins can be successfully used in diets for marine fish species, such as gilthead seabream and European seabass. Within the SEACASE project, several performance trials were undertaken to evaluate the effects of replacing fishmeal and/or fish oil in a practical diet of gilthead seabream with a complementary mixture of vegetable proteins (soy, peas, wheat DDGS[2]) and oil (soybean, rapeseed) sources, in terms of growth performance, feed utilization, apparent digestibility of nutrients and soluble nitrogen and phosphorus excretion. Data generated in the present study clearly shows that the growth performance of gilthead seabream (from 30 to 300 g) can be sustained by a practical dietary formulation containing as little as 13% of marine-derived proteins. The environmental impact of fish farming is closely associated to excessive feed wastage and sub-optimal nutrient utilization. In this regard, when using plant ingredients as major dietary protein sources in fish feeds; one aspect that deserves special attention is the phosphorus (P) bioavailability. The project data shows that when compared to a fishmeal meal based diet, soluble phosphorus excretion was significantly reduced by the use of plant-protein rich diets.

3. *Use of new research tools provided by molecular biology*

The goal of functional genomics is to better understand the role of genome elements directly or indirectly involved in organism physiology and health. The

[2] Wheat Dried Distiller Grains with Solubles.

microarray technology is a powerful tool to identify molecular responses associated with exposure to environmental stressors. Within SEACASE, microarray analysis allowed to gather information on gene expression response under cold exposure for thousands of genes and many different metabolic pathways simultaneously. The integration of genomic and physiological knowledge provides a reliable tool to identify a range of candidate genes endowing cold tolerance in sea gilthead seabream. Molecular tools were also applied in the Valliculture case study to distinguish wild and hatchery seabream at recapture. A DNA fingerprinting protocol, combining high reliability with low cost and low time consuming was assessed, providing an effective tool to trace gilthead seabream origin. Molecular tools provide an innovative knowledge base for future improvements of seeding strategies (fish origin; cold tolerant strains) and for production optimization in extensive aquaculture.

4. *The development of a new integrated approach to support traditional eel fishery*

The SEACASE project has demonstrated the importance of the numerous dyked saltwater marshes of the Atlantic coast (low chemical and parasitical contaminations, high potentiality of silver eel production) for the European eel. In spite of this, marsh areas with previous human intervention are often ignored in the management plans and research programs. The SEACASE project proposes that local/regional authorities launch specific contractual measures towards the regular maintenance of traditional fish ponds. An example could be the payment of a dredging operation every 10 years at the utmost, in exchange for a guarantee that the inlet/outlet are equipped to allow the free circulation of all size-classes and for halting the eel exploitation during a contracted period. Moreover, preliminary tests during SEACASE have been performed to conceive a monitoring method able to survey the evolution of the eel abundance within such special systems, thereby allowing for a follow-up of the results of management measures to be implemented.

Added value in carrying out the work at a European level

1. *Creation of a scientific network to support extensive & semi-intensive aquaculture in Southern Europe*

The SEACASE project created a network to support extensive and semi-intensive aquaculture in Southern Europe. The most visible aspects of this networking effort, are the project website (ww.seacase.org) and the project final workshop organized in Tavira (Portugal), in January 2010. The project coordinator will keep the website online for at least five more years, and regular updates will take place, in particular in what concerns the Doc library. The SEACASE consortium is decided to take advantage of the momentum created by the project, and is currently looking for funding opportunities for pursuing a collective research effort on extensive and semi-intensive aquaculture in Southern Europe. It is intended to organize regular meetings of the consortium members, most likely adjacent to international conferences (e.g., EAS meetings).

2. *The potential for future development*

Among the most important achievements of the project were the results coming from the scientific cooperation among countries from the Atlantic and Mediterranean coast about the current status and future prospects of extensive and semi-intensive systems, with analysis of their geographic characteristics and peculiarities. This information complemented with the socioeconomic studies undertaken within those systems, gave a clear picture of the importance of extensive and semi-intensive systems not only as methods to produce food, but highlighted their ecological, patrimonial and socioeconomic importance. Aquaculture in the future needs to be a responsible and sustainable activity, keeping in mind that there is no guarantee that fish farming will become a "green activity". Defined standards for what is considered "good fish farming" have not yet been widely agreed. However, within the SEACASE project technical improvements on the production methods, and multifunctionality of the systems proved to be important aspects to their maintenance. Moreover, it was possible to verify that in the long run it will be less costly to maintain low technology systems than wetlands with previous human intervention abandoned. In fact, non-economic profits should be included when economic viability of these systems is evaluated. The nutritional quality of those products was not very different from intensive systems. However, the special odour and wild-like external appearance might be used as the basis for a distinct consumers' image of non-intensive products, and thereby be used to add value to these products. This will require certification systems, and advantages can be seen if this process is done at the European level. The new Regulation (EC) 710/2009 on Organic Aquaculture may be an important tool to valorize extensive and semi-intensive aquaculture systems but. However, intensive products may also get this certification, what will tend to dilute the foreseeable consumer-image advantages in non-intensive aquaculture products. Thereby, there is room for a specific certification system for extensive and semi-intensive aquaculture products in Southern Europe.

RECOMMENDATIONS

For the Industry

The SEACASE consortium believes that many of its findings are directly relevant to extensive and semi-intensive farmers. Among these findings we would like to emphasise:

a) In extensive aquaculture and valliculture, management procedures should be carefully planned to face extreme climatic environmental conditions (e.g., high and low water temperature, dystrophic crisis) and ichthyophagous birds predation, and reduce potential huge losses of fish production. Extensive private enterprises should claim for sectorial policies, including financial and economic instruments and aids, that provide the necessary support to farmers in the management of coastal lagoons

used for fish production, but which also have important roles in ecosystem preservation and ecotourism.

b) The acquisition of an integrated knowledge on the physiological and genomic responses of seabream to very low temperatures, promoted by the SEACASE project, has a great potential for the future genetic improvement of seabream in aquaculture. An investment in research for the development and selection of cold tolerant fish strains should be considered also by fish farm companies.

c) The evidence of a comparable survival rate and performance between hatchery and wild seabream in valle should encourage the industry to utilize high quality hatchery seeds in valliculture. At the same time, extensive farmers are encouraged to seed high performing artificial propagated autochthonous juveniles from reliable hatcheries, in order to preserve natural resources.

d) Semi-intensive polyculture of seabream and sole in earthen ponds can bring added value, but recovery of stocked sole is variable. It depends on maintaining good pond bottom conditions and is viable only at moderate sole and seabream densities.

e) The use of eco-friendly diets - low in fish meal - may minimize farm waste and nutrient output in semi-intensive farming, also with benefits in pond water quality and lesser algal growth. In addition, this fish meal replacement with tend to make feeds cheaper.

f) Improvements in slaughter methods may bring better quality of the final product and better fish welfare, which are increasingly important issues for the European consumer. Improvements in the ice slurry method for seabass and seabream, resulted in reduced time to death and improved general sensory attributes, without changing fish quality.

g) Integrated aquaculture systems in ponds can be a solution to reduce pressures and impacts from intensive and semi-intensive systems. In this respect, macroalgae cultures are easier to manage than microalgae cultures in large ponds. *Ulva*, considered by some experts as an algae difficult to exploit, has a growing interest for the para-pharmaceutical industry in France if harvested during its early growth phase, i.e., before senescence (see Figure 8). *Chaetomorpha* is also a macroalgae with good nutrient removal performances that might find opportunities of economic valorisation in the future.

Figure 8. Integrated system developed in France in the marine fish hatchery farm, the experimental *Ulva* pond regularly harvested each week in spring 2009.

For the Environment

Development policies for the aquaculture sector should be 'equipped', as it was done for rural development in agriculture, with instruments to support the enterprises, and should be designed to reward environmentally valuable coastal wetland utilization. In other words, the extensive and environmentally friendly use of coastal wetlands should be compensated, through reward mechanisms, for the environmental services carried out by extensive aquaculture. Only the recognition of the environmental functions of extensive aquaculture productions can justify a support intervention that is not considered state aid liable to distort competition, as was done for rural development in agriculture. In order to retain its functions, valliculture, culture in *esteros*, as well as other extensive aquaculture practices, which have a strong environmental significance and have positive effects on the environmental, are in need of public intervention in order to enjoy equal market opportunities.

In general, extensive aquaculture is currently exposed to certain sources of risk, like pollution of water inlets, spatial competition with intensive fish farming close to valli, competition for market prices of intensive aquaculture products, and the inadequate legislative framework that fails to prioritize the multifunctional functions of extensive aquaculture. All these problematics disincentive the investment in extensive aquaculture. This situation clearly requires intervention from EC and governmental agencies.

Feed management in semi-intensive aquaculture in earthen ponds, should be better controlled, in order to minimize waste, solids and nutrients in effluent. This includes both feeding procedures and feed formulas used. The SEACASE project

demonstrated that optimized feed formulations may reduce dependency in the poorly sustainable fish meal use, while reducing phosphorus in the effluent water.

For the Society

Extensive and semi-intensive production systems settled in intermediate areas in terms of confinement (wetlands, lagoons, estuaries, rias, etc.) are under strong environmental and economic pressure. They modelled, designed, and maintained rich ecosystems, as well as structured rural and coastal communities. The development of more intensive production systems in open areas with lower production costs leads traditional systems to face profitability troubles. Competitive activities for access to land such as urbanization or stronger environmental constraints, over an ecosystem they contribute to structure and maintain, are additional difficulties (Figure 9). It could be argued that aquaculture is a business like any other private business and, as a consequence, should be managed accordingly. But beyond of providing economic activities in remote areas, extensive and semi-intensive coastal aquaculture have a societal function by structuring the territory and maintaining the ecosystem's functionalities and services derived from. It is then of public policy relevance too.

Figure 9. Water channel from the Aqualvor farm (in the first plan), Ria de Alvor, Portugal.

As a consequence, it is a key issue for local development and local territory structuring to integrate the multidimensional characteristics of traditional aquaculture. The simplest reason is that on long term it will be more costly for the society to maintain and restore such ecosystems rather than producing moral and economic incentives to maintain and support traditional aquaculture systems. Alternative

developments will not be intelligently thought without taking into account aquaculture. For instance, tourism development is closely and indirectly dependent from aquaculture, as it is often based on recreational activities supported by the ecosystem. Switching completely to other activities (e.g., marinas development) is a societal choice that should be justified. But considering the patrimonial value of traditional aquaculture, the added value chain and the added value distribution will be lower at the scale of the society.

For the Policy-makers

Regulatory, legal and political decisions should take into account the general recommendations made by SEACASE. To achieve more effective and realistic decisions, some of the most important points that should be considered would be:

- Precise and up-to-date statistical data about farms and their characteristics, farming and working methods, quantities produced, final product quality, among other aspects, are needed;
- Research effort is missing in many specific areas like stress, pain and welfare measurements, quality evaluations in different farming conditions, improved slaughter methods and combinations of methods, optimal nutrition for specific environmental conditions;
- Extensive systems, including Valliculture and earthen ponds (including recuperated saltworks), require efforts to expand the knowledge base referring to production cycles and to the quality of the production. It is also essential to guarantee the development of a system of indicators to allow the evaluation of the role played by this activity, and its relationship with the emergence of the environmental/cultural/social service functions performed in the coastal environment;
- Associative movement in some countries is relatively poor and/or dispersed (many small farms, very different among themselves, have necessarily a low collective presence) and should be encouraged;
- Non-intensive farming is a traditional activity that will need support to survive its present difficulties in competition for space and low market prices from intensive aquaculture. Thus policies that permit a wiser land use by farmers respecting landscape and water quality, e.g., integrated systems, would benefit both ecosystems and economics. The integration of semi-intensive, extensive systems in coastal wetlands management plans seems highly recommendable;
- Compensation for conservation services and incentive mechanisms such as diversification of income should be facilitated;
- Development of aquaculture should be rethought on long term in terms of quality rather than solely in terms of quantity and in close connection with markets evolution and demand. Both intensive and non-intensive aquaculture systems can coexist as SEACASE illustrated their products differentiation. In addition, they do not answer to the same societal objective.

For Future research

The SEACASE consortium identified several needs for further research relevant to the sustainable development of extensive and semi-intensive aquaculture. We would like to emphasise:

- Scientific and technical research should be developed in many specific areas, namely on hygienic-sanitary condition, stress, pain and welfare measurements, quality evaluations in different farming conditions, improved slaughter methods and corresponding rapidity by combination of existent methods (e.g., ice slurry combined with electricity and carbon dioxide; mechanization of simple methods like the percussion). Research should cover traditional and emergent species being used by farmers. Restricting research only to two or three main species may lead to wrong extrapolations when considering all farmed species.

- The welfare of fish reared in semi-intensive and extensive aquaculture has not been addressed in SEACASE and a list of specific welfare indicators needs to be developed and included, also for future extensive and semi-intensive aquaculture certification schemes (e.g., organic aquaculture).

- Further valliculture experiments are needed to compare the relative performances of hatchery and wild juveniles, and among juveniles obtained under different larviculture protocols, in different valli. Future research should also promote genetic data collection from natural populations to enlarge baselines for high-commercial species such as *Sparus aurata*, as well as cooperation with the main European commercial hatcheries to obtain and maintain genetic databases of the existing broodstocks. Deeper comprehension of gene networks playing a role in the cold adaptation process is needed, in order to start experimental marker assisted selections (MAS) of cold tolerant fish strains.

- A major need for experimental studies on limiting ichthyophagous birds predation on extensively reared fish emerged, taking into account that almost all extensive productions are carried out in wetlands protected by the Ramsar Convention (Iran, 1971), or are SCIs (Site of Community Importance, according to the EU Habitats Directive, 92/43/EEC) or SPAs (Special Protection Areas, according to the Bonn Convention on the Conservation of Migratory Species of Wild Animals, 1979) or else a WWF oasis. Evaluation of production losses in extensive and semi-intensive fish farms due to icthiophagous and other predators are needed, and animal-friendly techniques to prevent major losses should be developed.

- Further studies on the optimisation of semi-intensive polyculture fish farming are required, namely in defining the carrying capacity for the different species being farmed, and its relation with the pond geochemistry, while maintaining sound environmental conditions. Ideally this research effort should lead to convert the current semi-intensive monoculture fish farms into more profitable and more environmentally friendly integrated multi-trophic systems (IMTS). Development of methods to monitor biomass and feed intake in semi-

intensive systems, and assess the relative contributions of formulated feed and natural food, are needed.

- Research effort on developing environmentally friendly diets at low cost for semi-intensive farming in earthen ponds should be pursued. To go beyond macro-nutrient composition, the contribution of natural food in ponds to meet vitamin, mineral and PUFA requirements, would need to be assessed.

- Extensive and semi-intensive productions should not only consider marine species that can feed people directly, but also prey species, or species to extract compounds of high added value. Identification of such additional products, and development/refining of farming protocol requires considerable research effort. Their possible production in IMTS is also of obvious interest.

- Patrimonial assessment of all major of extensive and semi-intensive production systems, in order to evaluate and propose mechanisms for supporting farmers whom contribute with non-market benefits to public-interest wetlands.

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