SUDEVAB

"Sustainable Development of European SMEs engaged in Abalone Aquaculture"

Keywords:

Abalone, shellfish legislation, shellfish aquaculture, sustainable abalone aquaculture

Executive Summary:

SUDEVAB is a project totally designed by SMEs participating in the European abalone aquaculture sector and was aimed at addressing the technical, legislative, and commercial aspects that are hindering the development of this sector in Europe. The SME partners then sourced the best researchers who could address these complicated issues, and successfully submitted these proposals to the European Commission for funding under Framework 7 - Research for the Benefit of SMEs.

The project had 8 specific research work packages -

* legislation - aimed at separating abalone from other bivalves allowing freedom of movement within the EC between abalone producers

* hygiene and food safety - aimed at providing base line data which showed abalone to be a safer shellfish product not liable to contamination as found in other bivalve species

* genetics - aimed at identifying the European abalone species and providing selection criteria for better growth and disease resistance

* pathology - with specific aims of researching the pathogenic transmitters related to the mortalities caused by Vibrio harveyi in abalone with the development of a test kit to assist producers in identifying and monitoring the presence of the pathogen

* nutrition - the compilation of data for the potential macro-algae resources in the abalone producing regions of Europe, with the aim of being able to develop a 100% algae based artificial abalone feed

* production systems - A comparison of existing abalone production technology with the aim of designing a system that would significantly improve production capacity and efficiency for producers

* marketing - a comprehensive study to evaluate the potential for European abalone sales in Europe

* producers organization - the review of the best organisational structure that would benefit the future producers of abalone products in Europe.

An additional work package was dedicated to dissemination activities which included a website (www.sudevab.eu) where articles and photographs were collected for public access: the successful organisation of two open workshops (Galway 2009 and Brest 2010) where all of the results from the work packages were presented. Participants in SUDEVAB also presented research results in international forums and exhibitions and SUDEVAB participated in the development of abalone standards as part of the WWF aquaculture dialogues.

The project has received one patent for a new abalone production containment system (ABBLOX) for use in open sea production sites: has developed a testing kit and analysis technology for Vibrio harveyi: has developed satellite marker technology capable of being used to best select future stocks for abalone aquaculture, and has proved and tested an artificial diet totally composed of algal ingredients which would be suitable for commercial production.

The project's legacy will be the further cooperation in Europe and worldwide between the project's participants, due to the knowledge and contacts developed during the lifetime of SUDEVAB.

Project Context and Objectives:

Project Summary:

The Challenge:

SUDEVAB brought together the main producing SMEs and leading RTD Providers from the European abalone aquaculture sector, for a project that will have a significant impact for developing sustainable abalone aquaculture in Europe.

Abalone species have been considered potential candidate for aquaculture for a long time, and in recent years, abalone aquaculture in other parts of the world has surged ahead.

However, in Europe production has been restricted by the lack of reasonably priced juveniles, technological problems, and legislative issues. The opportunity presented by theFP7 call "Research for the Benefit of SMEs" provided the partners in SUDEVAB with exactly the right vehicle to develop this young aquaculture sector, by harnessing some of the best shellfish aquaculture research facilities and researchers to solve the significant technological problems facing producers, increasing production and competitiveness.

Project Objectives:

The core of the research work of SUDEVAB was aimed at solving the main technical problems encountered by abalone growers in Europe in the areas of:

* pathology
* genetics
* nutrition
* sustainable culture technology

However, abalone producers also have serious issues which need to be resolved alongside the main research work including; legislation, hygiene and food safety and marketing issues.

These are blended in the research programme to maximise the results, and raise awareness of the project as a whole.

Key Points addressed by SUDEVAB:

* Harmonisation and rationalisation of legislative issues that restrict and impact on abalone culture in Europe
* Reduction of significant technological barriers to abalone culture by research of key issues identified by the production sector SMEs
* Reduction of the economic costs of abalone production increasing competitiveness of European producer SMEs
* Creation of links between the consumers and producer SMEs to ensure the consumers gain knowledge and confidence of abalone products, increasing marketability and economic returns
* Enhancement of the cooperation within the abalone production sector by the scoping of an abalone producers organisation which can encourage the sharing of knowledge and technology as well as assist in marketing of production
* Creation of dissemination opportunities which allows open discussions with other stakeholders and enhances network opportunities for the participants of SUDEVAB for future business development.

Key New Knowledge Gained:

Policy - Legislation harmonisation:

A series of key recommendations will be supplied to the EU and member States controlling authorities which will impact on future development of the European abalone aquaculture

SME - Hygiene and food safety for abalone products:

Base-line data has been produced demonstrating the differences between bivalves and gastropods grown in the same environmental conditions. Moreover, guidelines for safe and hygienic production methods have been developed, including the tests required to ensure products meet these criteria.

SME - Pathology:

The infection transmitters of Vibrio and viral diseases have been investigated and methods for detection have been developed jointly with systems for treatment.

SME - Genetics:

The genetics of the main families of abalone in Europe have been catalogued with the aim to eliminate the potential for in-breeding. At the same time, data has been produced on the families' growth potential and disease resistance.

SME - Nutrition:

Natural seaweed resources have been evaluated for the nutritional values required for optimum abalone growth and utilising these resources an eco-artificial feed has been designed and trialled.

SME - Economically sustainable production systems:

Development of less expensive and more energy efficient on-growing systems. SME partners have designed and trialled a new system "ABBLOX" which is now in production and patented.

SME - Marketing and Product Placement:

New marketing strategies have been developed to promote abalone sales in Europe by the in-depth study of existing and potential markets for high quality European abalone

Potential Impacts from SUDEVAB research and beneficiaries:

Policy: Recommendations will be submitted to the EC and the relevant States, to ensure harmonisation in legislation that is relevant to abalone production, sites and methods. A framework for dialogue will be set in place that will result in a more level operating environment for abalone producers; enhancing competitiveness and encouraging trade.

SME: With respect to hygiene and food safety the difference between abalone and bivalves and therefore the difference in contamination risks will be demonstrated. With diversification and risk reduction, the potential for increased economic efficiencies exist for producers, allowing investment and promoting growth. Producers will be able to promote abalone as an alternative shellfish product to markets and commercial operators will have the opportunity to diversify their production with abalone. This will enhance their potential commercial returns as abalone is a high value species and at the same time reduce their risks from only culturing bivalves.

SME: Pathology - Vibrio and viral diseases will be thoroughly studied aiming to a 20% reduction in mortality rates, which would have significant economic consequences for all producers.

SME: Genetics -Amelioration of economical viability through selection of faster growers as potential brood-stock material.

SME: Nutrition -Comparison of the economics of production and the value of harvested vs. cultured seaweeds to estimate best-fit solutions for producers, in conjunction with availability, local legislation and logistics of supply, to improve efficiency and reduce production costs. Moreover, the production of an eco-artificial feed will have marketing benefits for consumers who are increasingly environmentally sensitive.

SME: Sustainable production technology - The identification of competitive technology and systems and of best shellfish production strategies (including poly-culture production) will increase availability of juveniles, market potential and market penetration and ultimately improve the economic return of producers.

SME: Marketing -the European abalone will be marketed as a new seafood product with high hygiene and food safety standards, meeting consumers' requirements. Criteria for eco-certification will be established and direct actions involving chefs and the gourmet catering sector will raise consumers' awareness and appreciation.

SME: Producer's Organisation (PO) - A formation of a producer's organisation will actively bring producers together and promote the product and the market simultaneously.

Conclusions and Legacy:

In each of the respective work packages, positive results were obtained or significant data developed that will be if use to the SME beneficiaries for the future development of the sector. However the project also brought together all of the existing European producers through its workshops and conferences, and by direct contact to interested parties by other visits from participating project members. This has already created business opportunities for the participating SMEs, and this will develop further due to the contacts developed during SUDEVAB. The project partners also met, presented papers and had extensive contacts with growers, scientific organisations, NGOs and official bodies worldwide throughout the life of SUDEVAB. European abalone producers and the European sector, as a whole, is now recognised worldwide as a small but enterprising area of expertise developing in the world of abalone aquaculture.

Project Results:

S/T Activities - Research programmes and results

SUDEVAB was set up in order to bring together the main producing SMEs and leading RTD Providers from the abalone aquaculture sector in Europe, to build up a project to develop sustainable abalone aquaculture in Europe while solving the significant technological problems faced by producers, increasing production as well as competitiveness.

Progress well beyond the state of the art:

The situation of the abalone aquaculture industry in Europe before SUDEVAB was grim. While the industry appeared to take off in other places in the world (China, South Africa, Australia, and Chile. Figure 1) the industrial projects which started in the late 1980's in Ireland, France or Portugal were bound to failure. Only a few hundred kilogram of abalone were produced from farms where investors and public bodies had invested millions. Results of these projects showed that many technical and commercial obstacles were still to be overcome.

Figure 1: World Abalone production statistics (source: Gordon & Cook 2010).

With this in mind the SME partners of SUDEVAB had imagined a special strategy which could happen only thanks to the FP7 "capacities" funding program. Indeed, the funding and the energy of all the partners were entirely dedicated to overcome each of the identified obstacles. And after 30 months of work on SUDEVAB, the situation for abalone aquaculture in Europe has changed completely. In many fields, the knowledge about European abalone was limited to a few key scientific works (Bonnot, 1930; Stephenson, 1924; Crofts 1932, Flasch and Aveline, 1984; Koike, 1978, Clavier, 1984). SUDEVAB has brought our knowledge of the species to a level comparable to the other main commercial species (Haliotis discus hannai, H. laevigata, H. rubra or H. midae) and well beyond in some fields i.e. genetics or pathology.

WP 2 & 3 - Hygiene and food safety

As a producer of high quality shellfish, the European abalone farmer must not only comply with mandatory quality criteria, but in order to maintain customer confidence and

acceptability of the product, ensure that maximum food safety is achieved. Fortunately, with abalone, this has been shown to easier than with bivalves.

Regulation EC 854/2004 requires competent authorities to classify bivalve mollusc production areas. The Regulation by Annex identifies the application 'by analogy' to live echinoderms, live tunicates and live marine gastropods'. Additionally, ISO 6887-3 provides methods for the preparation of gastropod samples for microbiological examination. In practice European countries have regarded gastropods and by inclusion abalone as low risk although little evidence existed to back that view. As a consequence classified areas for abalone do not currently exist in the direct sense and the onus is on producers to maintain 'end quality standards'. The experimentation undertaken by SUDEVAB was in two forms. Firstly back to back sampling of product from two physically different farms (Jersey, Channel Islands, open seawater, and the Fal Estuary, Cornwall) and using the standard sampling procedures for designated waters with the species reared on those farms. The abalone consistently recorded less than 8% of the contamination recorded in 125 samples of co-cultured, Crassostrea gigas, Ostrea edulis and Mytilus edulis. The highest single sample was 42 E. coli/100g. The 'in field' sample assessment is that abalone have not been shown to exceed Category A designation even if placed in an environment that would put bivalves for consumption at the upper boundary of Category B (<4200 E. coli /100g). The second was a comparative challenge test between C. gigas/H. tuberculata/M. edulis using known initial concentrations of E. coli and Norovirus. The E. coli uptake and discharge of a 72hr period mirrored the 'in field' sampling data, with abalone consistently an order of magnitude lower than the bivalves. Virus was accumulated very quickly by oysters, reaching a plateau within 5 hours and possibly as quickly as 30mins. Mussels also accumulated very quickly but peaked much later at around 9 hours and concentrations were much lower than in oysters. Abalone appeared to accumulate much more slowly and no significant amounts of virus could be detected until 9-hour exposure. These results indicate that the competent authority general approach to gastropods and abalone specifically is justifiably based on lower health risks than with bivalves.

Fundamentally, abalone are a very safe shellfish to consume. Any future change in legislation regarding monitoring organisms is likely to re-enforce that position.

WP 4 - Pathology

Diseases are at the heart of the recent, severe abalone stock depletion around the world: e.g. the withering syndrome in California (Friedman et al., 2000), or more recently outbreaks of herpes-like virus infections in Victoria (Australia) (Hooper et al., 2007b) and Taiwan (Chang et al., 2005). European wild abalone stocks are currently threatened by several pathogens causing severe mass mortalities in wild or farmed stocks (Azevedo et al., 2006; Balseiro et al., 2006; Huchette and Clavier, 2004; Nicolas et al., 2002): Xenohaliotis californiensis, Vibrio harveyi and Haplosporidium sp. (Azevedo et al, 2006). The transfers of exotic abalone

species to Europe (H. discus hannai) and the transfer of infected abalone through Europe may be vectors and they need special control, legislation and enforcement. SUDEVAB partners aimed at improving our current knowledge of the diseases present in the European stocks and of the basic mechanisms of immunity. More appropriate detection protocol needs to be developed, adapted to farming practices and legally implemented to improve the sustainability of this new growing industry.

Identifying pathogens in farm stocks

SUDEVAB partners had the opportunity to implement sustainable farming practices in conjunction with the reference laboratories in shellfish pathology. Before any animal transfers it was planned to check the health status of the various batches. Many obstacles to sustainable practices were identified such as:

- Inappropriate delays in the processing of the samples for pathologies: even though the project had planned these analyses well before the start of the farming experiments and although a post-doc staff was recruited and fully dedicated to this activity, it required 3-6 months for the analyses results to be returned to the SMEs. This was due to many difficulties: time consuming analyses or unreliable detection methods, restricted availability of the information about pathology.

- Administrative delays in making the results available or in the decision process in case of positive results. All the diseases required to be identified and listed according to their degrees of risk for the industry. European abalone remained unknown in many cases and more fundamental work is required to protect this new growing industry.

These unreasonable delays are not acceptable on the economic time scale of a farming activity and would certainly encourage farmers to proceed to transfer without authorizations. The work carried out during SUDEVAB in this field provided great improvements. It is important that this work is continued in the future.

Health status of farmed stock

Analyses based on histological examination, bacteriology and molecular techniques were carried out on juvenile and adult abalone during the course of SUDEVAB project. The objective was to define the health status of animals before making transfers in the different SME partners farming facilities. Sample examination allowed the reporting of the presence of Candidatus xenohaliotis californiensis in abalone. This prokaryote was detected by PCR and its detection constituted the first evidence in French abalone. No other pathogen including Vibrio harveyi was observed in analysed samples.

Susceptibility of European abalone to pathogens and parasites

The susceptibility of abalone to Perkinsus olseni was also investigated. No mortality was observed in abalone in contact with P. olseni during the course of the experiment. Thioglycollate analysis indicated that abalone appeared not to be infected. In comparison to V. harveyi ORM4, 6 strains of Vibrio isolated from French moribund oysters C. gigas presented a low pathogenicity to H. tuberculata. Mortality rates significantly different were observed between abalone injected with the OsHV-1 suspension and with the control suspension. However, to the view of mortality rates observed in control batches, the virus OsHV-1 seems not to be highly pathogenic to H. tuberculata. No significant mortality was evidenced in abalone incubated in presence of moribund oysters infected by OsHV-1.

During the project, a rapid real time PCR technique has been developed for specific detection of pathogenic strains of V. harveyi.

Although not initially included in the SUDEVAB project, the influence of the type of farming on the infestation of the abalone by polychaetes worms was also investigated by PhD student Erika Burioli from the university of Bologna and France Haliotis. It was clearly identified that abalone farming economic results would be directly affected by the presence of the different type of worms.

Although abalone could easily stand the presence of Nereids or Spionids worms, the worst damage was provoked by Sabellid worms. They were more prevalent into older animals or into animals reared near other shellfish such as oysters. Tank rearing increased the chance of infection and the prevalence of parasites.

Abalone cell cultures as tools for in vitro pathogenicity assays

Cell cultures provide alternative and controlled experimental models for fundamental studies as well as for various applications in developmental biology, physiology and host-pathogen studies. Here SUDEVAB reported the development of primary cell cultures from abalone H. tuberculata tissues and their use for studying pathogenicity at a cellular level. Primary cell cultures were developed from the gill which is a target tissue for two abalone parasites, V. harveyi bacteria and the Ostreid Herpes Virus OsHV1. Cells were obtained using the explants culture method as previously described for abalone tissue culture. First, the investigations focused on cell characterization, intra-cellular metabolism and viability of cultured cells. Cytological staining as well as flow cytometry analysis was used to characterize the cell populations. The results showed that gill cells could be maintained in sub-cultures over 13 days with a significant metabolic activity. In a second part, the project reported on the use of

gill cell cultures to investigate the mode of action of both pathogens at the cellular level. The results showed that in the presence of V. harveyi bacteria, phenol-oxydase activity of gill cells increased during the first four hours of contact and strongly decreased afterwards. Flow cytometry experiments are in progress to investigate furthermore the interaction between gill cells and abalone pathogens.

To conclude, primary short-term cultures derived from target tissues are suitable tools for in vitro investigations and open the way to innovative biotechnological assays for abalone aquaculture.

Improving our knowledge of the most threatening pathogens to abalone stocks

The marine bacterium V. harveyi (ORM4 strain) is recognized as being responsible for mortalities in abalone H. tuberculata (Nicolas et al., 2002). Yet it is important to locate the Vibrios present in an individual, depending on its condition and its sampling point to understand the ecological relationships existing between abalone and bacterial populations associated with it. To this end, isolation of strains of bacteria is made from different tissues of individuals to try to identify and define whether they have a pathogenic activity or not. Also, isolations of bacteria from surrounding sediment and algae have been performed. After isolation on a selective medium, molecular identification was made on the basis of phylogenetic classification of ribosomal DNA 16S. It was shown that the temperature increases the sensitivity of abalone V. harveyi and mortality was significant for temperatures above 18 ° C (Austin and Zhang, 2006). However, in a context of global warming, it is interesting to know the real impact of temperature on generation time of different strains of this pathogen of abalone. Of bacterial growth followed by subjected to temperatures ranging from 16 ° C to 34 ° C are achieved experimentally using an incubator with an integrated optical density reader and allowing growth monitoring in real time (Bioscreen, Norden Lab Professional). The calculation of generation time is performed on twelve strains of V. harveyi pathogenic or not, and from three different origins.

Improving knowledge about pathogens will improve profitability of farming

SUDEVAB contributed to improve our knowledge about abalone pathogens and made new information and tools available to farmers and scientists. This new information will provide great advances and reduce the risk of farming by providing better information to farmers who can make better technical choices. The risks for mass mortality will significantly be reduced.

WP 5 - Genetics

Introduction

The genetic work package of the SUDEVAB project was designed to provide essential and basic information on European abalone genetics. The knowledge on this subject was very limited and quite unreliable making it difficult to initiate appropriate breeding programs for a very young industry with a strong development potential. Before SUDEVAB, modern genetic tools had not been applied to validate this hypothesis and H. tuberculata was represented by 3 subspecies: H. t. tuberculata, H. t. coccinea, and H. t. lamellosa (Mgaya, 1995). All 3 were thought to be found in specific areas of the European shores.

The study of H. tuberculata genetics only started in France in 2007 and was given a new turn with SUDEVAB. The work conducted consisted in 3 distinct approaches to the field of genetics:

- Abalone population genetics allowed the identification of the various sub-division in the population structure. A better knowledge of wild stocks genetic structure is essential to evaluate the genetic potential of H. tuberculata.

- A laboratory approach to genetic selection allowed the provision of new information on the way to conduct the selection program for the growing abalone industry. This part of the work was aimed at identifying the selective potential of some of the production traits, and quantify their potential heritability. Domestication of ormers through selective breeding will allow producers to farm animals that are more adapted to the cage or tank environment, improving their survival, behavior, growth and welfare.

- A farm-based approach provided key information on how to implement laboratory findings in an industry based environment where the production constraints have a different reality.

Abalone population genetics

The aim of the work was to study genetic diversity and structure of the European abalone (H. tuberculata) populations using molecular markers (mitochondrial gene, microsatellite and nuclear markers). 21 populations of this species from Canary Islands to Normandy and from the Mediterranean were collected and analyzed. By using different analysis a phylogeographic scenario of evolution was proposed taking into account the variation of the level of the sea and the currents changes during the Pleistocene era. The COI results evidenced the presence of two groups of sequences which did not fit with the two subspecies defined by morphological traits and geographical localization; H .t. tuberculata in Northern Europe and H. t. coccinea in the Canary Islands. The existence of a mitochondrial introgression was characterized in the two subspecies. The results obtained with the microsatellites markers evidenced the presence of three genetic clusters located in Northern

Atlantic, Canary Islands and Mediterranean. In this latter region, especially in Banyuls, a recent mixture with Atlantic cluster was demonstrated whereas, in the Adriatic, an isolation of the population was evidenced. These results were confirmed by using another nuclear marker: a lysin protein gene which presented a specific signature. These results will be useful for further aquaculture improvement programs.

Laboratory approach to Genetics: first steps of a MAS (Marker Assisted Selection) program

As the European abalone becomes of higher economic importance in Europe, especially in France, the aim of the SUDEVAB work was to initiate a MAS (Marker Assisted Selection) program for this marine gastropod. As we worked on farming conditions, we disposed of ten families issued from different crosses, which were supposedly full-sib families. The first step was to determine the parentage of the descents by using microsatellite markers. Three families were shown to have a pluri-parental origin, and seven families were a compound of full-sib individuals. We used these seven families to study different traits of interest and obtained preliminary results concerning weight, size, and color. These traits presented a unimodal distribution revealing a polygenic determinism. Concerning the size parameter; we evidenced a high heritability for length, width and weight (0.37, 0.29 and 0.40 respectively) with an important correlation between them, but a low heritability for condition factor and length/width (0.12 and 0.02 respectively). Concerning the shell color trait, a medium to high heritability was evidenced for the red color and hue (0.33 and 0.20 respectively) with a high correlation between them. No correlation was evidenced between size and color traits. To obtain more precise results concerning these traits, 14 new full-sib families were created and this will permit the study to more precisely the differentiate characteristics.

Selection of abalone (Haliotis tuberculata) strains for a better resistance to Vibrio harveyi

Since 1998, episodic mass mortality of the abalone H. tuberculata has been observed along the northern Brittany coast of France caused by a complex interaction among the host, pathogen and environmental factors.

During SUDEVAB, new and more efficient techniques were developed by the CNRS team. This innovative technology was developed in conjunction with the medical research team. It allows to identification of how resistance mechanisms would act against pathogens. Resistance genes could be identified rapidly providing great information for future selection programs.

Abalone were subjected to two successive infections with the pathogen V. harveyi under controlled conditions. During the first challenge, infection by V. harveyi resulted in 64%

mortality of mature abalone. After a second infection of those surviving the first challenge, only 44% mortality was observed. Physiological variability in the host response appears to be a major determinant in susceptibility to V. harveyi. In order to isolate differentially expressed genes in H. tuberculata challenged with this bacterium, suppression subtractive hybridization (SSH) cDNA libraries were constructed from muscle of moribund abalone (susceptible), surviving individuals (apparently resistant to the bacterium) and control (unexposed) animals. Of the 1,152 clones sequenced, 218 different partial cDNA sequences were obtained and represented 69 known genes. Of these, 65 were identified for the first time in H. tuberculata. Using real-time PCR, a time-course study was conducted on 19 of the genes identified by SSH. A majority of differentially expressed transcripts were down-regulated in susceptible individuals as compared to their resistant counterparts. Bacterial challenge of abalone resulted in the up-regulation of three transcripts (encoding ferritin, Heat Shock Protein HSP84 and Fatty Acid Binding Protein FABP) in those that survived exposure to V. harveyi.

Genetic markers have been developed for H. tuberculata genotyping by using a recent technique, High Resolution DNA Melting Analysis (HRMA) that moreover has never been used before this study for marine organisms. This method consists simply in a high flow screening and genotyping method based on melting curves analysis of amplicons, mutations modifying the curves compared to references. The entire procedure we proposed of HRMA in combination with qPCR is completed within 1h20 min as a single closed-tube assay that allowed in the same time to monitor PCR quality and to perform a scanning of more than 300 samples on two 384- or four 96-well plates on a LightCyclerTM 480 Instruments and will be a very useful technique to identify some spots of resistant populations in the field.

Farm based genetics: First step of genetic selection in France.

Twenty one selected full-sib families were produced in France Haliotis hatchery during SUDEVAB to conduct test on heritability and prepared for the drawing of a reliable genetic mapping of H. tuberculata genotype. These are the first steps towards the domestication of European abalone. The main technical difficulties were identified and technical solutions provided. The first assessment of the families during their first 90 days after settlement provided information about the influence of the culture environment on the performances and on the relative heritability of growth. These have set down the foundations of a large scale selection program aimed at the domestication of European abalone for aquaculture purposes.

Conclusion for genetic WP

The work carried out for the work package 5 of SUDEVAB has greatly improved our knowledge of the genetics of H. tuberculata. The study of the phylogeny of the species has shown that the geographical structure of the population is not as simple as it was described in the first place (Mgaya, 1995). The European ormer population does not present 3 sub-species

as taxonomists thought. We have two subspecies: H. tuberculata tuberculata and H. t. coccinea. The 3rd subspecies is only sub-taxon of Haliotis tuberculata tuberculata.

The work carried out during SUDEVAB program brought new and essential information on the genetic diversity and structure of European population. This could be taken into consideration while planning the future genetic selection program for the industry, especially when original genes will be needed in improvement programs. Heritability potential of essential traits for aquaculture was evaluated within farm stock and showed that size and color are genetically transmitted to offspring.

Future development perspectives

SUDEVAB partners are confident that these results will be a great competitive asset to the European aquaculture industry. Further research works are already under way to apply these findings, and these include:

* Design of the genetic map for the species,
* QTLs (Quantitative Trait Loci) identification for growth and resistance traits
* Association mapping to evidence genes involved in traits of interest
* Microarray and eQTLs, to understand the regulation mechanisms of these genes.

These findings have led to the beginning of a marker assisted selection program within France Haliotis hatchery. Multi parental families have been produced and will be used to optimize future breeding programmes.

Objectives are to obtain 30% gain in productivity in the first few generations leading to major gain in competiveness for the industry.

WP 6 - Abalone nutrition:

A major limiting factor to expansion of abalone cultivation is the ready availability of an economic suitable food. SUDEVAB partners have investigated two major ways to improve food availability and quality to the farmers: the integration of macroalgae culture to the farm and the sustainable production of a 100% vegetable-based diet.

Seaweed cultivation

The increasing demand from various industries for macroalgae biomass as a source of bioactive molecules, animal feed and/or for biofuel production is helping to develop intensive sea and tank cultivation of various macroalgae species all over Europe.

Seaweed cultivation trials of relevance to abalone feed were performed in Ireland (long-line cultivation) and Gran Canaria (tank cultivation). In Ireland during the reproductive season for each species, seaweeds were brought to the laboratory, spores were released and after a few weeks seeded long-lines were taken to sea growing locations. Seaweeds were placed next to salmon cages. In Gran Canaria, four trials were carried out evaluating the biological indexes of the seaweeds Gracilaria cornea J. Agardh, Hypnea spinella (C. Agardh) Kützing and Ulva rigida (J.Agardh) under different rearing conditions. Maximum growth rates and yields were obtained at a low initial stocking density and high water exchange. Production was significantly highest in G. cornea whereas U. rigida showed the highest growth rate.

Preparation of a 100% vegetable-based artificial diet

The process of developing a new artificial diet incorporating seaweed as the raw material consisted of reviewing the existing scientific literature on abalone nutritional requirements and investigating the nutritional variations observed geographically and seasonally, as well as the function and efficacy of macroalgae preservation methods. Finally the present project enabled the formulation and processing of experimental vegetable-based diets of optimum nutritional value and which are adapted to the nutritional requirements of the European abalone.

The following key results were observed:

- The biochemical composition of the macroalgae studied varied seasonally, geographically and as a function of their growing environment.

- Protein content of Ulva sp, Gracilaria sp and Palmaria palmata grown in enriched conditions were found in higher amounts and were maintained and not affected by the different drying methods tested.

- Lipid levels of the macroalgae species tested were diminished by the drying methods employed: they were especially affected by light - however suitable levels required by the abalone were still present after drying. All the seaweed species investigated, presented

variations in their proportion of monounsaturated fatty acids (MUFA) according to the season and generally the red algae presented lower levels throughout the year.

- Carbohydrates values were not affected by the drying methods and were higher in wild macroalgae and lowered in enriched conditions

Moreover, considering all the wild macroalgae studied, they all presented an increase in protein and a drop in carbohydrates between summer and spring and it would make them more suitable to respond to abalone nutritional requirements if collected between winter and spring i.e. a higher protein content. Growing all the macroalgae studied, except laminaria digitata, in enriched conditions could enable a better control and smoother changes, through the seasons, of their nutritional quality in order to better respond to abalone nutritional requirements.

Taking these variations into consideration, the biochemical composition and fatty acid profiles of the macroalgae studied indicate that they have the potential to match the abalone requirements and to be suitable to be included in a macroalgal-based diet.

According to the literature review the existing artificial abalone diets to date are remarkably similar in their proximate composition. They generally contain a high protein and carbohydrate content and a low lipid and fibre content. The average protein content found in abalone diets is about 30%. Lipids are important constituents as a source of energy and essential fatty acids and are normally averaging 4% in abalone diets. Carbohydrates constitute the bulk of the diets, averaging 45%.

Hence, three isoproteic and isoenergetic, seaweed-based diets, with proximate biochemical compositions, of 35% protein, 4% lipid and 40% carbohydrate on average, and gross energy matching the ones of other artificial diets according to the revision, were formulated and processed.

Survival, growth, consumption and feed efficiency were assessed on H. tuberculata sp specimens. Animals fed diets containing three macroalgae ingredients, performed better than those that were fed with just two macroalgae ingredients, especially the diet including P. palmata which showed higher dietary values and resulting in a higher shell growth rate (29µm day-1), specific growth rate (0.4%) and weight gain (41%).

These results are a first steps towards the processing of sustainable vegetable-based diets that could be considered as a new abalone feeding source in the future for a sustainable and quality culture of the European abalone.

WP 7 - Technical and economic performance of abalone farming

Commercial farming trials of abalone (Haliotis tuberculata) in offshore and intertidal sea cages: technical results*

In the context of SUDEVAB, four commercial cage trials were programmed to assess the economic and technical feasibility of abalone farming in four different European countries. Three types of cages were tested: lanterns, ORTACs and large offshore cages. Three trials were successfully set up in western France (Aber Wrac'h), South western England (Portland) and South of Jersey in the Channel. The set up of a fourth trial in Spain aborted in the early stage of the set up due to very high handling mortalities in the first 2 weeks. The trials lasted from 18 to 21 months. Mortality was mostly observed in the early stages of the experiment and was probably associated to initial /transportation and handling stresses. It ranged from 0 to 73% mortality. Growth ranged from 0.23 to 1.90 mm per month with the best growth obtained in France where the stocks had the minimum handling. The biomass gained over the 21 months of experiment ranged from 0 to 2 kg of abalone per square meter of available habitat. At a given density of abalone, the best biomass gain per square meter of available habitat was obtained in ORTAC cages in an offshore set up. Lantern cage were rapidly disqualified because of their fragility when located in intertidal and offshore set ups. Large offshore cages were not adaptable to intertidal set ups, but were very efficient to reduce labour feeding cost in offshore locations. Despite the very variable results between experimental sites, it appeared quite clearly that experience gained and know-how, are a key to successful production. Production cycles that aim to cultivate 45g to 50g abalone from 20mm spat were calculated at being 3 years. Abalone farming will remain a highly "technical" activity.

Technical and economic analysis of three types of abalone farming systems in Europe

The technical and economic operation of three types of abalone farms were analyzed to better understand the potential of halioticulture in Europe. Slower growths are obtained by sea-farming compared to farmed land in semi-recirculating farms. The control of temperature and photoperiod allows for better growth performance and shortens the production cycle. However, the labour required for feeding and cleaning of tanks is more important in semi-recirculating systems. The rearing at sea requires the use of natural and live food (algae) that are more expensive but can also reduce maintenance time throughout the production cycle. Below is an example of economic analysis of a sea based farm:

Economic analysis of FRHAL sea cage system for a sale price of 60€/kg

Key variables to understand the breakdown of cost for FHRAL sea cages:

- Feed Conversion ratio using seaweed: FCR= 1:10 to 1:15 with Feed cost at approx. 0.50 €/kg

- Juvenile cost will be directly affected by on farm mortality and harvest size.

- Labour is limited to feeding (once a fortnight), grading and maintenance of the system: there is no daily feeding or cleaning required in this system. The system remains competitive despite its longer production cycle because the low labour cost.

- Depreciation is limited because the investment is quite low in this system.

The choice of farming system is based on several technical and financial criteria i.e. availability of sea or land sites suitable for culture activities; environmental conditions; security; introduction of non-native species (abalone); the level of investment and potential returns, etc.

"Abalone farming is a long-term economic adventure with many risks. The risks of long cycles that are often incompatible with the usual economic rhythms have also been analysed".

The technical and economic analysis of abalone grow out systems is difficult due to the lack of reliable statistics. There are only a few farms currently operating in Europe and each of the farm has chosen a different mode of production: there are no standard production techniques available for the European ormers, but these techniques need to be created.

Following SUDEVAB project, more reliable information is available to new projects managers allowing for more realistic business plans. Several new projects are starting in France and Spain in 2011 which carry a lot of hope for the future of the industry. SUDEVAB has provided technical guidelines for a more efficient and sustainable industry by analyzing existing technology, and developing new systems.

SUDEVAB provided tangible new development opportunities for the industry

The research activity in the field on commercial scale was of great benefit to SMEs and allowed for the design and patenting of a new rearing system at the end of the SUDEVAB program in 2010: the ABBLOX®. This new system provides all the benefits of the

various systems tested at a reasonable cost and is encouraging new farmers to get involved in abalone aquaculture. Two new farm projects started in France during the last year of SUDEVAB (Groix Haliotis and Les coquillages du Phare de l'Ile Wrac'h) and 4 new project have been initiated following the SUDEVAB final workshop (3 in France - Beg Ar Vil,, EARL Vincent FEAT, EARL Le bot and 1 in Spain). Many French shellfish producers have approached France Haliotis to enquire about the possibility to buy abalone spat and get technical advice for abalone aquaculture since the final workshop in Brest and its press coverage.

WP 8 - European abalone marketing

For aquaculture to be sustainable, a project has to be able to make money to repay its investment. To achieve this, a project has to be designed to function technically, but also to produce products that are in demand from the market. A project therefore should be a market led development - just because the technology exists to produce a product does not mean that a project will be economically successful unless the product it produces sells for a profit. Market analysis is there to ensure that the markets exist and that the demand and prices will provide the expected returns which will sustain the project development.

In the case of market analysis for abalone, the market data is difficult to obtain, clouded in secrecy, and has a large volume of "black" traded products being fished illegally due to high market prices. During SUDEVAB, extensive market data was collected to assess products available, prices in worldwide markets, volumes traded from aquaculture and wild production, and the future standards that have been developed by the WWF abalone dialogue for sustainable abalone production. In Work Package 8 an assessment was also undertaken to understand and estimate the potential demand for abalone in European markets and the type of products the European gastronomy sector desired.

The marketing study concluded that there is a strong demand for "live" quality European abalone in Europe, and these products were also seen as premium products in the major Far Eastern markets. Producers in SUDEVAB, notably France Haliotis and Tower Aqua Products are both receiving €60,00+ per kilo live abalone from European customers, and in the latter half of 2010, France Haliotis also entered the Brest fish market to acquire wild abalone from fishermen to supply the increasing demand from his customers. This also supports the price for fishermen of abalone, strengthening the European market.

World abalone prices are still controlled by Chinese and Japanese buyers, and are closely linked to species, size, taste, texture, quality. Although abalone prices in general weakened in 2010 due to economic pressures worldwide, the top grades of abalone remained stable, partially due to supply shortages due to disease and stricter controls on landings, and thanks to the prestige value of abalone in Far Eastern delicacy dishes. Product form does not

significantly influence price with dried and tinned products being as expensive as live. The European species has been favorably compared to the Australian, Californian and Japanese top grade species, and as long as production focuses on quality the European abalone will continue to command the top process worldwide.

WP 9 & 10 - Dissemination & Producers Organisation

Dissemination activities occurred during the whole project program. These actions were conducted by all the partners in order to promote the consortium research or industrial activity. The dynamism of SUDEVAB partners is clearly visible through the amount and impact of their dissemination activity.

These actions were coordinated by Aqua-Gold and France Haliotis in order to be efficiently promoting abalone in Europe. Public and media were regularly informed about the consortium industrial development activity. This focused on the following during the project:

The first level of focus for abalone - as food and a delicacy targeting restaurant chefs or the general public to improve the awareness and knowledge of the product. This was done through the organisation of meetings with journalists, promoting abalone in food shows and organising tastings or visits on farms. This yielded a great number of articles in mass media journals or TV.

The second level of focus for abalone - as a new aquaculture activity. At different stages of the project, the professional shellfish farmers were invited to visit partners' farms or to attend a workshop. Two workshops were organized; one in Galway, Ireland (May 2009) and one in l'Aber Wrac'h, France (October 2010).

The emphasis on sustainable farming techniques for abalone within a European context highlighted the challenges and opportunities to existing and potential abalone farmers. The workshop focused on the presentation of sustainable farming techniques taking into account the necessities, specificities and considering the possible future benefits of European abalone production.

The unique format and scope of these workshops was designed to ensure that the results were disseminated and that a broad range of shellfish producers, scientists, technical and governmental organisations contribute to the discussions on abalone culture and its methods and future development. The activity was also thought to connect more closely the diverse

communities dealing with abalone culture in different ways, thus enhancing dialog and an important partnership necessary for the further development of the culture of that species.

Through the workshops it became increasingly clear that there was significant interest from existing producers, and potential producers for a network (or some form of producers association) that could link everyone together. Investigative work during the SUDEVAB project about what transnational organisation might best fulfill the needs of abalone producers at present indicated that a European Economic Interest Group (EEIG) might be most suitable given the current developmental stage and level of production and marketing within EU Member States. A loose (or structured) network of producers will greatly enhance the capabilities of the abalone aquaculture sector in Europe in terms of; technology transfer; disease monitoring and treatment; supply of juveniles; supply of equipment; cross cultural exchange between producing regions and eventual marketing data and opportunities. An example of the diverse audience and interest in this species was demonstrated in the last workshop in Brest (October 2010).

The example of l'Aber Wrach Workshop

After a visit to the grow-out installations of "France Haliotis", the audience was brought up to date on the SUDEVAB project and its key research elements. The rest of the workshop focused on describing the results obtained within each research area covered by the project.

The presentations and discussions focused on various aspects e.g.: pathology, more specifically the impacts of the bacteria V. harveyi; genetic issues, describing the characteristics of European abalone; and nutrition - discussing the uses of macroalgae and vegetal based artificial diets.

Finally the technical results of commercial farming in Europe were discussed together with an economical and marketing analysis. The format and scope of the workshop served to ensure that a broad range community including; scientists, students, shellfish producers, governmental organisations and scientific divulgation organisations could benefit from the results and contribute to discussion on future abalone production in Europe.

Discussions were taken further on the benefits and future of sustainable abalone production in Europe through participation of the audience and interactions with the project partners.

The participants agreed on the necessity of such a workshop and stated that it enabled to go one step beyond in the development of abalone culture therefore having a positive impact.

Over ninety participants from a broad range of expertise attended the SUDEVAB workshop.

- The third level of focus for abalone - dissemination of abalone as research activity. Scientists involved in SUDEVAB were encouraged to present SUDEVAB related activities in international conferences and workshop.

- The forth level of focus for abalone - relate SUDEVAB to an activity enabled only by the support and funding from the European Community "Research for the benefit of SMEs" under the Framework 7 programme, without whose support the abalone aquaculture sector would still be a fragmented and unknown activity.

Potential Impact:

Potential Impacts of SUDEVAB through Socio-Economics and Dissemination

Introduction:

During the design and writing of the SUDEVAB proposal documents, it was agreed by all partners that abalone aquaculture was a virtually unknown entity in Europe. Abalone as a product was known in areas where wild resources had been harvested historically (Brittany, Channel Islands) but was not known as a gastronomy item.

Aquaculture activity was potentially strongest in Ireland, but even here some of the pioneers and first farms had ceased operations due to poor aquaculture practices, and lack of market opportunities.

SUDEVAB was therefore seen as a vehicle which could have a major impact on this sector and the partners set about designing the project with the following key objectives:

1. Reducing or eliminating the restrictions on the movement of abalone in Europe, promoting the trade and development of potential new sites for abalone production in Europe by harmonization of legislation

2. Evaluating the food safety and hygiene aspects of abalone with the aim of being able promote abalone as a safe alternative shellfish food source

3. Reducing technological barriers to culture practices and systems that would improve production and economic performance through improved growth (genetics); improved disease resistance (pathology): improved diets using locally sourced ingredients (algal diets and nutrition) and improved grow-out technology (sustainable culture systems)

4. Improved marketing opportunities by assessing the potential for higher value products being available to target markets

5. Evaluating a system for the long-term sustainability of the sector, by providing an umbrella organization which could link the sector's participants for further technology development, improve inter-trading opportunities and potentially add value to future marketing activities

All of the partners knew if the above objectives were realized that there would be significant socio-economic impacts for the sector, and that by also including special dissemination events involving potential future sector participants, the economic returns for the partners could also be enhanced, as well as seeing the sector grow as a whole.

In this review, the SUDEVAB partners try to put into perspective the success or failure of the project and its activities.

Socio-Economic Development:

Socio-economic development - is the process of social and economic development in a society. This can be measured with large indicators such as GDP, life expectancy, levels of literacy, etc. which in the small sector of abalone aquaculture would be difficult to measure, but on the other hand, even a few new employment opportunities in regions where unemployment is traditionally high would be significant.

When the definition of socio-economic impacts is further investigated, the causes of socio-economic impacts are often itemized as; new technology; changes in legislation; changes in physical environment, and ecological changes, it can be seen that the objectives of SUDEVAB were closely linked to the areas where changes were likely to occur.

As part of the project proposal contained in the Technical Annex, the SME partners estimated the potential economic benefits that may accrue to themselves over a five year period after the completion of SUDEVAB - and arrived at a figure in excess of €3 million. Was this too optimistic? Or have there been other developments created in part by SUDEVAB which may see this figure exceeded?

To analyse the socio-economic impacts "post" SUDEVAB, it is probably easiest to review the key areas of project, and asses how these will affect the future development and performance of the sector as a whole.

Economic Performance indicators:

Harmonisation of European Legislation:

During SUDEVAB the new EC shellfish legislation (EC 2006) was finally ratified by all States, and this has seen the first transhipment of live abalone juveniles from France to the UK, Spain and Ireland. For France Haliotis this has major impacts for future trading development, especially with start of operations in Ireland of Tower Aqua Products and the proposed opening of a new production facility in Spain in 2012. Both of these producers will eventually be harvesting 20 to 30 tonnes of abalone per annum - this equates to a need of 400,000 juvenile abalone per year, which have a current market value of €0,25 per piece at time of stocking. Even with conservative estimates for other producers entering the market for juveniles (especially in the French oyster producing regions) the juvenile market in Europe can be expected to exceed 3 million in the next five years. This will have a market value of €750,000 at today's prices, and the freedom of movement due to legislation changes will significantly assist this business development.

Food Safety & Hygiene issues:

SUDEVAB has supplied categorical evidence that abalone are not so susceptible to in ingestion and ability to store typical toxic elements that are associated normally with the commonly consumed mollusc species e.g. mussels and oysters. This in itself is not of direct economic benefit to producers, but it must be viewed in the greater context of marketing in the future, especially when greater volumes are available and consumers become more aware of the product. However, there are potential savings in terms of post harvesting operations i.e. depuration of shellfish typical with oysters and mussels.

Pathology:

The knowledge gained during SUDEVAB into the significant mortalities caused by Vibrio harveyii and its links to temperature can have significant implications for aquaculture development, in terms of site selection, operational parameters for enclosed recirculation systems, and with the development of a test kit, abalone used in culture can be screened as to their susceptibility for potential vibrio infection and subsequent mortalities. When mortalities can be measured in percentages in excess of 50%, the economic impacts of a vibrio outbreak are clearly seen. At current market prices of €60 per kilo for 70g animals, a 50% mortality rate equates to €30,000 per ton. In one farm alone (e.g. Tower Aqua Products) producing 25 tonnes per annum, it is not only the harvest sized stock that would be affected, but the following years stocks that need to be considered. It would be easy for a significant outbreak to account for more than €1 million in stock value losses, with additional knock-on effects to marketing strategies and continuity of supply to customers. The advances made during SUDEVAB in understanding and being able to control the potential impact of vibrio outbreaks will therefore have a significant and long-term impact on abalone aquaculture development in Europe.

Genetics:

Genetics has been traditionally seen as a major component in all aquaculture sectors as a tool for improving economic performance - and abalone aquaculture is no different. Being able to select a group of families which have better growth performance, increased disease resistance will ultimately increase the economic benefits to a producer in terms of operational efficiency. A production facility always has constraints on the number of animals that can be produced due to the physical nature of the site, the carry capacity of the system, and the logistics of feeding, harvesting, etc. If the throughput time can be reduced by selecting families that are better performers by identifying their genetic traits, economic advantages will accrue to the producers.

In the case of SUDEVAB the isolation of better performing families of abalone used in European aquaculture by the research which has identified the genetics of the families used, has already shown that there are groups which will be more suited to increasing production performance, without increasing production costs. France Haliotis calculated that it costs €27 to produce 1kg of abalone. It has been further estimated that genetic selection has the potential to increase performance by 10%-20% over the next 5 years. This will have several potential economic impacts for producers;

1. Initially saving €2,70 - €5,40 in production costs
2. Providing additional production capacity due to faster through-put
3. Creating a stock of better performing abalone juveniles that have a better market value to producers wishing to acquire abalone stock
4. Providing stocks that have better disease resistance

Interest has also been seen from the worldwide abalone producing community in this genetic research as it has the potential for other abalone species used in aquaculture. The European sector which was seen as a relatively "poor brother" in the world of abalone production, is now gaining recognition as a leading sector in terms of research, which may well have additional benefits to further research efforts in the future.

Nutrition:

Feed costs in aquaculture are often recognised as the single most costly element in production costs for a producer. In abalone aquaculture this is also the case with feeding activities

(seaweed collection, handling and feeding) being very labour intensive and contributing to 37% of the operational costs of abalone production.

Any savings in actual feeding costs would have great impacts on economic efficiency, but in SUDEVAB and abalone aquaculture it was recognised that the main feed input (seaweed) was also potentially very variable in quality due to its seasonal availability. Research work showed that the nutritional values changed significantly during the year, and these variations could negatively affect the growth of abalone. Research was then focussed on calculating these variations and linking it to the availability of the resource in different European locations, and how through seaweed culture these variations could be limited to provide a sustainable and nutritionally complete seaweed for better abalone growth.

Research also undertook the development of an "artificial" (100% seaweed based) abalone feed which did not use any fish meal components as found in currently available commercial abalone feeds. This has progressed to the point where the RTD performer (GIA) has attracted significant attention from commercial feed companies for further development of seaweed based diets.

The main economic benefits that are likely to accrue to SMEs engaged in abalone aquaculture are; a significant reduction in feeding costs due to less labour required for seaweed collection and handling and better year-round nutrition for abalone by the use of a standard feed which contains the correct nutrient values to optimise abalone growth. It was felt that it will not be the feed cost that will be an issue for producers, but the potential for increased growth and lower labour costs for feeding that could result in 10%-15% better economic efficiencies.

Technology:

The on-growing technology of abalone in Europe has divided itself into two main categories: Sea-based production systems (e.g. France Haliotis and Jersey Sea Farms) and recirculation technology (e.g. Tower Aqua Products). Both systems have benefits and disadvantages and have been developed to suit the sites where they are located, but the systems have been developed and adapted for abalone aquaculture using existing structures and technology, rather than being specifically designed for abalone aquaculture.

In the case of sea-based production systems, during the experiments undertaken during SUDEVAB, it was clearly seen that although the cage systems used functioned, there were deficiencies in each of the designs trialled. Due to the information being collated by SUDEVAB activities, two of the SMEs (France Haliotis and Jersey Sea Farms) worked

together to design a totally new abalone containment system (The Abblox) which has now been successfully patented and is now in production.

This development will have an impact on the European abalone production sector as a whole, by providing a specific abalone sea-based production unit which will enhance growth and provide better economic returns; and provide the two SMEs involved in its design with additional economic returns from the sale of the Abblox to producers in Europe and worldwide.

On a more general basis, SUDEVAB has given all of the SMEs involved; greater involvement and contacts within the technological development of the abalone sector in Europe; the potential to provide technological services to the developing sector; and a heightened profile in the world of abalone culture. All of the above have the potential for economic returns to the SME partners involved in SUDEVAB.

Marketing:

Almost no data existed on abalone markets in Europe prior to SUDEVAB which made investment evaluation very difficult. It was generally accepted that abalone were only sold and consumed in the Far East, and some abalone were available as regional delicacies (i.e. Brittany). However, with the growth of the gastronomy sector in Europe, and the general interest in novel sea-foods with the public, it seemed logical that there should be potential for abalone sales in Europe.

The market research undertaken in SUDEVAB proved this, and highlighted the extent of potential markets in Europe. Marketing activities undertaken by the producing partners in SUDEVAB further confirmed the existence of these markets to the point where existing producers could not source sufficient products to supply existing customers.

With good marketing data now available for the producers, it will be possible for existing and new producers to source investment finance for start-ups or expansion of existing facilities. This has been a major hurdle for abalone entrepreneurs and should contribute to the further development of the sector.

The marketing report has the potential to increase economic returns to the SUDEVAB partners by;

1. Increasing the potential for sales by better knowledge of the existing markets

2. Highlighting the potential for new markets

3. Providing market data for new producers entering abalone aquaculture, which in-turn leads to opportunities for sales of juveniles, services, etc. from SUDEVAB partners

4. Better understanding of market demands, which will lead to further development of supply logistics and supply economics

Producers Organisation:

SUDEVAB has created a network of interested parties engaged in abalone production, and future abalone production. The project has brought together the best abalone researchers and all of the abalone production sector for the first time in Europe, and through this engagement of interested parties has allowed the sector to share common interests.

Although this cannot be finalised immediately, there is a strong interest and economic incentives for the sector that this network, and the professionals associated with SUDEVAB, maintain contact after the finalisation of SUDEVAB so that the sector can continue its development.

The economics of shared information and further cooperation are a clear benefit to all, and the leading producers and entrepreneurs who created SUDEVAB see the synergies and benefits of continuing collaboration, with the potential for joint ventures in the future.

A producers organisation could formalise the current group that has developed within SUDEVAB, and provide an umbrella organisation for the future. This organisation could represent the abalone sector at regional, European and international levels; provide a single "head" representing the interests and concerns of abalone aquaculture within the shellfish industry; provide a base and portal for the future storage and dissemination of abalone information for producers; provide marketing data and act as a link between producers and end users for abalone products; potentially create a group that can act as a catalyst for the sectors development by promoting sustainable culture systems; Provide a group that can attract economic savings through buying power with major suppliers.

The Perceived Development of Economic Returns to SMEs created by SUDEVAB

The data developed during SUDEVAB indicates that the current production costs for 1kg of abalone are between €25 to €35. The variation depends on the seasons that the crop of abalone are grown through, and the systems used for on-growing. The current market price for live abalone in Europe has been stable at €60/kg. The world average market price for abalone has tended towards €25-€30 per kg, but this also includes less valuable abalone produced from tropical regions. However, the future prices for abalone in Europe (with the potential increase in production) are likely to fall, and as has been seen in other aquaculture products, this fall could be significant. Therefore it will be essential that abalone producers immediately reduce their production costs to anticipate the reduction in future market prices.

The results from SUDEVAB show the potential exists for reducing production costs by more than 25%. It should be possible for abalone culture systems in Europe to have production costs between €15 to €20 per kg in the next 5 years, which will ensure that even if European abalone prices decline to meet the world price levels, sufficient margins will exist for successful abalone producers to operate in Europe, and compete with world producers and for more investments to be made in new abalone production.

It must be remembered that the European species Haliotis tuberculata and H. discus hannai which is also cultured in Europe are recognised as two of the world's best species in terms of taste, texture, etc. which will always put it above many of the cheaper species that are produced, and for the selective major markets in the Far East who will continue to dominate the market, this will be a major factor. Developing the European taste for abalone will only enhance the end price received for European products, and with the ability of European producers to ensure quality, the European markets will be more secure sourcing "home grown" products.

The research results from SUDEVAB have received a worldwide audience, and the European abalone aquaculture sector is now recognised as one of the leading areas in the world engaged in abalone research. This can only lead to increased economic activity, not only for the SMEs, but for the research centres who have been involved in SUDEVAB, and there are proposals already in existence for future cooperation and collaborative projects. The legacy of SUDEVAB will also have a socio impact for the future.

Socio impacts and developments attributable to SUDEVAB

During the life cycle of SUDEVAB, there has been increased interest and activity in European aquaculture. This increase will create socio and employment opportunities in the near future, as well as providing potential for long-term impacts.

These will include:

* Direct employment creation - with the producers increasing in size and new projects being started, employment for both technically trained staff (pathologists, geneticists, nutritionists, etc) and general labourers

* In-direct employment in the service sector for companies supplying specialist services e.g. electrical, mechanical, marine supplies, technology, etc.

* Technical support - due to the relationships that have been established between research centres and producers, continued post doctorate studies and positions will be available for researchers with additional opportunities of research being linked to producers

* Skill development - abalone aquaculture requires that all employees have to learn a range of new skills which increases employees skill levels in new areas

* Diversification - one of the key factors witnessed during dissemination workshops was the attendance of other shellfish producers e.g. oyster farmers; who are interested in adopting or changing to abalone production. This will create opportunities for the existing abalone producers for increased revenues through technology transfer and direct sales, as well as assisting existing producers to reduce their own culture risks by not relying on mono-cultures.

It should also be noted that all abalone aquaculture facilities that are being developed and existing producers are located in isolated coastal communities. These locations are more suited to abalone culture for numerous reasons, notably, water quality, land & site availability, lack of alternative industrial development.

Most of the abalone culture sites are in regions that are already classified by the EC as category 1 development areas. This means that there are limited full-time employment opportunities (many areas depend on tourism e.g. Brittany, Cornwall), traditional industries (fishing & farming) are in decline, and young people tend to move away from these regions due to lack of good employment opportunities (communities are aging). An abalone production facility located in such a region will help to reverse these trends, and although a production facility will only be a relatively small employer, in small coastal communities the impact of a production facility can be significant.

Impact of SUDEVAB dissemination activities

SUDEVAB partners arranged two open workshop events - Galway, Ireland (May 2009) and Brest, France (October 2010). Both events were well attended with a wide range of interested parties being present including producers, researchers, media, policy makers, and other

interested parties. These events provided an opportunity for SUDEVAB participants to inform the audience of the range of SUDEVAB activities and research results, as well as bringing the participants into contact with the team and other interested parties which could develop into new business opportunities and activities.

SUDEVAB team members also participated in international conferences (Thailand; China; Brazil, Spain, France) where the European research efforts were also presented to the world of abalone culturists and the aquaculture sector. This has also seen members become part of the International Aquaculture Society (IAS) which has regular symposiums and conferences focussing on abalone aquaculture development worldwide. European abalone is now recognised as a growing sector with excellent research capabilities which will result in long-term benefits for cooperation and research collaboration.

SUDEVAB was also party to the development of the World Wildlife Fund's development of standards for sustainable abalone culture as part of the WWF's aquaculture dialogue programme. The standards that were developed by the international team showed that European producers already met the criteria for excellent production protocols.

SUDEVAB has created strong links between the project participants and the European sector, as well as forging new contacts worldwide. Through the dissemination activities of SUDEVAB, the European abalone sector no longer stands alone, but is now part of the world of abalone producers which will have long-term benefits for future research and marketing of European abalone products.

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