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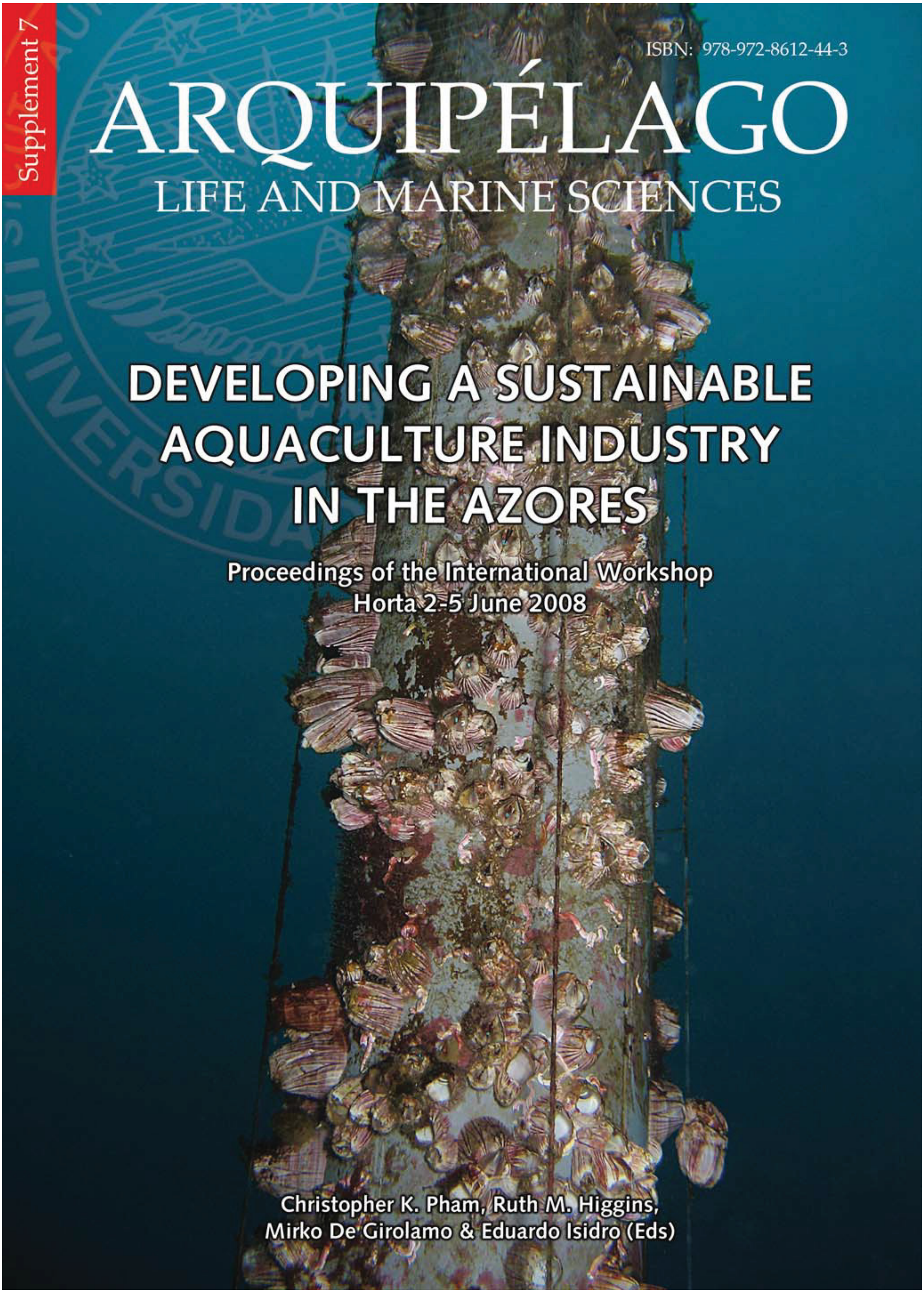

DEVELOPING A SUSTAINABLE AQUACULTURE INDUSTRY IN THE AZORES

Proceedings of the International Workshop
Horta 2-5 June 2008

Christopher K. Pham, Ruth M. Higgins,
Mirko De Girolamo & Eduardo Isidro (Eds)

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FOREWORD

The first workshop on developing a sustainable aquaculture industry in the Azores was organised as a joint venture between the Institute of Marine Research at the Department of Oceanography and Fisheries of the University of the Azores (IMAR/DOP) and the private enterprise *seaExpert*. The aim of the meeting was to determine the necessary steps to establish a sustainable Aquaculture Industry in the Azores and to identify priorities for further aquaculture research in the Region.

Experts were invited from diverse areas, bringing specialized knowledge and understanding of a broad variety of factors involved in setting up an aquaculture industry. Speakers from across the world shared experience of aquaculture projects from other island ecosystems including: Madeira, the Canaries, Malta, Cyprus and Hawaii. Representatives of official institutions such as the Food and Agricultural Organisation of the United Nations (FAO), the National Oceanic and Atmosphere Administration (NOAA) of the U.S.A., and Centro Tecnológico del Mar of Spain (Fundación Cetmar) offered advice regarding planning, management and policy issues. A specialist from an independent company, *Akvaplan-niva*, with vast experience in Aquaculture development in Europe was also invited to offer suggestions and advice to local government representatives and stakeholders.

The first part of the meeting was composed of a series of lectures: issuing the status of Aquaculture Worldwide and on the Portuguese scale; regulatory measures for aquaculture in the EU; trade, marketing, quality and safety of aquaculture products; oceanic and land-based production systems; and partitioned systems. Attention was also given to specific species that could be potentially produced in the Azores Region.

A series of discussion forums were launched during the second part of the meeting. These were designed to determine the specific requirements and steps needed in order to launch an aquaculture industry in the Azores. Amongst the topics discussed were: the structure of management of a successful aquaculture initiative, the steps needed to establish such an initiative, focal species, and suitable technologies and strategies.

WORKSHOP PROGRAMME

Monday, 2 June

Session 1: Opening and Introductory Communications

09:00 Documentation deliverance

09:20 Opening

09:50 Coffee break

10:05 Objectives of the workshop and characteristics of the Azorean archipelago relevant to aquaculture
EDUARDO ISIDRO

10:35 Overview of world aquaculture: trends and future prospects
DORIS SOTO

11:05 Review of aquaculture development in Portugal and Europe
ANTÓNIO AFONSO

13:00 Field trip to view and better understand coastal and near shore features of Island of Faial

Tuesday, 3 of June

Session 2: Planning and Management of the Sector

09:00 Policy framework and regulatory measures for aquaculture in the E.U.
LUCIA MOLINA

09:35 Planning and management of aquaculture development: lessons to be learned
WILLIAM FAIRGRIEVE

10:10 Some Guiding Principles for the Sustainable Development of the Sector in the Azores
PATRICK WHITE

10:40 Coffee break

10:55 Aquaculture products: Trade, Marketing, Quality and Safety
DORIS SOTO

11:30 Aquaculture Enterprises: Considerations and Strategies
PATRICK WHITE

12:05 Aquaculture Project Formulation
JOSÉ GONÇALVES

12:35 Lunch

Session 3: Implementation of Aquaculture: Relevant Case Studies

14:05 Madeira
NUNO GOUVEIA

14:40 Canary Islands
LUCIA MOLINA

15:15 Hawaii
CHENG-SHENG LEE

15:50 Coffee break

16:05 Malta
CARMELO AGIUS

16:40 Cyprus
YIANNOS KYRIACOU

17:15 Round-table discussion

Wednesday, 4 of June

Session 4: Production Systems and Potential Species

09:00 Oceanic production systems
HUNT HOWELL

09:35 Experiences in Aquaculture on land cases and tendencies
MARIA LUISA GONZÁLES

10:10 Polyculture/ partitioned systems
MIKE MASSINGILL

11:40 Coffee break

10:55 Abalone (Haliotidae)
PAUL OLIN

11:30 Giant Barnacles (*Austromegabalanus psittacus*)
DANIEL LOPEZ

12:05 Sea Urchins (Echinoidae)
GERASIMOS MOUZAKITIS

12:35 Lunch

14:05 Review of *Seriola* spp. Aquaculture Technology
DANIEL BENETTI

14:40 Red porgy fish (*Pagrus pagrus*)
LUCIA MOLINA

15:15 Tuna
VERNON SCHOLEY

15:50 Coffee break

16:05 Round-table discussion

Thursday, 5 of June

Closing Session

09:00 Discussion to finalise/amend the outcome of the discussion on sustainable aquaculture development in the Azores

10:15 Coffee break

10:30 Continuation of the discussion

11:30 Approval of first outline of workshop report

20:00 Closing Dinner

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Some aspects of the Azores relevant to aquaculture and objectives of the workshop

EDUARDO ISIDRO, C. PHAM, E. SILVA, R. GUEDES & M. DE GIROLAMO

Isidro, E., C. Pham, E. Silva, R. Guedes & M. De Girolamo 2008. Pp. 1-2 in: Pham, C.K., R.M. Higgins, M. De Girolamo & E. Isidro (Eds). Proceedings of the International Workshop: Developing a Sustainable Aquaculture Industry in the Azores. *Arquipélago*. Life and Marine Sciences. Supplement 7: xiii + 81 pp.

The contribution of aquaculture to worldwide seafood production has seen a steady increase over the past decades, becoming a significant economic activity for many nations. Although Portugal is one of the biggest seafood consumers in Europe, aquaculture remains poorly developed (Afonso this volume) and the Azores is one of the few places where aquaculture remains completely inexistent. Previous evaluation of aquaculture for the region were not encouraging (Menezes 1991), but successful development of mariculture activities in other oceanic islands such as Madeira, Malta and the Canaries suggests that this sector might be implemented in the Azores. Furthermore, as most of the local stocks are reaching full exploitation, aquaculture might become indispensable to reduce pressure on natural resources and promote diversification of products, employment, economic growth and social wellbeing.

Located in the middle of the Atlantic Ocean, the limiting factors for mariculture development are obvious. These include geographic isolation, rough weather conditions and great depth. Moreover, the coastline is dominated by high and steep cliffs making this zone difficult of access. Sheltered bays are rare and the shore environment is typically exposed to strong wave action. Seawater temperature might be regarded as favourable to mariculture activities. In winter mean SST shows a minimum of 13 ºC (January/March) and a maximum of ~24 °C (August September) with an annual variation of 8 %. In addition, the Azores benefit from clean oceanic seawater with low pollution levels, another strong asset.

Great pride exists in the region's natural beauty (both terrestrial and marine), attracting tourists from all over the world to visit the islands. Conservation of the natural patrimony is a priority and is an important factor needed to be taken into account in a future aquaculture development plan for the region. Under the "Natura 2000" network, 38 localities, with an area of approximately 45.5 thousand hectares, have been earmarked for special conservation status. Many of these include marine surface areas, parts of the coastal zone, shallow water reefs and banks. Fishery plays a principal role towards the economy of the archipelago. The regional fleet consists of about 650 small vessels with fishing capacity beyond the 50 miles operating with gill nets, traps and various forms of hook and line. Bottom topography limits the fishing grounds to the vicinity of the islands and nearby seamounts. Tuna represents most of the total catch, followed by demersal and small pelagic fishes (see Morato et al. 2001).

The consumption of marine products has a very long tradition in the Azores and interest is growing for developing mariculture activity in the region. This workshop intended to form an initial step into its implementation; the primary objective being to open the discussion on its feasibility. The meeting includes presentations aimed to cover the field of aquaculture comprehensively thus providing the audience with a clear view on what is aquaculture. The round table discussions will respond to specific questions regarding: 1) Planning and management; 2) Potential systems and species. The last round-table discussion will be dedicated to bring together the, recommendations and conclusions of the three previous working sessions in order to produce the first guidelines for the development of sustainable aquaculture industry in the Azores.

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Status of world aquaculture and its future development within an ecosystem's perspective

DORIS SOTO

Soto, D. 2008. Status of world aquaculture and its future development within an ecosystem's perspective. Pp. 3-5 in: Pham, C.K., R.M. Higgins, M. De Girolamo & E. Isidro (Eds). Proceedings of the International Workshop: Developing a Sustainable Aquaculture Industry in the Azores. *Arquipélago*. Life and Marine Sciences. Supplement 7: xiii + 81 pp.

Global production from aquaculture has been increasing steadily in recent decades. Records from 2008 indicate that aquaculture products now account for 50% of the world's seafood production (Fig. 1) and are likely to continue to contribute heavily to international seafood demand. Expansion in both freshwater and brackish/marine aquaculture has meant that commercially produced seafood now rivals the output from more traditional capture fisheries.

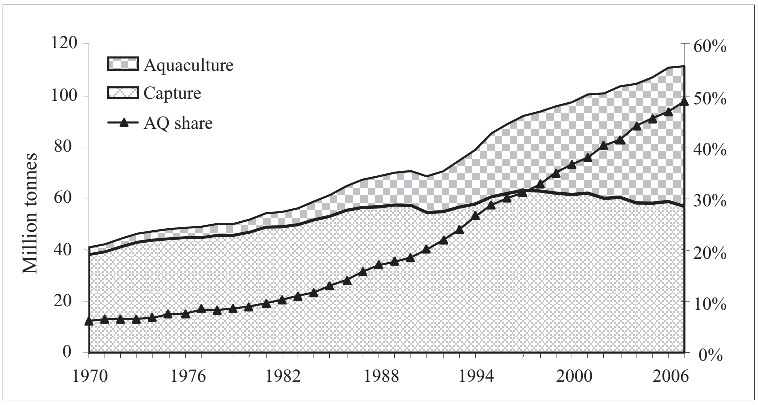

Fig. 1. World food-fish production for the period 1970-2006.

Greater market demand and consequent increased production have taken lace in Asian aquaculture in particular. In 2006, 90% of the world's aquaculture production came from Asia-Pacific, with the final 10% being derived primarily from Western Europe, Latin America, North America and the Near East, respectively. Although there was some production in Central and Eastern Europe and Sub-Saharan Africa, this contribution was minimal to the global context.

Aquaculture provides nutritious food and supports reducing global hunger and malnutrition but also have important socio-economic benefits, beyond food production. Given projected global population growth, an additional 37 million tones of aquatic food will be required by

2030 to maintain the current *per capita* consumption. Prospects for employment through aquaculture may also contribute to increased standards of living. In 2004, for example, aquaculture directly employed over 12 million people in Asia alone.

In terms of composition, according to records from 2005, finfish comprised the majority of aquaculture products, followed by seaweeds and molluscs. Although production of crustaceans was lower than for other categories of seafood, their monetary value was second only to finfish, corresponding to 21% and 56% of world aquaculture profits. Cyprinids, salmonids and penaeid shrimps were by far the most valuable species. More diverse aquaculture could possibly be more sustainable and although there have been trends towards increased diversity the benefits of such development requires further investigation and more support.

There are major forcing factors, external to the sector itself, which influence the growth of sustainable aquaculture. These include: aquaculture governance, availability of feeds, availability of space and water for aquaculture, global trade, world food production, and climate change. Although the aquaculture sector appears ready to meet the future global demand for food fish supplies, creating an “enabling policy environment” remains a challenge. Establishing an Ecosystem Approach to Aquaculture (EEA) is one way in which policy can support sustainability. There are three main principals behind such an approach:

- Aquaculture should be developed in the context of ecosystem functions and services (including biodiversity) with no degradation of these beyond their resilience
- Aquaculture should improve human-well being and equity for all relevant stakeholders
- Aquaculture should be developed in the context of other sectors, policies and goals

The EEA as a strategy needs to be developed on several scales such as the farm, the watershed and the global market scale. At the farm scale, for example, relevant elements for the strategy are relatively easy to define, issues and problems can be defined, although monitoring, control and regulation can often be challenging. At the watershed/aquaculture zone scale, a major problem that arises with the implementation of EAA is that often relevant water bodies and boundaries do not coincide with administrative and even national scales/ boundaries. Globally, international partnerships and agreements need to be established. Under EEA, Site selection becomes one of the most important management tools. Finding easy indicators of significant environmental impacts to avoid further biodiversity losses becomes a priority. At the local level, indicators can include early hypoxia detection as well as other indices (e.g. AMBI, particle tracking etc.). At the watershed level there is still a need for proper indicators. Global Monitoring Programs and Clean Production Agreements enable industry to be pro-active in the application of EEA. For the most part, however, integrated management and integrated aquaculture can be a very good tool: coupling aquaculture with other uses of the coastal zone, developing multi-trophic aquaculture, accommodating recreational fisheries and tourism, developing aquaculture and fisheries, and reconciling aquaculture with agriculture/husbandry/forestry.

For any aquaculture initiative biosecurity measures must be taken into account, particularly where exotic species are concerned. This includes the responsible movement of live animals and use of exotic species following thorough risk assessment. However, culturing native species does not always guarantee lower impacts on biodiversity and on societal perception of aquaculture when escape of individuals may affect local genetic biodiversity.

In conclusion, the future is likely to see a continued growth in aquaculture worldwide, continued use of introduced species, increasing pressure on feed sources, and increasing pressure on freshwater resources. Climate change will add additional pressure and mariculture is likely to increase more under such scenarios. It is also likely that with the growth of mariculture breakthroughs in biotechnology will occur. Culture of more environmentally friendly filter-feeder species and macroalgae should be encouraged. Culture of fish and other fed organisms should be moved further off-shore and be accompanied by larger infrastructure investments. Consideration should also be given to the culture of species that are lower in the food chain. These measures should be associated with improvements in FCR (feed conversion ratio) and further developments of environmentally friendly feeds.

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Review of aquaculture development in Portugal and Europe

ANTÓNIO AFONSO

Afonso, A. 2008. Review of aquaculture development in Portugal and Europe 2008. Pp. 6-7 in: Pham, C.K., R.M. Higgins, M. De Girolamo & E. Isidro (Eds). Proceedings of the International Workshop: Developing a Sustainable Aquaculture Industry in the Azores. *Arquipélago*. Life and Marine Sciences. Supplement 7: xiii + 81 pp.

Europe is a large region that includes countries with a wide variety of climatic conditions, from close to the North Pole, such as Norway and Finland, to the Mediterranean Sea, such as Italy and Greece. As in other regions a wide variety of marine organisms are cultured in Europe at present. Fish species are generally farmed in ponds, integrated pond systems, and tanks; molluscs on pole, raft and long-line systems; crustaceans in ponds tanks and raceways; and seaweeds and macrophytes using offshore floating/suspended cultures as well as onshore pond or tank cultures. There is also some scope for the aquaculture of minor species including echinoderms and coelenterates.

The main fish species for European aquaculture include both cold and warm water species, most notably: atlantic salmon (*Salmo salar*), trout (*Oncorhynchus* spp.), turbot (*Scophthalmus maximus*), european eel (*Anguilla anguilla*), sea bass (*Dicentrarchus labrax*), Seabream (*Sparus aurata*) and carp (*Cyprinus* spp.). New species are also being targeted for production. Several sparids, including *Dentex dentex*, present an attractive growth rate, are easy to produce, and have a good market value. Further, gadoid farming, which began in Norway in 1984, successfully produced 30,000 tons within the first ten years and has more recently shown good potential in the UK and France. The FAO outlook for gadoid farming is very favourable, expecting in the region of 2 MT by 2015. Other potential new species for aquaculture, including tunas (*Thunnus thynnus*, *T. maccoyii* & *T. albacares*), meagre (*Argyrosomus regius*), halibut (*Hippoglossus hippoglossus*), wolffish (*Anarhichas minor*) and sole (*Solea solea* and *S. Senegalensis*) are under intense research. However, development of such species has been faced with problems in terms of larval and post larval mortality due to nutrition, diseases, malformations, cannibalism, tolerance to handling and stocking density.

Aquaculture infrastructure varies greatly throughout Europe, as do climate and water resources and quality. In order to help the discussion of the central topic of this meeting "The development of aquaculture in Azores", instead of making a large review of European aquaculture development, some examples will be presented and their advantages and drawbacks will be discussed. In Norway, for example, sea pens are commonly used and are easily located in the many fjords of the region but, to face the winter extreme weather conditions and a varied biological and environmental requisites, high technology devises and sophisticated technologies and processes had to be developed. On the other hand, Hungary is an exclusively continental country and has no costal waters at all. Aquaculture facilities in that country use onshore ponds and tanks. They maintain an accurate balance between water quality and exploitation. Instead of focussing on their limitations, Hungarian fish culturists have developed an outstanding reputation for carp breading and production. The case of Galician aquaculture is also a case study because they developed one of the more novel aquaculture structures, relying on the natural tendency for mussels to settle and grow on ropes suspended in the ocean. With some of the most simple methods and technologies, they could come to be the biggest producers of mussels in the word.

THE CASE OF PORTUGAL

Portugal has always had a proud connection to the sea. The rate of fish consumption in Portugal is the highest in Europe, yet Portuguese aquaculture remains remarkably under-developed. Despite having natural environmental conditions that are well-suited to industrial production facilities, only 5% of all seafood production comes from aquaculture. In fact, hand-collection of bivalve molluscs is perhaps the most prevalent form of "aquaculture" present in this country. In 2007, however, the National Strategic Plan for Portuguese Fishing Sector (PEN Pesca 2007 – 2013) made better provisions for the development of an aquaculture industry including to: promote competitiveness, reinforce innovation and diversification, add more value to the produced seafood and ensure development of coastal fishery dependent areas.

Portugal has a naturally high population density near the sea. Recent measures have led to the declaration of a large proportion of the coastal zone as ecological reserves under Natura 2000 and other initiatives. For this reason, conflicts that inhibit aquaculture facilities have arisen in terms of use of the coastal zone. Competition for space and activity is high. These facts, coupled with a national prejudice against aquaculture and a complicated bureaucratic system have precluded the development of industrial production of marine species in this country. A promising factor is that research support for aquaculture is high in Portugal. A number of established marine research centres already exists in the country: IPIMAR (Algarve/Olhão), Univeristy of Porto (ICBAS and FCP), University of Lisbon (IMAR), University of the Algarve (Campus de Gambelas and Ramalhete), University of the Azores (DOP/IMAR), and two research centres, one connected to University of Porto CIIMAR (Centro Interdisciplinar de Investigação Marinha e Ambiental) and other with University of Algarve CCMAR (Centro de Ciências do Mar do Algarve).

THE CASE OF THE AZORES

Some issues need to be overcome in order to establish an aquaculture facility in the Azores. Despite being well-located in terms of production and water quality, and having little competition with respect to spatial usage, markets are distant and transport costs expensive. In addition there is no tradition of aquaculture in the region, and therefore, little existing know-how. Overcoming these issues will enhance the potential for such development in the Azores.

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Policy framework and regulatory measures for aquaculture in the EU

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The benefits of aquaculture are numerous. There is a generally strong worldwide market for seafood and a growing demand for fisheries food. Although there is a strong global tradition of freshwater and marine exploitation, advanced research and world-class technology have been considerably advantageous to aquaculture production. A rich resource of qualified and trained entrepreneurs and fish farmers exists within Europe. This coupled with appropriate climatic conditions and a large number of sites that are suitable for the production of the majority of farmed species, has proved very favourable to aquaculture development. Challenges still exist in the form of space limitations, the need for more harmonized legislation, the lack of conformed standards (virus test, EIA, etc.), low quality water in certain locations, and high standards on public health and environment imposed by the EU.

One of the main challenges for policy development in aquaculture lies in the conflict of interests related to usage of the coastal zone. Homogenised management approaches are more fully equipped to deal with such conflicts. Under the present EU regulations, individual member states are responsible for managing these areas. Although the EU currently has no jurisdiction to interfere with management strategies, member states have called for more coherent standards and legislation across the EU in order to manage coastal resources more efficiently. Unfortunately, nowadays, once most of the biological and pathological problems are surpassed, one of the factors that could jeopardise aquaculture development in a country is the lack of a suitable legal framework promoting aquaculture activities.

The Common Fisheries Policy (CFP) of the EU incorporates aquaculture, although aquaculture was, in the beginning of CFP, a secondary concern under this policy. Previous funding for aquaculture research has focussed on increasing aquaculture production and improving pathogen control in addition to the development of new technologies. More recently, in an attempt to lay down a framework for aquaculture, European policies have prioritised (i) improvement of environmental protection, (ii) improvement in food quality, and (iii) increased consumer safety.
These priorities fall under a series of policies, namely:

- Environmental Policy: sustainable development and preservation of water quality including the Water Framework Directive
- Health and Welfare Policy: New hygiene and welfare regulations

- Food Quality Policy: new regulation on organic farming
- Structural Policy: providing support to sustainability 2007-2013 via EFF
- Trade Policy and common organization of the market: producer organizations
- Research Policy
- Maritime Policy

Licensing can be complicated as there are many directorates at the EU level and agencies at national level with competencies in aquaculture management and development. For example, at EU level aquaculture falls under DG Mare, DG Sanco, DG Agriculture, DG Trade, and DG Research. Consequently, numerous policies and directives (>400 related to aquaculture) need to be negotiated.

Within the EU framework there are not only intervention rules, but moreover "policies". These can be broken down into prevention policies, usually related to the environment, and promotion policies, designed to support the creation of aquaculture facilities and ventures. The 2002 Strategy for the Sustainable Development of European Aquaculture, highlights the importance of maintaining competitiveness, productivity and durability of the aquaculture sector. The challenge is to create the best possible conditions that will enable producers to offer a healthy product in the quantities required by the market, while simultaneously preventing degradation of the environment. The objectives of the strategy are threefold:

- Creating long term secure employment, in particular in fisheries dependent areas
- Assuring the availability to consumers of products that are healthy, safe and of good quality, as well as promoting high animal health and welfare standards
- Ensuring an environmentally sound industry

The EU has still to cope with several problems in the context of health protection requirements including the evaluation of the environmental impacts of aquaculture and the stability of the markets. Public powers must guarantee that the economic viability be parallel to respect for the environment and ensuring the quality of aquaculture products in terms of management priorities. Eco-labelling has gone a long way towards reassuring consumers about the origins and quality of aquaculture products. With regard to the markets, the balance between control and demand must be wisely controlled. Producers, organisations and Interbranch Organisations (IOs) have a strong role to play in this respect.
Recommendations. Community policies should be focused on:

- Promotion and improvement of aquaculture image
- Reduction of negative environmental impacts
- Promotion of "site selection" and ICZM
- Food safety and security control

States that do not address problems with current regulatory approaches may lose aquaculture development opportunities to other regions and countries. The aquaculture sector needs a judicial security framework in order to facilitate investments for aquaculture.

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The roles of government and the private sector in planning and development of aquaculture

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Fairgrieve, W.T. & C.E. Nash 2008. The roles of government and the private sector in planning and development of aquaculture. Pp. 10-15 in: Pham, C.K., R.M. Higgins, M. De Girolamo & E. Isidro (Eds). Proceedings of the International Workshop: Developing a Sustainable Aquaculture Industry in the Azores. *Arquipélago*. Life and Marine Sciences. Supplement 7: xiii + 81 pp.

Aquaculture is an important economic, social, and food production sector which has grown dramatically throughout the last five decades. The global production of aquatic animals and plants has risen annually from less than 1 million tonnes in 1950 to over 59 million tonnes by 2004 (FAO 2006). However, although the total growth of the worldwide aquaculture industry continues and approaches that of the natural harvest, the achievements in production for the hundred or more domestic species under culture have not been similar. For example, fresh and brackish water facilities rearing species such as penaeid shrimp, tilapia, and various cyprinids accounted for about 49% of the 2004 production total; marine aquaculture accounted for the remaining 51%, or about 30 million tonnes. However, the freshwater production consisted mostly of fish (94 %) whereas molluscs and plants together made up about 89% of marine production. Improved marine culture techniques have dramatically increased production of high-value fish species, such as salmon, trout, seabream, seabass, tuna, and groupers, but compared with the rest of the sectors, total production remains relatively low.

In general, national aquaculture industries produce products primarily to supply the domestic markets with fresh food. Consequently, like agriculture, the various sub-sectors provide many national jobs which, in turn, reduce the demands for more expensive imported products. In several cases there is a balance of aquaculture products which may be exported and these industries function importantly as a source of foreign exchange. In terms of economic value, farmed aquatic products have become dominant among exported agricultural commodities for many developing producer countries. Chile, for example, is a country noted for its strong agriculture sector based on exports of fruit and other products. However, in 2004 the value of farmed aquaculture species exceeded 1.4 billion dollars. This compared with a combined total value of 4.9 billion dollars for the top 20 agricultural commodities. Similarly, several other countries, such as Vietnam, Thailand, and China, have also demonstrated dramatic increases in aquaculture production specifically targeting export markets.

In recent years those countries with extensive marine resources have been looking to develop aquaculture industries. In many cases where the near-shore opportunities have been fully exploited, or where conflicts with other uses exist, then the move has been to exploit the deeper waters offshore. This industrial development has required technological advances in cage design, mooring systems, feed delivery equipment, and harvesting methods. However, success has permitted installation of economically viable facilities for rearing a variety of species in high-energy offshore areas not previously considered for development. Such practical developments have led many nations, especially those without long, well-protected coastlines, to examine the feasibility of initiating marine aquaculture activities offshore, and often in Exclusive Economic Zones. Consequently, aquaculture in one form or another is practiced in every region of the world. However, the rates of progress between one country and another have been very uneven. While the sustained effort of private enterprise is the driving force behind all successful aquaculture programs, government plans and policies also play critical roles in the degree, rate and sustainability of sector development. The roles of government and the private sector in fostering socially, economically, and environmentally sustainable aquaculture have much in common with other food production activities. Nevertheless, some challenges unique to aquaculture exist, particularly with respect to environmental protection, equitable allocation of (natural) resources, and competition with other practical uses - such as navigation, tourism, fishing, and even conservation. However, nowhere are the challenges more apparent for the industry than in the policies and regulations that have been established for its diverse practices developed from country to country.

Like all industrial producers, fish and shellfish farmers prefer less complicated and better coordinated regulatory processes. In fact the most efficient national aquaculture industries are those where the fewest number of federal or state agencies have regulatory authority. Good examples are Chile, Japan, and Australia, where the government staffs are familiar with the topics in detail, and continuously trained on advancing production technologies. A second goal is to make sure that government and regulatory policies keep up with advancing technologies and the changing needs of the industry. This implies that some flexibility must be built into the regulatory process and that the government agencies need to have well trained and technically competent staff. The three key areas of activity for governments to achieve successful aquaculture development have been listed and reviewed by Nash & Fairgrieve (2007). These are (i) government policy and sector management, (ii) institutional support, and (iii) environmental management. Approaches to challenges and issues confronting the sector are illustrated by examples from producer-countries and regions with significant marine aquaculture activities. From their surveys the authors identify nine topics or sets of constraints. These describe all the realistic values of aquaculture that might be considered by a government policy statement. These include, for example, the need for commitment to a plan; for the government and the industry to communicate and work together, and to remember that the consumers are the driving force. Each of the nine topics has very real financial costs and therefore the government has the responsibility to select only those which can be achieved effectively within the economic, social, and environmental framework of the country.

GOALS AND POLICY OBJECTIVES

Foremost among governmental responsibilities toward a relatively new, technologically advancing sector such as offshore mariculture is to identify both long and short term goals and objective, and to promulgate policies and rules that, within the economic, environmental and social context of the country, foster sustainable development. Governments must also show genuine commitment to aquaculture as an important economic sector by allocating sufficient human and financial resources to the development process. The importance of long-term planning and effective implementation of plans and programs to the success of orderly aquaculture development cannot be overstated. Effective organisation and management of the aquaculture sector cannot take place with out a national development plan, a detailed program of work to achieve the desired goals, and a budget to ensure that the work takes place and to maintain continuity of development through successive administrations. Long and short term development plans, to remain relevant, must be updated annually to reflect current progress, assess the achievement of goals, set new priorities, and revise or develop work plans and implementation strategies. Lack of progress can in many cases be directly linked to problems with implementation, especially during the early stages of development when industrial expansion most depends on government to establish a regulatory framework, provide financial support, technical know-how and other essential services, such as product quality assurance and market development.

For most countries, aquaculture represents but a small proportion of total food production and must compete with other sectors for limited government resources, whether for basic development activities or for more advanced needs such as research and development, specialised training and educational programs, veterinary or health inspection services, or environmental monitoring and compliance programs. Rural development schemes remain very dependent on state or international technical and financial support, but in cases where aquaculture has attained high levels of production, private sector (producer) organisations have assumed many of these functions. These include producer-funded marketing and product development boards and research and development organisations that coordinate with public sector agencies to co-develop and implement policies and practices. These relationships improve flow of information, enhance compliance with regulation, and reduce conflict among users with differing needs. The Norwegian and Chilean models are noteworthy examples.

SECTOR ADMINISTRATION

Implementation of these policies requires an administrative structure with the mandate and authority to manage the sector but few, if any countries have true “parastatal” agencies with legal status and adequate financial resources for managing the national aquaculture sector. Instead, these functions are often fulfilled by a department or ministry of agriculture (rather than fisheries) because aquaculture production systems and husbandry practices closely parallel those of terrestrial agriculture. Aquaculture tends to interact more closely with other government agencies, such as those responsible for fisheries, coastal navigation, undersea lands and resources, food safety and drugs, and environment, however. Administrative responsibility and regulatory affairs are often abrogated to lower levels of government or delegated to several agencies that may have contradictory, confusing or inappropriate requirements.

Nowhere are the effects more apparent than in the permitting process which may requires separate permits from several different agencies, for example; maritime authorities (for navigation), environmental regulators (for water quality), for mining or mineral extraction (seabed leases) or agencies governing marine construction (for cage installation). The process may take years to complete and be costly in terms of license, legal and other professional fees.

For example, permitting for aquaculture in the Gulf of Mexico EEZ (U.S.A.) currently requires permits and/or consultations with eight Federal Agencies. These requirements pose clear impediments to offshore development and efforts are being made to streamline the process by identifying a lead agency to coordinate and facilitate permit processing. In contrast, marine aquaculture in Chile is regulated by three agencies (one for site leasing, for operating licenses, and for environment impacts). Sifting conflicts involving aquaculture and tourism, tourism, maritime traffic and safety, and conservation have been reduced by establishing areas suitable for aquaculture via regional commissions and a public hearing process.

Governments also bear the ultimate responsibility for enforcing regulations governing production conditions, sanitation, product quality, and food safety. As worldwide consumption of high-value farmed products has grown, consumer demands for high quality, safe, and nutritious farmed fish products have mandated adherence to international norms by producer countries. As evidenced by recent reports of mislabelled fish products, some contaminated with bacteria or prohibited veterinary drugs or chemicals having been exported from Asia to the United States and other markets, this cannot be achieved through government regulatory actions alone. There is an increasing recognition that producers and producer organisations working together with government to develop best management practices and other forms of self-regulation have contributed to better management of the sector, particularly where international trade and other agreements are concerned.

Codes of Conduct and Best Practices aimed at increasing self-regulation and compliance with established and anticipated regulations are now in place in major producing countries and regions. Governments, such as those in Latin America and North America and elsewhere, have taken this approach and have additionally supported implementation of Hazard Analysis and Critical Control Points (HACCP) practices, certifications of quality and environment (ISO 9000, 14000), and other standards. Private companies and producer organisations have also taken a lead role in establishing standards followed by members.

INSTITUTIONAL SUPPORT

Government services in support of developing industries, including aquaculture, are initially costly but necessary investments in long-term growth and sustainable achievement. Most countries compile and report annual production statistics (by weight and farm-gate value), and may gather data on farming activity, area under production, labour and wages, and other measures of the economic importance of the sector. Management services of this type may inform decision makers on the need for other types of services and establish priority areas for investment. These might include, among others: establishment of marketing boards and other producer or consumer organisations; special technical services, such as veterinary and disease diagnostic laboratories; infrastructure development; and providing opportunities for education and other professional training. Some governments support industry by establishing mariculture demonstration projects, providing high quality seedstock from government-run hatcheries, or through special zoning or aquaculture parks.

The use of demonstration projects is common and a proven technique for supporting aquaculture development. Fundacion Chile, for example, established commercial scale, for-profit projects to evaluate technical requirements and feasibility of salmon farming in Chile. The governments of Malaysia and the Philippines have encouraged private business investment in marine farming by establishing Aquaculture Investment Zones and Open-water Mariculture Parks. In both cases, participants are eligible for certain economic incentives, such as loans, provision of feed and seed, and infrastructure development. Although technological, financial and other services can be obtained by hiring foreign experts, long-term sustainability and accrual of benefits to the citizens is most likely if government invests in capacity-building. This can be done by providing institutional grants for research, opportunities for post-graduate education, vocational training, and technical courses for farmers and farm staff. Training should also be provided to civil servants, loan officers, insurers and others in the financial sector that are responsible for development and administration of various financial support schemes and financial incentive, such as tax credits for equipment, feed and seedstock; crop insurance; or exemptions from duties or taxes.

Governments are well-positioned to provide a variety of market related services, for both the producer and consumer, especially during the early stages of sector development. Transportation, storage, and sales campaigns (for producers) and advertising campaigns for diet and health (for consumers) are examples. They also can provide essential services in the areas of food safety and hygiene by testing or otherwise certifying product quality. On the other hand, government authorities are unable to provide timely advice on new marketing trends, consumer preferences, or new global agreements on health and hygiene. These services can be assumed by producer organisations that in some cases have grown large enough to pursue international markets and independently prepare development plans. Organisations such as the Norwegian Seafood Federation-Aquaculture, the Chilean Association of Salmon and the *Trout Producer* (now *SalmonChile*) include farmers, processors, suppliers and service providers not only represent industry needs to government but also play key roles in marketing, quality control and other practices aimed at building global market share.

ENVIRONMENTAL MANAGEMENT

Reliance on fish meal and oil for feeds, introduction of non-native species that may become invasive, effects of genetically selected farmed animals on wild ones should they escape and interbreed, impacts on protected marine mammals and birds, and water pollution are among many environmental concerns surrounding aquaculture development, particularly in marine environments. Well-publicised reports of escaped salmonids colonising coastal rivers in Chile and displacing native populations in North America and Europe, and the appearance of pathogenic organisms imported with eggs or live fish illustrate these concerns. Nutrient and organic effluents from aquaculture have demonstrated local impacts on water quality and benthic organisms, particularly when marine farms are improperly located in shallow, low current areas, and improper feeding techniques are used. In the past, most governments did not have in place adequate plans and policies with strict environmental regulations, and lacked sufficient surveillance and enforcement capabilities. These shortcomings were complicated by inadequacies in scientific research capabilities, which limited the capability of regulators deal with emerging issues. More recently, however, government authorities and private sector institutions have increasingly collaborated to developed codes of conduct and better management practices, certification systems and standards that comply with international norms.

Governments with successful aquaculture sectors take these concerns seriously and have taken action to resolve or mitigate the impacts of aquaculture on the environment. For example, government-sponsored research into alternatives to fish meal and oil (e.g., the FORM and RAFOA thematic programs of the European Union) have reduced the per-unit-of-production dependence on these products and renewed interest in developing more sustainable terrestrial protein and oil sources. Risk assessment frameworks developed by the World Health Organisation of the United Nations have been adapted to aquaculture, gaps in scientific knowledge regarding potential impact and mitigation strategies are being developed and implemented by major producing countries worldwide. The impact of these approaches on farming practices in salmon farming regions is noteworthy. Improvements in site evaluation and monitoring practices, feeds and feeding technology, biosecurity and other measures have increased productivity and reduced detrimental environmental effects.

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Some guiding principles for the sustainable development of the aquaculture sector in the Azores

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Principles for sustainable aquaculture development include a) responsible use of fresh and saltwater resources, b) of wild fisheries resources to supply fish meal and fish oil for fish feed, c) protection of the environment, d) strategies for mitigation impacts, e) ecosystem based management, socio-economic benefits, and business profitability. The ways to implement those principles are through planning, management, monitoring and control. The methods used to ensure that the principles are implemented include: regulations, voluntary codes of conduct/practice and market requirements such as certification.

a) Responsible use of water resources: Freshwater is more limiting than marine. There is strong competition for those limited resources for drinking water, agriculture and industry. Therefore in the long term, mariculture will be dominant.

b) Responsible use of resources for fish feed: In 2002, aquaculture was the largest consumer of fishmeal and oil using about 46 percent of the global fishmeal supply and 81 percent of the global fish oil supply. These percentages were anticipated to increase to 57 % and 100 % of global supply respectively by 2010. For continued sustained aquaculture growth, less fishmeal and fish oil must be used. This will require reduced level of inclusion in fish feed, fish meal and fish oil substitutes found, produce fish lower on the trophic level.

c) Protection of the environment: Impacts of aquaculture can be in separated into 3 categories: physical, chemical and biological. Physical impacts include the construction of physical structures, cages, pens, jetties along the coast; visual impacts (problem for tourism), and net friction to water exchange. Chemically, aquaculture can impact the environment via oxygen depletion, release of nutrients leading to eutrophication, antifoulants boats and nets, and the administration of medications and treatments. Biological factors include the local deposition of products from faeces, excretion and waste food, in addition to more complex effects on genetics and biodiversity of the ecosystem and its inhabitant species. There are three major time and space scales for the impacts of finfish farms, localised effects close to the cages, near field effects up to 500 m from the cages and far field effects up to 5 kilometres from the cages. There are primary effects such as the release of nutrients into the water column. These lead to secondary effects such as the nutrient release leads to enhanced primary productivity or in the case of excess nutrients, eutrophication. There are changes in flora and fauna due to the organic loading on sediments under the cages due to uneaten feed and fish faeces. At low nutrient enrichment the conditions are close to normal with an increase in benthic productivity closer to the cages. At higher nutrient enrichment the benthic scavengers cannot assimilate all the additional enrichment. At very high levels, the seabed becomes azooic with bacterial mats (Beggiatoa). Soluble compounds, such as ammonia and urea, which are excreted by the fish, accumulate and become oxidised to nitrites and nitrates. Soluble compounds can also re-enter the water column from the sediments. There is a risk of transmitting pathogenic organisms to wild fish stocks particularly with the transmission of sea lice from farmed to wild fish especially those that pass close to the cages. There can be impacts on sensitive habitats such as sea grasses, corals, wild fish spawning areas and wild fish nursery grounds. In the Mediterranean it has been found that within 3 km of the farm, the biomass of wild fish is double compared with normal levels. Pharmaceuticals such as antibiotics used to treat diseased fish and antifouling agents can have effects on wild fish populations and other organisms.

d) Potential strategies for mitigation of impacts: There are a number of strategies for the mitigation of aquaculture impacts and these will differ depending on the culture systems, species, intensity and environment. The primary objective of the strategies is to minimise the amount of nutrients released into the environment through improved feed management and feeds, use of extractive species to reduce nutrient loadings, fallowing and natural recovery. Another guiding principle is the precautionary approach where potential impacts are evaluated carefully and if there is great uncertainty, then the development should not go ahead. This is usually undertaken by undertaking an Environmental Impact Assessment for large projects or undertaking a Risk Assessment before the introduction of non-native species.

e) Ecosystem based management: Aquaculture development should be sustainably integrated within the ecosystem. The aquatic ecosystem should be considered from the watershed to the water body. It should also consider the socio-economic context and interaction with other users of the water resource.

PLANNING SUSTAINABLE AQUACULTURE

Planning should be science based and use the tools of Risk Assessment and Environmental Impact Assessments when necessary. There should be zoning of aquaculture to reduce conflicts with other users of the aquatic resource and there should be an estimation of the safe carrying capacity for aquaculture in the zones.

MANAGING SUSTAINABLE AQUACULTURE

Sustainable aquaculture needs holistic management. Management can be forced onto the farmer in the form of regulations, voluntary in the form of Codes of Conduct or Codes of Best Practice or forced by the market through certification schemes where the producer has to follow certain practices.

MONITORING SUSTAINABLE AQUACULTURE

Strong monitoring of aquaculture is required to ensure that it industry remains sustainable. In many countries this is strictly enforced by Government regulators. Undertaking regular monitoring surveys ensures that the impacts are within the limits described in the Environmental Impact Assessment, the impacts are within any Government water quality standards and whether the impact on the environment is getting any worse, remains stable or getting better.

CONTROL OF SUSTAINABLE AQUACULTURE

There is the need for controls on aquaculture in the form of checking that the farm conforms to the quality standards such as water quality standards and sediment quality standards. These standards are usually enforced by the national regulators. Production levels should be checked against licenses. There needs to be penalties or action taken if these are breached

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Aquaculture trade, consumer protection, international regulatory requirements and traceability

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According to FAO data, the outlook is good for aquaculture trade. It has been estimated that by the end of 2008 aquaculture products will be worth in the region of 92.3 billion USD. Globally speaking, around 37% of fish production is traded across borders and net revenues (export value – import value) of developing countries from fish trade exceed that of meat, dairy, cereals, sugar, banana and coffee altogether. Aquaculture, which is practiced almost entirely in rural areas and concentrated in developing countries, contributes ab increasingly significant share of fish trade. As such, aquaculture trade presents an opportunity to help rural and more remote communities. Governments, however, do not appear to exploit fully the opportunity that this scenario presents for rural development. Trade impacts on the policies of government. Governments, in response to the creation of The World Trade Organisation (WTO) in 1995, have evolved policies that range from directly intervening in the economy to playing an indirect, regulatory and fostering role. Policy and institutional adjustments that have been introduced include:

- Changes in laws and regulations to integrate government functions to the market economy while taking a more indirect role in trade activities
- Encouraging of farmer organisations
- Tax reforms to make the rural economy (or to assist less developed localities etc.) more competitive

The issue for an international regulatory framework is to foster liberalisation of trade, while maximising protection of plant, animal and human health, and minimising technical obstacles to trade. Importing countries should develop sanitary requirements that enable them to achieve an ALOP (Appropriate Level of Sanitary Protection) but sanitary requirements and technical standards should not be used to shield domestic producers from foreign competition. Unfortunately, pressure to do so in fish trade is high as other trade barriers (tariffs and quotas) are reduced (4.5% tariffs for fish and fishery products on average). In addition, SPS (Sanitary and Phytosanitary Standards) measures and technical standards are complex, which makes them particularly deceptive and difficult to challenge.

The SPS agreement recognizes the Codex Alimentarius Comission (CAC) and the Organisation Internationale des Epizooties (OIE) as the international standards setting body, respectively for food safety and animal health. The CAC was created in 1962 to implement the Joint FAO/WTO Food Standards Programme. The primary objectives of the CAC work are the protection of the health of consumers, the assurance of fair practices in food trade, and the coordination of the work on food standards. When setting up the ALOPs between exporting and importing countries certain factors need to be taken into consideration. These include establishing standards for sanitary measures and meeting certain concessions in this respect (Fig. 1). Members shall accept other member measures as equivalent if the final results are the same (i.e. if they achieve the same ALOP). Members shall consult to achieve bilateral and multilateral agreements (e.g. Mutual Recognition Agreements).

Scientifically-based methods to develop SPS measures are to be established according to the assessment of risks to humans, animals or plants, using internationally accepted risk assessment techniques and taking into account available scientific evidence. SPS measures should minimize negative trade effects; arbitrary and unjustified measures should not be considered.

In Aquaculture, safety hazards can exist in pre-harvest (e.g. chemical contaminants and biotoxins) or both pre- and post-harvest (e.g. residues and microbiological pollutants). Development of private standards, which is at the center of many debates by the SPS Committee of the WTO because of the trade implications, is the result of:

- A consolidation in the food industry (e.g. processing, retail)
- The Emergence of coalitions (Global food safety initiative GFSI, British retail consortium BRC)
- “Supermarketization”, including in developing countries
- Increasing influence of civil society and consumer advocacy groups over how fish is reared, produced, processed and distributed
- Increasing role of retailers as the last link between suppliers and consumers.
- The use of business to business B2B standards to protect reputations
- In the case of aquaculture, several private have developed (e.g. ACC, EUREP, GAP)

Traceability is currently a chief concern in aquaculture production and associated world markets. Traceability is defined by ISO as the ability to trace the history, application or location of any entity by means of recorded identifications. The EU extends the definition to feed to encompass the ability to trace and follow a food, feed, food-producing animal or substance intended to be or expected to be incorporated into a food or feed, through all stages of production, processing and distribution.

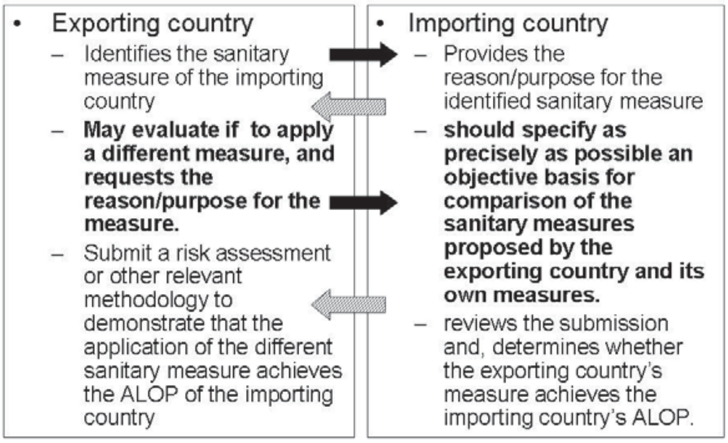

Fig. 1. Considerations when setting up ALOPs between exporting and importing countries.

Traceability is currently a chief concern in aquaculture production and associated world markets. Traceability is defined by ISO as the ability to trace the history, application or location of any entity by means of recorded identifications. The EU extends the definition to feed to encompass the ability to trace and follow a food, feed, food-producing animal or substance intended to be or expected to be incorporated into a food or feed, through all stages of production, processing and distribution.

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Trends, constraints and opportunities for the business sector

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The main considerations for setting up an aquaculture business are water temperatures, culture species, competitors in production and the market and weaknesses and strengths of being located in the Azores. The strategies for a profitable business are to have lower production costs, added value, niche markets, and high value or specialise. The average sea surface temperatures in the Azores are close to the central Mediterranean. The main competitor is Greece with many sheltered sites, having enjoyed EU funding to kick-start the industry and now operating with economy of scale. However, Greek companies have top heavy management, site competition with tourism and slow technological progress. The other main competitor is Turkey which also has sheltered sites, low labour costs and had the advantage of access to wild fry to kick-start the industry. However there is competition for inshore sites with tourism and so are being forced to move further offshore, it is outside EU and far from the main European markets.

The weaknesses of the Azores are that it is remote from Mainland Europe leading to high transport costs for supplies and sales. It has an energetic coastline which needs strong cages. There is a lack of specialised aquaculture workforce. There is a narrow shelf around the coast of suitable depth. There is low local consumption of fish. The strengths of the Azores are that it has clean unpolluted seas, existing fisheries with existing fisheries distribution network. It already has eco certification for fisheries products. It has access to fish waste from the tuna industry. There is possible geothermal energy (boreholes). Although it is remote from Europe this can be an advantage as it is inbuilt bio security. Although it has a narrow shelf, this has the advantage that it has access to deep cooler water.

There are certain strategies that the Azores can take if it is to competitive are to lower production costs. Lessons for this can be learned from the most efficient producer in Europe which is Norway. This can be done by reducing feed wastage and improve FCR by the use of automatic feeders coupled to feedback systems. Labour costs can be reduced by automation using live fish pumps, live fish graders and live fish counters. Production facilities should be standardised such as having one size of cage so all nets fit all cages. There should be a flat company structure with no more than 4 management levels between the owner and the worker. Servicing the cages can be outsourced or centralised. The production units should be large to benefit from economies of scale. The production decisions should be based on science and not always economics. The workforce should be well trained and efficient.

Another strategy for the Azores is to add value to the product and at the same time reduce the volume of product to ship to the market and so reduce transport costs. There is an increasing trend by consumers to purchase filleted fish rather than whole fish. Fillets are only around 35% of whole body weight and have higher value in the market. This can be coupled with vacuum packing or controlled atmosphere packaging that is suited to sales by supermarkets. An additional trend is to purchase convenience foods which are ready to be cooked with no further preparation. A further strategy is to specialise high quality products by accreditation to quality labels which have been developed by supermarkets such as *WallMart* and *Carrefour*. There are other general quality labels such as *Label Rouge*, *Eco-labelling* or organic labels. The Azores should take advantages of its unique location by branding aquaculture production as ocean fresh products and avoid competition with lower cost producers. In 2007, 99% of Mediterranean marine production was still seabass and seabream. There is an opportunity to diversify into new species and pursue niche markets. Examples of species that could be grown are the Meagre (*Argyrosomus regius*) which is available from hatcheries and grows well in and very fast in cages. Other niche markets are for larger fish. In 2007, 86% of seabass and seabream sold at 200 to 600 g size. By growing these fish to a larger size, there is less competition in the market and the fish reach prices closer to wild caught fish.

In summary, the Azores should capitalise on its natural advantages such as:

- The availability of fisheries waste from the tuna industry could be converted into fish meal which can lead to reduced feed costs
- The clean seas around the Azores with no pollution can be a marketing tool
- Eco labelling of aquaculture products can lead to higher market price
- The remoteness of the islands leads to inbuilt biosecurity and the Azores could gain from having disease free status

The requirements for any successful aquaculture business area as follows:

- Good investment climate for potential investors
- Banks knowledgeable about the needs and risks of aquaculture business
- Low or subsidised bank interest rates available from development banks
- Government incentives in the form of small grants to kick-start the industry
- Tax breaks on profits until the business is profitable and tax exemption on imported capital equipment
- Enabling governance in the fast and efficient licensing process and sensible regulations
- Scientific research and development support
- Training especially for technician level
- Entrepreneurial spirit with local businessmen willing to take calculated risk in new industry

Many countries new to aquaculture have benefited from a pioneer or champion in the form of one person or company that is committed to making aquaculture work, who is passionate about the subject, dedicated to make it work and has enough money to see it through.

Taking all this into consideration, it is my recommendation to capitalise on the Advantages of the Azores and develop high value service industries to support the aquaculture industry on mainland Europe by:

- Developing broodstock holding facility and sell eggs to European Industry
- Supply high quality out of season eggs
- Supply specific pathogen free eggs
- Developing a marine hatchery to supply specific pathogen free fry
- Develop a genetic selection program for the selected species and supply eggs and fry of fast growing strains

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Aquaculture project formulation

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The need for planning in the aquaculture sector will vary according to the type of facility. The planning of a fish farm based on few excavated ponds is fairly simple when compared with a more complex setting that occurs when planning a land-based fish farm for indoor production using RAS (Recirculation Aquaculture System) technology. Before deciding to invest you should be conscious of how the industry is governed, the costs implicated in establishing and running a business and the timelines involved. Investment should be a structured process comprising a series of steps, the duration of which can vary according to the size and complexity of the business enterprise. There is a large gap between the farmer, who relies on family labour and the commercial operator, who hires employees and invests capital for production facilities. The access to capital to facilitate growth from self-employment to small businesses is crucial.

THE KEY SUCCESS FACTORS OF THE INDUSTRY

Key success factors of the industry include site selection and tenure, economies of scope and scale, management ability, sufficiency of capital, strategic alliances and market. In our opinion, the success of any fish farm venture results of two basic components: a) appropriate selection and careful husbandry of the stocks; and b) appropriate design of the facilities, inducing favourable stock development and labour saving. An important principle should also be considered: Aquaculture business is not about growing fish. It's about selling fish… at a profit. Otherwise it's a hobby.

STARTING A PROJECT

Before starting any project a pre-decision stage or a first step is required. We tell our students that aquaculture venture means a "strong commitment to a new, high risk activity". Aquaculture represents a permanent challenge (new production techniques, new marketing strategies, etc.). In order to work properly in aquaculture it's essential to have the following attributes: to like to work with "mother nature" (part of the work is done under heavy rain, snow, etc.), to have the ability to perform diversified tasks (communicate effectively with people, understand about pathology, plumbing, informatics, etc.). Important requisites are also: not to be governed by 9 to 5 syndrome (are you willing to work long hard and irregular hours?) and have good sense of humour (e.g. appropriately manage predators; start-up & running-in of the fish farm). In addition, during the pre-decision stage we have to: establish goals (e.g. small operation, full time business, vertically integrated, etc.), make a feasibility study (begin with a checklist: which species to culture, where to locate, any legal constraints, marketing capabilities, and other aspects), and prepare a business plan.

According to numerous authors, the two most important decisions are: site selection and species choice. In site selection it is important to check: the amount and quality of available water; current, depth and bottom conditions; access to electricity, good roads, etc. In species selection: The primary criteria are that the animal should be suited to the local climate extremes, and should be a native species. In our opinion, both decisions (site selection and species choice) are not equivalent due to the following: species choice is the most important criteria, with a weight of approximately 70%, compared to 30% for site selection. How to justify this distribution?

To access relevant target markets is crucial that the aquaculture production have: market acceptability; availability of state-of-the-art technology; and buyers for the size and quantity of product planned. In Portugal, the Top-10 Food Retailers (*Sonae Distribuição*, *Jerónimo Martins*, *ITM/Os Mosqueteiros*, *Auchan*, *Lidl*, *Minipreço*, *Metro*), represent more than 85% of total food retail sales in Portugal in 2007. Figure 1 characterises the selling of fresh fish in Portugal, noticing that 57% occurred in Supermarkets and Hypermarkets. The conclusion is that it is necessary to have quantity in order to operate with such food retailers, which grows at a 6% rate each year.

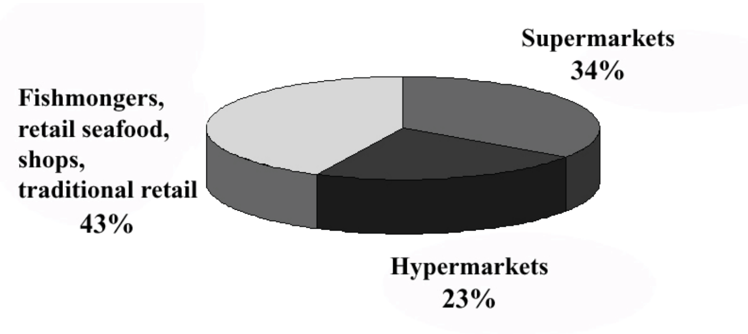

Fig. 1. Locations of the greatest number of fresh fish sales in Portugal (source: *Hipersuper* 2007)

To conclude this subject, our criteria regarding the major characteristics of the "ideal" species for aquaculture in Azores are: large commercial size for filleting (several kg per unit); low production cost, which means low conversion index; good adaptation to handling; high growth rate (use of fast-growers species): short production cycle; and standard flesh quality (white, without bones, no strong flavour).

DEVELOPMENT OF THE PROJECT CONCEPT

The Goals in Facility Planning are to maximize plant efficiency/output, production flexibility, and quality while minimizing production costs, work in process, project costs.

When planning a land-based fish farm for indoor juvenile production the essential components are (Rowland 2005): office, toilet, washroom and meal room; laboratory; general workroom with tanks for holding, sorting, and quarantining; plant room with filters and air-blowers; store rooms for chemicals, feed, equipment; garages for vehicles and boats; workshop for repairing and making equipment; handling and packaging room. Their design and location should be planned so that space, labour and equipment are used efficiently and economically.

A project is a "series of activities aimed at bringing about clearly specified objectives within a defined time-period and with a defined budget". The process of planning and management projects can be drawn as a cycle. Each phase of the project leads to the next, and their check points are carried out through specific milestones. Different project cycles are proposed in bibliography: 6 phases and 17 steps (Insull & Nash 1990), 10 phases (Lekang 2007), 6 steps (Bishop 2001) and 3 steps (Kerzner 2002). The simplest version is: 3 steps or phases (Planification, Execution, Delivering phase and starting operation). We propose the following 6 steps scheme (Fig. 2).

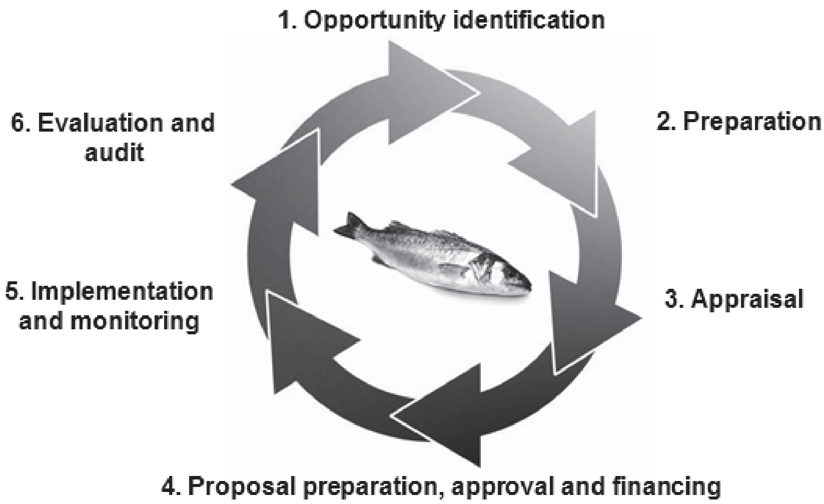

Fig. 2. The Project Cycle

1. Opportunity identification: generation of the initial project idea and preliminary design including first estimation of the size of the different rooms and installations. It is important to notice that two crucial considerations influence hatchery design: energy efficiency, disease epidemic control, etc.

2. Preparation: Detailed design of the project addressing technical and operational aspects. Drawing up alternative solutions (Alternative plans should be developed before choosing the final layout). For example: At the end of the 80's, building a cage farm was three times more economic then to build a pumped ashore unit for the same capacity. Actually due to mainly the utilization conflicts (aquaculture sector *versus* tourism sector) and environmental restrictions, this correlation has changed. According to Dempster (2007), cage fish farm changed: from sheltered bays and fjords to exposed sites; from small to large cages; from wooden cages to rubber, plastic and metal or from a simple structure to a documented construction. Today some proposals mean more then 90 US$ per m^3 (*FarmOcean* - 4000 m^3 (US$ 80/m^3; and SADCO Shelf - 1200 m^3 (US$ + 90/m^3)), with very high risks. Moreover, in the Preparation Phase, the final plant is finished and the detailed plans and drawings are concluded. Detailed design of the water systems and its various structures, adapted to the site topography, and including flow diagrams of the water supply and drainage systems. If the project involves cage farming, it is then necessary to specify the mooring lines after studding: shore line contour; depth profile; exposure to wind; fetch; currents; maximum wave height; and tides.

3. Appraisal: Analysis of the project from technical, financial, economic, social, institutional and environmental perspectives. Projections for the grow-out period must be prepared on a best- and worst-case scenario, and expected basis with enough contingencies to address the downside risks. We have economies and diseconomies of scale. Declining costs result from for example: fixed costs being spread over more and more units. Increasing costs result from for example increased congestion of workers and material, which contributes to: increasing inefficiency, difficulty in scheduling, damaged goods, and other diseconomies

4. Proposal preparation, approval and financing: writing the project proposal, securing approval for implementation, and arranging sources of finance. Regarding legislation, it is important to keep in mind that different rules may be applied to land-based and marine (or offshore) aquaculture, while different restrictions can be applied according to the species and production sites.

Freshwater legislation

- Portaria no. 747 de 16 de Dezembro de 1986
- Decreto-Lei no. 236 de 1 de Agosto de 1998
- Decreto-Lei no. 58/2005, de 29 de Dezembro (water law)
- Lei no. 7/2008 de 15 de Fevereiro
- Decreto-Lei no. 69/2000, de 3 de Maio, changed and republished by Decreto-Lei no. 197/2005, de 8 de Novembro

Seawater legislation

- Decreto-Lei no. 278/87, de 7 de Julho (artigos 2º, alíneas c) e f), 11º e 12º), given by Decreto-Lei no. 383/98, de 27 de Novembro
- Decreto Regulamentar no. 14/2000, de 21 de Setembro
- Decreto-Lei no. 69/2000, de 3 de Maio, alterado e republicado pelo Decreto-Lei no. 197/2005, de 8 de Novembro

6. Implementation and monitoring: The phase concerning construction and procurement begins as soon as the first tender or procurement dossier has been approved. After finishing building the plant or part of the plant, a period of testing is necessary.

7. Evaluation and audit: periodic review of project with feedback for next project cycle, to assess long-term impact and sustainability, learning by reflecting and acting.

In conclusion, in the Project development the first objective is to provide an adequate artificial habitat for the species. Equally important design goals are that the system should be: reliable, fault tolerant, and cost effective. Since so many variables are implicated, planning is not simple to perform and ideally several specialists will be involved. The final design must ensure that the proposed facility will operate in an environmentally sustainable manner and in accordance with the Codes of Practice of the industry.

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Ten years of marine aquaculture development in Madeira archipelago

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The Archipelago of Madeira is situated in the North-Eastern Atlantic, about 600 miles off Casablanca. It has a small but growing economy based on tourism, attracted by the dramatic relief and deep blue seas. In the early 1990's the Regional Government of Madeira decided to evaluate the islands' potential to develop marine aquaculture. Demersal fish stocks were under intensive pressure, leading to an increase of fish product imports. A preliminary study followed FAO criteria to assess biological, social and economical factors of the islands relevant to the development of aquaculture. The report presented by Andrade & Hughes (1990) was the groundwork of the following planning initiatives, leading to the development of several aquaculture enterprises in the last ten years.

PLANNING AND EVALUATION STAGES

Recommendations set out in the preliminary study were used to draw up a four step strategy:

Evaluation stage. The study and subsequent workshops (Andrade 1995) selected offshore fish farming as the most appropriate culture system for Madeira. Complementary actions were recommended such as, to include aquaculture into the regional development plans, chiefly the integration of aquaculture into Coastal Zone Management, the allocation of financial support through EU programmes, the establishment of environmental monitoring and data collection programmes (Memorandum 1995).

Market study. A study by Stirling Aquatic Resources (1996) determined the viability of locally cultured fish such as seabream (*Sparus aurata*), based on the acceptability by the local market, existing dealers willing to pay for quality and potential to export to mainland Portugal.

Implementation of a Pilot project. The first offshore fish farm installed in Portugal, in November 1996, was an initiative of the Madeira Fisheries Department, in order to demonstrate the technical and commercial feasibility of the operation in the open and deep seas south of the island (Andrade 1995; Scott 1995). The two types of cages under trial, triple plastic collars and semi-submersible maritime steel from *Farmocean*, proved to withstand the most severe physical conditions of Madeira seas. All sales were made to local dealers.

Installation of support facilities. The success of the previous stages prompted the need to implement support facilities. The Madeira Fisheries Department installed the Centro de Maricultura da Calheta (CMC), with extensive services to farmers and including hatchery and research facilities to evaluate the culture potential of local species.

The offshore pilot project of Bay of Abra was a success both in terms of production and sales of gilthead seabream (*Sparus aurata*). The project gave an opportunity for training of local people and to establish links with suppliers locally or abroad. Also, the sales and marketing demonstrated the assumptions initially made by market studies and encouraged the private sector to advance the establishment of new ventures.

By 1998 another fish farm with a production output of 90 tonnes per year was installed in the North of the island. This facility used concrete tanks aimed at producing *S. aurata* for the local market. Since then, this farm has diverted its purpose to pre-fattening fish up to 30 grams, to be sold to local farmers. With the privatisation of the pilot project in 2004 two other offshore fish farms using plastic cages have been installed, again in the South of Madeira: a) a private enterprise with 6 cages and 210 metric tonnes production capacity per year; b) a government pilot project near CMC, using 4 cages with 80 metric tonnes capacity per year, aimed at testing "new" species. Presently, the total annual output capacity of the marine fish farms of Madeira is approximately 790 metric tonnes. Though, according to farmers' estimates the 2008 production will be about 500 metric tonnes of gilthead seabream.

MOST COMMON CONSTRAINTS

The most common constraints to fish farming in Madeira are typical of small island industries far from the continent. The business is based on the purchase/importation of production supplies (fingerlings, feeds, chemicals) and sales of end product (fish or fish products). Local fish farmers face this additional cost and problems whenever any transport disruption occurs, such as with bad weather conditions or sea storms; the latter may affect farming operations (no food no fish growth; no harvest no sale), damage cages and nets, or through loss of fish. Two other common logistical constraints are the lack local services (cranes, repairs, etc.) and space for land bases near service piers. Both have high costs, as expected.

NEW CHALLENGES FOR NEW STAKEHOLDERS

Some of the local industry bottlenecks previously mentioned had positive institutional responses. The POSEI Programme (EU) for ultra-peripheral regions is an incentive to export aquaculture products and present them at competitive prices in mainland Europe. Industrial parks made space and services more available. Extensive government services and R&D are in support of farmers. The next step for government intervention, currently under evaluation, is the establishment of Marine Aquaculture Zoning in Madeira to avoid conflict with other marine water users.

In conclusion, the establishment of private fish farming companies in Madeira followed the Regional Government strategy and measures to initiate new industry. Innovation and quality are nowadays regarded as keywords for competitiveness and business sustainability. It is now up to these new stakeholders to promote and develop offshore fish farming in Madeira as a thriving industry.

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Aquaculture in the Canary Islands

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Domínguez, L.M. 2008. Aquaculture in the Canary Islands. Pp. 33-34 in: Pham, C.K., R.M. Higgins, M. De Girolamo & E. Isidro (Eds). Proceedings of the International Workshop: Developing a Sustainable Aquaculture Industry in the Azores. *Arquipélago*. Life and Marine Sciences. Supplement 7: xiii + 81 pp.

Although aquaculture is an old activity (e.g. carp culture, 3.500 A.C.; Tilapia in Egypt 2.500 A.C.; some molluscs and marine fish in Greece and Rome in 500 A.C), its development as business activity is almost new, due to different reasons such as the extended idea about the never ending limit of fisheries, the aquatic environment difficulty and the complicate reproduction and culture of aquatic organisms in captivity. The aquaculture sector changed approximately from one million tons in the last century 50's to more than 64 millions tons in 2007. Between other systems of food production, aquaculture represents the biggest increase (9% annually) producing almost the 50% of global consumed aquatic products. Annual per capita consumption of aquatic products averages around 21 Kg. Both FAO and World Health Organisation recommend a 30% increase of this figure, reaching 25 Kg per person and year. Even though this raise might not be achieved, the growth of the world population, estimated to reach 12 billions in 2054, will generate an increasing demand. It seems evident that this growing demand for aquatic products could not be satisfied by a corresponding increase in fisheries landings (due to the overexploitation of the majority of fisheries) resulting in a foreseeable expansion of aquaculture.

Aquaculture in Spain represents a consolidated sector. Spain is amongst the 20 first producers in world aquaculture, and the third world producer of seabream and seabass after Greece and Turkey. Mussel production is mainly located in Galicia, a region in the northeast of Spain, where molluscs are produced within natural environment, using drafts as facilities. Spain also represents the 3rd producer of molluscs in general, including clams, scallops and oysters. Turbot, oyster and salmon production is increasing slowly face to seabass and specially seabream. Spain produces about 15% of the european seabream and seabass. Considering the Spanish regions, Canary Islands produce about 28% of Spanish seabream and seabass, almost as much as Valencia (29%).

Fish production in Canary Islands increased very quickly reaching in only 7 years, 15000 Tons. The reasons for this increased relate to different factors. Seawater characteristics (yearly constant photoperiod and temperature, clean oceanic waters), fisheries and market access, infrastructures, and the close relationship between farmers and researchers. The fast increases in aquaculture in Canary Islands face different limiting factors determining its evolution. Some examples include the same challenges related with European aquaculture, such as the dependence on fisheries for fishfeed production and the need of species diversification.

Despite the increase of aquaculture production, its use of fishmeal has not changed from the 90's due to a better conversion and/or its substitution by other ingredients Despite these data the aquafeed production continues to be depending on fish oil and fishmeal production. This highlights the need to reduce reliance on these products and to improve the efficiency of its use. Considerable research about partial substitutions of these products by vegetables ones is currently underway in many producing countries. Regarding species diversification, considerable research is also underway in different countries, and the number of cultured species commercially available is increasing continuously. Other limiting factors for aquaculture in Canary Islands are specific and related with geographical situation of the islands and its economy, as the dependence of fry and fishfeed imports and the coastline sharing, especially in reliance of tourist sector. The first challenge faced by the enterprises initiatives in the Islands, is the integration of a new activity with other well developed sectors. The answer is not easy, and perhaps not only one: a better integration of aquaculture within local economy, sea cages far away from coastline, promotion of this sector as strategic for the islands economy and of course, the support of the wide use of environmentally friend practices by farmers

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Sustainable aquaculture in island environments of the Pacific

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In 2005, from capture fisheries and aquaculture combined, the total global supply of fish, crustaceans, molluscs, and other aquatic animals reached 141.6 million tons (source: FAO 2007). Aquaculture contributed to 33.8% of the total worldwide seafood supply or 44.9% of seafood consumed by human beings. Given the stagnant growth of capture fisheries during the past decade, the continued growth of aquaculture production was the key contributor to the maintenance of a constant per capita seafood supply during the same period. With the ever-increasing world population, aquaculture production must be increased to meet demand.

Island countries surrounded by water have great potential in aquaculture development. Indonesia and Japan, as island countries, were among the top 10 aquaculture producing nations in 2005. On the other hand, many island countries produce only negligible amounts of seafood. Each island environment has a unique range of natural resources; therefore, the potential for aquaculture development varies among island environments. This report presents the experience of the Centre for Tropical and Subtropical Aquaculture (CTSA), one of five Regional Aquaculture Centres funded by the U.S. Department of Agriculture, in developing aquaculture in Hawaii and the U.S.-affiliated Pacific Islands. The U.S.-affiliated Pacific Islands (U.S.A.PI) include American Samoa, the Republic of the Marshall Islands (RMI), the Federated States of Micronesia (FSM), the Commonwealth of the Northern Mariana Islands (CNMI), Guam, and the Republic of Palau (Palau). This region, composed of thousands of tiny islands widely spread between the latitudes of 15º N to 14º S and the longitudes of 134º E to 170º W, extends across an area as large as the continental United States. For aquaculture development, this region enjoys superior natural resources, such as pristine water, year-round warm weather, and abundant fisheries in surrounding waters. Yet opportunities for aquaculture development in this region have yet to be fully realised.

The status of aquaculture activities is different between Hawaii and the U.S.A.PI. Excluding Hawaii, the land mass for each island group is less than 549 km^2 and the region's total land area is only 2,558 km^2. Despite their small size, the U.S.A.PI are complicated. The political status of these islands includes three independent countries and three U.S. territories. Also, these islands can be divided into three main physiographical types: high volcanic islands, raised limestone islands, and low coral atolls. Constraints of aquaculture development - including land area, natural hazards, knowledge base, capital, markets, transportation systems, and legal systems - have to be overcome in order to sustain aquaculture practices. CTSA has been assisting farming technology development for the past 20 years, with a focus in the U.S.-affiliated Pacific Islands on giant clams (*Tridacna gigas, T. crocea, T. maxima, T. squamosa, T. deresa*, and *Hippopus hippopus*), bath sponge (*Coscinoderma mathewsi*), tropical ornamental fish, hard and soft coral, and black pearl oysters (*Pinctada margaritifera*). None of these farming efforts have yet to make a significant contribution to the local economies of these island groups. The challenges and opportunities for developing aquaculture industry in the U.S.-affiliated Pacific Islands will be presented in my talk. Technology alone cannot assist development, and input from political and socioeconomic studies is critical.

Aquaculture has been practiced in Hawaii for more than 1,000 years. Commercial production and research and technology transfer are the two major sectors in Hawaii's aquaculture industry. The industry's total value was estimated at $39.7 million in 2003. More than 30 different species of plants and animals are raised in Hawaii, mainly seaweed (Gracilaria), spirulina, marine shrimp, freshwater prawns, and freshwater and marine finfish species. Taking advantage of singular environmental conditions, Hawaii has become the global centre for specific pathogen-free white (SPF) shrimp (*Litopenaeus vann*amei) and home to the first offshore cage culture of Pacific threadfin (*Polydactylus sexfilis*) in the U.S. The current status of SPF shrimp culture and offshore culture ventures in Hawaii will be presented in this talk. SPF and offshore culture are important advancements, but how do they affect the sustainability of aquaculture? The concept of "ahupua`a," or the ecosystem-based management practiced by ancient Hawaiians, may be a good way to protect this region's fragile environment.

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From zero to a multi-million euro industry - 20 years of aquaculture experiences in an exposed island state: Malta

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Despite the fact that the culture of aquatic species in the Mediterranean Sea has a very long history particularly in the estuarine areas such as the Nile delta (Eastern Mediterranean Sea) and the Po delta (Adriatic Sea) it was, until recently, a largely unknown industry in the majority of the Mediterranean countries. Despite the declining wild fish catches and consequential rising fish prices, the lack of suitable environments and commercially viable technology discouraged investors. During the late 70's and throughout the 80's hatchery techniques for the production of European seabass and gilt head seabream juveniles were commercialised, and a number of cage fattening farms started to appear.

CONSTRAINTS

The availability of fingerlings in commercial quantities led to rapid developments of fattening systems mainly land based systems and low energy site cage units. In a small island like Malta with virtually no low energy sites and with enormous pressure from urban development and other competitive users such as tourism, commercial shipping and pleasure craft it was imperative that aquaculture be developed directly in high energy, open water sites. This entailed pioneering approaches not only in terms of appropriate cage and ancillary structure technology but also in terms of adaptability of fish species and farm management strategies for such harsher environments.

THE NATIONAL AQUACULTURE CENTRE

Aquaculture developments started with the establishment of the National Aquaculture Centre by The Ministry of Agriculture and Fisheries in 1988. The primary role of the Centre was to assist with the development of a commercial aquaculture industry. Within this framework, one hatchery and experimental cage facilities were established. Concurrently training, conference, library and laboratory facilities were also established. The Centre also collaborated with other Government departments and other Institutions such as banks and regulatory bodies to establish a legal, financial and environmental planning framework for commercial aquaculture developments.

REGULATORY FRAMEWORK

Planning Policy and Design Guidelines for regulating aquaculture developments were incorporated into the National Structure Plan published by the Planning Authority. These included guidelines on production limits, technology to be adopted, application procedures including EIA's, environmental monitoring and other relevant criteria.

SEABREAM AND SEA BASS PRODUCTION

The first commercial farm was established in 1991 with a production capacity of around 1000 tonnes of seabass and seabream. Between 1992 and 1994, three more offshore farms had been established with a production capacity of 500 tonnes each. The production was almost exclusively destined for the Italian market. Malta's proximity to Italy and the relatively reliable supply in fairly large quantities being guaranteed attracted the interest of the main Italian importers. However the 15% tax imposed on fish of non-EU origin began to have its toll as prices started to decline in the wake of increasing competition from Greece, Turkey and other producing countries. The industry started to go into decline and was on the verge of collapsing by the late nineties.

TUNA FARMING

With Malta's strategic position in the migratory route of bluefin tuna and by following developments in tuna farming in Australia, Spain etc., operators were quick to take the opportunity to diversify into bluefin tuna farming. Between 1999 and 2002, three of the four operating offshore sites had switched to tuna farming and one new company had started operating giving a total of four tuna farms with a production capacity of around 4,000 tonnes per annum. Since then the Fisheries Department has established a new aquaculture zone some 6 kilometres offshore wherein two other operators have been operating for the last two to three years. At present Malta is producing around 7.000 tonnes of bluefin tuna and around 2,000 tonnes of sea bass and seabream with an ex-farm value in excess of 100 million Euros.

TECHNOLOGY

Over the past twenty years, considerable innovative technologies have been employed in Malta in an attempt to optimise cost effectiveness and performance under such highly exposed conditions. In the early years, rubber cages (*Dunlop*) and steel cages (*Farmocean*) were employed but with the advent of reliable plastic cages, all rubber and steel cages have been phased out and High Density Polyethylene (HDPE) is now exclusively the material of choice due to its versatility, strength, low maintenance and cheaper cost. British suppliers *Fusion Marine Ltd* are the main players in the Maltese offshore cage aquaculture industry.

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Aquaculture development in Cyprus

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Cyprus is the third largest island in the Mediterranean Sea, with an area of 9251 km² and an almost totally exposed coastline of 650 km long. It is situated in the Eastern Mediterranean sea (Levantine Basine). The island has no natural freshwater bodies and there are no perennial rivers except from small streams in the mountain range of Troodos. Draughts which are not uncommon affect significantly the availability of freshwater.

Aquaculture in Cyprus started in 1969, with the development of trout farming in the Troodos mountain range. The first marine aquaculture attempts were made in 1972, when the construction of a Marine Research Station was initiated by the DFMR at Gastria, situated on the east coast of Cyprus. In 1974 the government lost access to the Station, because of the Turkish invasion. Research work in marine aquaculture continued, from 1978-1989, in auxiliary facilities of the DFMR, and a new Experimental Marine Aquaculture Station at Meneou, near the Larnaca airport, was built by the DFMR in 1989. The first private commercial marine fish hatchery started production in 1986 while the first marine fish fattening unit, which was land based, started operations in 1988. In early 1990's the government reconsidered its policy for land based marine aquaculture, taking into consideration the high price of coastal land, its extensive exploitation by various users (mainly the tourist industry) and the environmental considerations. The outcome of this was to promote offshore cage culture technology. Cyprus became one of the first Mediterranean countries to carry out the commercial culture of seabass and seabream in offshore cages. The first commercial offshore cage farm was established in Cyprus in 1989-1990 for the production of seabream and seabass and by 1997 a total of eight open sea cage farms were in operation on the south coast of the island.

Cyprus aquaculture mainly refers to marine aquaculture, which also has the biggest prospects for growth. The farms are located in open sea, exposed mainly to south, western and eastern winds. The existing prevailing coastal currents in these areas have an average speed of 0.2 m/sec at mid water depth. Aquaculture sites are exposed to long wind fetch distances, as the nearest land to the south is Egypt. During winter waves of 3-4 m height are not uncommon. In very exceptional cases, during storms, waves of 8-9 m have been experienced which caused damages to cages and fish losses. Salinity of the waters around Cyprus is 39 ppm and surface water temperature ranges between 15-30 ^{0}C during the year. The thermocline is established during summer months usually at about 18-20 m .Generally the water is clean, without serious pollution problems and no serious fouling problems are experienced on the cage nets.

Farm technology involves round floating cages in a grid system. These are comprised of 2-3 high density polyethylene pipes, ranging from 15 to 50 m diameter, and a net depth usually 8-25 m. Generally the diameter of the cages increased over the years. Many cage types, including *Farm Ocean*, *Sea Station* sinking type, *Flexfloats*, *Dunlop* etc., have been tried. The farms are gradually employing mechanised systems for feeding and harvesting in an effort to cut down production costs and become more efficient and competitive, at national and international level.

The main advantages of the aquaculture sector in Cyprus are the: (a) application of the offshore cage culture technology, (b) very favourable environmental conditions (clean sea, high temperatures), (c) absence of serious fish diseases, (d) existence of entrepreneurship and strong interest for investments, (e) existence of know-how and human capital and (f) existence of relevant infrastructure and legal framework. In 2007, the total aquaculture production (marine and fresh water) reached approximately 3260 tons of market size fish and 15 million marine fish fry valued at € 31 million (Fig. 1).

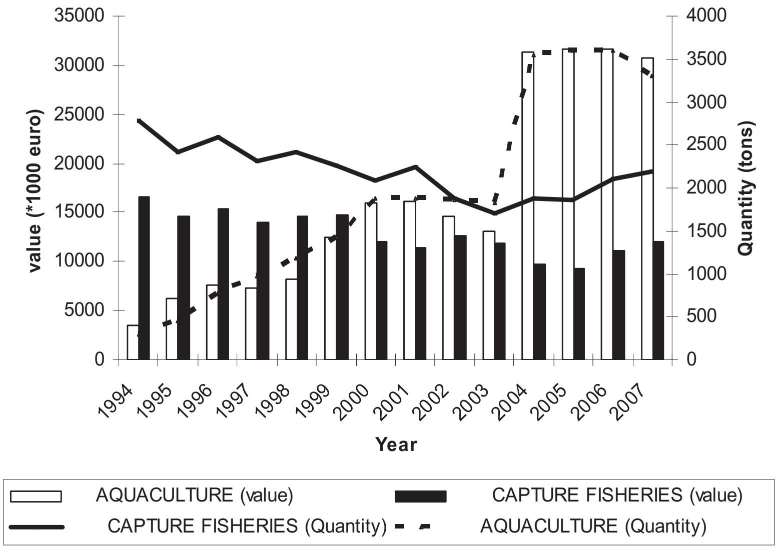

Fig. 1. Aquaculture versus fisheries production in terms of quantity and value.

Aquaculture production of market size fish, cultured in open sea cages, reached 2200 tons of sea bass and sea bream and 1000 tons of blue fin tuna. The total production of market size trout from the private sector reached 60 tons valued at € 410.000. Additionally 150.000 ornamental fish were produced by the private sector valued at € 250.000. The total production of marine hatcheries reached 15 million fry, mainly sea bass and sea bream valued at € 2.6 million. Approximately 50% of the seabass/seabream production and 100% of the Tuna production is exported mainly to non EU countries.

In 2007, three marine fish hatcheries and one shrimp hatchery/farm on land were in operation, as well as six private offshore cage farms culturing mainly sea bass and sea bream and three offshore cage farms culturing/ fattening blue fin tuna. Additionally, six small trout farms, culturing mainly rainbow trout and two farms culturing ornamental fish were also active. Other marine species that are currently cultured in small quantities or are cultured on an experimental basis are the rabbit fish (*S. rivulatus*), common pandora (*P. erythrinus*), common dentex (*D. dentex*), amberjack (*S. dumerili*), the drums (*U. cirrosa* and *A. regious)*, and octopus (*O. vulgaris*). Regarding freshwater aquaculture, the culture of sturgeons and European perch is also under evaluation.

Cyprus aquaculture production is small, when compared to that of other Mediterranean EU producer countries, nevertheless it is considered important for the economy of the island. Aquaculture accounts, in terms of volume and value around 70% of the total fisheries production. At the same time, it constitutes an important part of the consumption of fish and fisheries products, with an annual per capita consumption of 2,5 kg per person, out of the 18 kg per person that are annually consumed. The total direct employment in the aquaculture sector in 2007 was 260 persons with the majority employed in marine aquaculture operations. It is estimated that marine aquaculture has created more than 200 employment positions in ancillary professions. Marine aquaculture employs specialised scientific staff that has completed relevant studies in tertiary educational institutions as well as technical personnel of various specialties. Trout farms employ a small number of individuals with empirical technical knowledge and usually operate as small family businesses. Despite of this, trout farming creates employment opportunities in the mountainous areas and thus contributes to the creation of economic activities and the encouragement of residents to stay in these isolated rural regions.

Aquaculture in Cyprus is supported by the Ministry of Agriculture, Natural Resources and Environment, through the DFMR. The DFMR has a Division for Aquaculture dealing with Aquaculture Management and Development, Aquaculture Research and a section for the Implementation and Management of the EU Fisheries Funds. The Aquaculture Division of DFMR is operating two research stations, the Meneou Marine Aquaculture Research Station (MEMARS) and the Fresh Water Aquaculture Research Station at Kalopanayiotis. The main focus of research deals with diversification. Furthermore the research stations provide technical and scientific support to the industry. The main objective of the government policy concerning aquaculture is the sustainable development of aquaculture taking into consideration the protection of the marine environment by applying the precautionary approach and the gradual development of the sector. As far as marine aquaculture is concerned, which represents 95% of the sector, off shore cage culture methods are used which are considered as techniques that substantially reduce environmental impacts.

Within the framework of the Government policy and the EU Common Fisheries for promoting the development of aquaculture, Cyprus has included in the Programming Documents that are co-funded by the EU aid schemes for the development of Aquaculture. This involves the co funding at a rate of 40% of productive investments in aquaculture as well as investments regarding processing and marketing of fisheries and aquaculture products and a premium for aqua-environmental measures such as organic aquaculture. Priority has being given for the expansion of marine fish farms with the objective of achieving "economies of scale". This implies that that a large part of the production will be exported, since it is generally accepted that the small Cypriot market cannot absorb all the production.

The environmental issues and aspects are an integral part of the government policy concerning aquaculture from the early development stages of the sector. Cyprus being an island considers the protection of the marine environment and the aquatic resources of outmost importance. According to the relevant legislation, the measures implemented to integrate the environmental aspects are: a) establishment of an Aquaculture Advisory Committee b) for the establishment of new marine farms all stakeholders views to be taken into consideration, c) for the establishment, expansion, and diversification of farming units an operating license is given that requires first that the applicant brings forward all other necessary licenses such as an environmental permit, town planning permit (except for projects undertaken in the sea), Permit for water usage (freshwater), Permit for effluent discharge, Permit for the use of sea area, d) Offshore cage culture farms are obliged to perform twice a year an environmental monitoring program.

In conclusion, the main issues that need to be addressed by the aquaculture sector (public and private) involve a) the sustainable development of aquatic resources recognising the right of usage to this resources to aquaculture, b) the improvement of monitoring of the environment, c) food safety awareness and improvement of the public perception towards aquaculture, coastal zone management and establishment of aquaculture zones.

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Review of oceanic production systems

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There are a wide variety of aquaculture systems available for use in the ocean. To a large extent, system choice will depend on the species being cultured and the characteristics of the aquaculture site. This review tries to describe the most common systems available for fish and shellfish, for both inshore and offshore locations. Information about these systems' operation is included.

FINFISH PRODUCTION SYSTEMS

Virtually all oceanic fish production occurs in net pens; sometimes referred to as sea cages. The system is simply an enclosure of netting held open by a rigid frame that is either circular or square. The frame also functions in floating the net pen, and serves as a platform for the workers. Frame materials may be steel tubing, rubber, or high-density polyethylene pipe filled with expanded foam, and welded together. Netting material is nylon, or less commonly *Dyneema*® (a very strong, but more expensive polyethylene fibre). Netting is typically treated with an anti-fouling coating. The upper part of the netting is attached to the frame, and weights attached to the bottom of the netting pull the bottom below the surface, and keep the netting walls taut. Anti-predator nets cover the top of the net pen to keep out birds, and are sometimes used on the submerged part of the net pen to deter marine mammals and sharks. Net pens are typically deployed in multiple units, often attached to a shared grid of mooring lines and anchors. Size of net pens is quite variable, ranging from as small as 100 m^3 on small artisanal farms, to ~10,000 m^3 on typical salmon farms. The largest net pens (>100,000 m^3) are used for tuna in the Mediterranean and southern Australia. Common net pen accessories include underwater lights (to prevent early maturity), underwater surveillance systems to observe the fish, and mortality removal systems.

Inshore net pen systems – The net pens are as described above. They are always deployed at the surface, and are typically placed in protected, or semi-protected, tidal coves or bays that are 10-20 m deep. They are not designed to operate in sea conditions where wave height exceeds ~1m. Examples include the majority of net pens used for seabass and seabream in the Mediterranean, and Atlantic salmon pens in northern Europe, Chile, the United States and Canada.

Offshore net pen systems – These systems are designed to function in exposed, highly energetic locations, where wave heights can exceed 10 m. There are three fundamentally different types of offshore net pens. One type relies on its large size and flexibility to be 'transparent' to the waves, i.e. it flexes with the waves rather than resisting the extreme forces.

The second type is semi-submersible, where most of the net pen is submerged, leaving only a small part exposed to the surface conditions. The third type is submersible. These are deployed below the surface to avoid the high energy and waves, and are fully enclosed to contain the fish. Sub-surface feeding capabilities and video systems to observe the fish are essential. All submersible cages can be raised and lowered, with varying degrees of ease, with built-in pneumatic systems.

The establishment and operation of farms utilising net pens is complex. It begins with site selection and obtaining permits from federal and/or local governments. The system (anchoring grid and net pens) is then installed, often requiring large vessels. Juveniles are obtained, either from hatcheries (hatchery-based production, e.g. seabass and seabream) or from the wild (capture-based production, e.g. tuna), and stocked into the net pens. Specialised vessels ('well boats') are typically used to stock the fish. These same vessels are used to transport feed to the site, and to move the fish from the farm to the processing plants at harvesting. Fish must be fed daily, and there are a variety of feeding systems, ranging from simple hand feeding to large computer controlled feed barges capable of feeding all the net pens on the farm. Observation of the fish, particularly for feeding, is done with video cameras. Netting must be cleaned periodically to remove "biofouling" organisms. This is done either by changing nets, or by SCUBA divers using specialised equipment. Finally, it is essential to have an environmental monitoring program to ensure that the farm is not having any negative environmental impact.

SHELLFISH PRODUCTION SYSTEMS

A wide variety of oceanic systems are available for culturing shellfish. The simplest is bottom culture, where juvenile shellfish, sourced from either a hatchery or the wild, are spread in a relatively shallow (<10 m), leased area containing optimal growing conditions (substrate, temperature, etc.). The small shellfish may be covered with netting to reduce predation as they grow. No feeding is necessary because shellfish obtain their food by filtering it from the water. Once they reach marketable size, they are harvested, typically with a dredge. Examples of this include oyster, clam and blue mussel culture in the U.S. More typically, shellfish are grown in the water column to avoid benthic predators.

Some species are grown in suspended netting or wire enclosures. Good examples include scallops, grown in 'lantern' or 'pearl' nets, oysters grown in plastic mesh bags suspended on inter-tidal racks, and pearl oysters, grown in suspended wire cages.

A third system is 'raft culture' where multiple lines, to which the shellfish are attached, are suspended from a surface raft. The shellfish filter food from the surrounding water, and are harvested simply by pulling up the lines when they have reached market size. Bottom culture, and the use of small enclosures, is only practical in relatively protected, inshore water.

The fourth system is the longline system, which is essentially a long (>100 m) rope, anchored at each end and suspended horizontally by a series of floats, from which smaller lines ('droppers') are suspended vertically. The shellfish are attached to the smaller vertical lines, which are typically ~5 m long. Blue mussels (*Mytilus edulis*), Mediterranean mussels (*Mytilus* *galloprovincialis*), and New Zealand green shell mussels (*Perna canaliculus*) are commonly cultured using longline systems. Juvenile mussels ('seed') are typically collected through natural settlement onto smaller ropes deployed for this purpose. These are then harvested, sorted by size, and attached to the longline droppers using a variety of techniques, all of which involve lengths of biodegradable, tubular mesh that hold the mussels in place until they attach with their byssal threads. It is necessary to add floatation to the longline over time to compensate for the increased weight of the growing mussels. Horizontal pegs or disks are sometimes used in the droppers to prevent the mussels from falling off. Longline systems can be deployed at the surface in relatively protected, inshore waters, or suspended below the surface in offshore locations.

The establishment and operation of shellfish farms is somewhat less complex. As with finfish farms, site selection and permitting are the first steps. The systems (rafts or longlines) are then installed. The only part of the installation that requires large vessels is placing the anchors. As noted, no feeding is necessary, so maintenance is limited to checking the integrity of the system, and adding floatation as necessary. Harvesting is more complex because the shellfish are clumped together, either by their own byssal threads (mussels) and/or by fouling organisms. Thus there are typically a series of steps in the harvesting process that involve de-clumping, de-byssing, size grading, cleaning and packaging. Specialised equipment is available for all of these functions.

Integrated Multi-trophic Production Systems

These are systems in which the by-products (e.g. nitrogenous wastes, particulate matter) from one species (e.g. fish) become inputs (fertiliser, food) for a second and/or third species in the system. An example is the combined production of fish, seaweed (which extracts inorganic compounds produced by the fish), and shellfish (which extract organic particles). Such integrated systems can minimize environmental impacts, diversify production, and lead to more socially acceptable aquaculture operations.

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Land-based cultures: a case study applied to Chilean Aquaculture

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Growth of Aquaculture in Chile has increased exponentially over the past few decades, reaching an annual production over 800 thousand tonnes. Salmonids represent the most important group in production terms (over 600 thousand tons), together with various species of molluscs (over 100 thousand tons) and algae (around 15 thousand ton). Production is undertaken principally in suspended systems (rafts and long-lines) in the wave-protected zones of southern Chile. Nevertheless, the hatchery stage of salmon and some invertebrates, in addition to the entire life cycle of introduced species of fish and molluscs, are carried out in land-based cultures. Land-based cultures must resolve the following water-related requirements: supply, transport, flow, accumulation and quality, as well as maintaining an energy supply for the pumps that provide the water. Furthermore, environmental and hygiene measures must be implemented, such as those related to the use of feed. An example of land-based culture in Chile is the semi-industrial culture of octopus, both in the fattening and hatchery phases.

There are 20 species of octopus registered in Chile, although only two form part of national fisheries activities, the northern octopus, *Octopus mimus* Gould and the southern octopus, *Enteroctopus megalocyathus* Gould. The "baby octopus" *Robsonella fontanianus*, is caught on the Argentinian coast. At present, semi-industrial and pilot cultures of *Enteroctopus megalocyathus* and *Robsonella fontanianus* D'Orbigny are currently being developed, financed by the State, university and private companies. In the case of *Enteroctopus megalocyathus*, cultures are mainly directed towards optimising the on-growing processes, while in *Robsonella fontanianus*, towards both the on-growing stage and production of juveniles.

On-growing of the "southern octopus" is undertaken using juveniles caught in traps placed in the natural environment (polythene cylinders), placed, in line, between 10 and 20 m depth. In the culture centre the animals are separated according to sex and size, and marked with a chip in order to monitor their growth. Culture is undertaken in semicircular tanks with a 2500 l capacity, that include artificial den (PVC tubes), stacked in three layers at the edge of the tank. Culture density is approximately 5 Kg/m^2.Feeding comprises defrosted fish and live crab, offered every two days in a proportion of 5 to 10% of the tank biomass. The waste and food remains are removed the day after feeding. The water supply necessary for the tanks is provided by a pumping system installed on a floating platform, that includes two 20 hp and one 15 hp electro-pumps, fed with a land-based electricity supply and a back-up petrol generator, as an auxiliary energy supply. The water is accumulated in a concrete 18 m^3 tank. This accumulator has an alarm system as a warning measure in the event of failures in the pumping system. The water is treated in two 50 micron sand filters, and then transported by force of gravity through a network of PVC hydraulic pipes of 110 to 40 mm diameter, thus supplying the tanks with a continuous flow of water between 40 a 70 l/min. The used water is channelled away from the tank by a series of concrete ducts, to a settling tank where the solid material is deposited, and subsequently returned to the environment.

The “southern octopus” reaches a maximum weight of 4 kg. Cultures of this species are currently being carried out on a semi-industrial scale to evaluate the effect of food on the growth of juveniles and adults. Consumption of crustaceans ensures high juvenile growth rates with a relative growth of up to 2% over 4 months, in specimens of between 200 and 600 grams. Specimens between 1 and 2 Kg can be produced in tanks over a period of one year. Mortality varies between 7.1% on a diet of crustaceans and 75% on a diet of mussels. Feeding with mussels does not permit on-growth of specimens. Nevertheless, freshly discarded fish parts can also be used as feed for juveniles and adults. Culture potential for this species is high given that growth is rapid, similar to the majority of cephalopods. Furthermore, unlike other species of octopus, juveniles tolerate culture conditions adequately. Efficient production technology in circular tanks is available for culture of this species of octopus (Fig. 1).

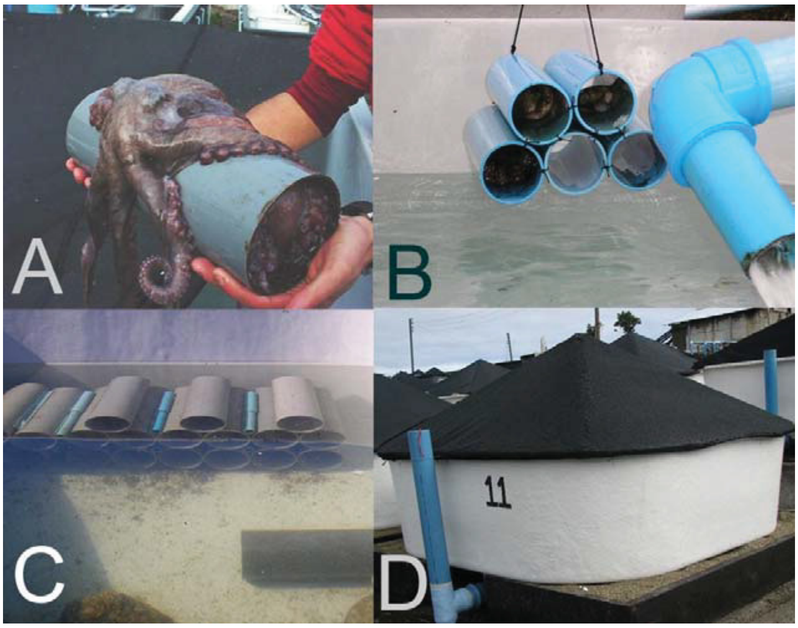

Fig. 1. Octopus in land-culture. A) and B) *Enteroctopus megalocyathus* in artificial dens; C) and D) tanks used for land-based cultures.

The "baby octopus" (*Robsonella fontanianus*) is a smaller species, reaching a maximum size of 69 mm in females and 68.8 mm in males. In Argentina, it is gutted and consumed whole with a 70 to 80% yield, and is processed as both a frozen and canned product. Knowledge of the biological aspects of this species is scarce. However, it has been successfully reproduced in land culture-systems and progress has been made with regard to the natural feeding of larvae and artificial feeding of juveniles, obtaining good yields. In addition to being a gourmet product, the facility with which reproduction can be achieved in this species could serve as a model for further reproduction studies on an industrial scale in other species. In order to avoid environmental variations in salinity and temperature, both juveniles and breeders are maintained in a closed circuit culture system (shell biofilter). The system consists of 60 litre culture tanks; the used water is transferred to an accumulator tank and subsequently pumped with a submergible pump towards the biofilter (aerobic, anaerobic biofilter), where the ammonia oxidizes to nitrate. This is then denitrified and finally the free nitrogen is eliminated. As an end product, the water, free of toxic products, is ready to be reused, adding 5% water to the total volume of the system. This system ensures 24 daily water renewals per tank, with a water flow of 1.6 l/min. Feeding, waste removal and water treatment systems are similar to those used in the *Enteroctopus megalocyathus* culture tanks.

Inland culture is a valuable alternative for intensive culture of endemic species. The diversification of Chilean Aquaculture depends of in land-cultures development.

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High-rate, zero-discharge aquaculture in the partitioned aquaculture system

MICHAEL MASSINGILL & DAVID E. BRUNE

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Twenty years of research has gone into the development of Clemson's Partitioned Aquaculture System (PAS, US-patent, 2002). Five years of field operation with 1/3 and 2 acre PAS prototypes has demonstrated a catfish and tilapia production capacity of 15,000-18,000 lb/acre, as compared to conventional aquaculture pond production of 4000-5000 lb/acre. Furthermore, this production has been demonstrated with limited or zero discharge of water or pollutants to public waters. The basic concept of the PAS is to partition pond fish culture into distinct physical/chemical/biological processes linked together by a homogenous water velocity field. This physical separation of the fish culture process from algal production and water purification allows separate optimisation of these processes and thus, maximizes overall system performance and productivity.

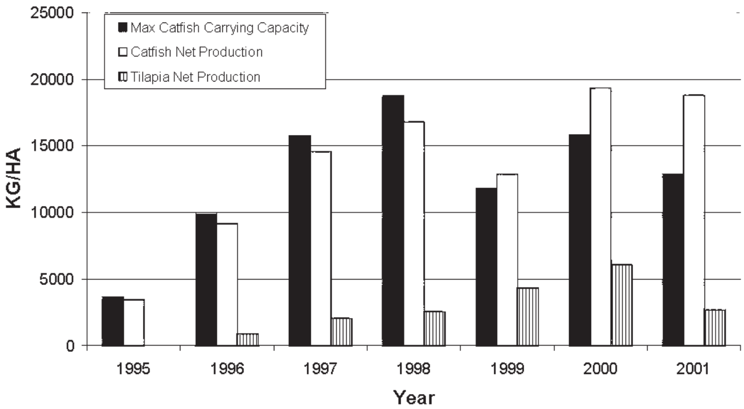

Fig. 1. Catfish and Tilapia yield (kg/ha) in Clemson Partitioned Aquaculture System

In addition, four 250 m^2 marine Partitioned Aquaculture System (PAS) units have been used to demonstrate production of Pacific white shrimp *Litpenaeus vannamei*, at densities of 125 to 250 animals /m^2. Demonstrated shrimp yields have ranged from 16,800 to 37,339 kg/ha, we have field-demonstrated that the PAS is capable of increasing shrimp and fin-fish production 4-fold over conventional aquaculture to 20,000 kg production per hectare with additional 5000 kg/ha of filter-feeder biomass production (tilapia or shellfish), while simultaneously reducing costs, feeds and energy inputs.

The basics of PAS culture technology was reviewed, and PAS design requirements are outlined, together with capital and operating costs to support high-rate, zero-discharge fish, shrimp and fingerling production.

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Abalone culture: current status and future prospects

PAUL G. OLIN & SUSAN SCHLOSSER

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Abalone are herbivorous marine gastropods represented throughout the world's oceans by almost 90 species comprising the family Haliotidae. Abalone have traditionally been a highly prized seafood item. Early Japanese references to abalone divers date back to 30 A.D. From 1865 to 1912, dried abalone comprised about 80 percent of Japan's marine exports from Nagasaki, its only foreign trading port during this time. In North America, abalone were collected more than 7,000 years ago by Native American Indians along the Pacific coast for food, and for the manufacture of shell implements and mother-of-pearl decorations. In Europe, local populations of *Halotis tuberculata*, commonly found from the south of the English Channel to the Northwest coast of Africa have been harvested for millennia. Abalone have long been known throughout the world as a highly prized delicacy and as a result, heavy fishing pressure has resulted in serious overexploitation throughout their range. Declining commercial harvests, closed fisheries, and continuing demand have created opportunities for abalone culture and farming has expanded throughout the world where ideal conditions exist. These include suitable water quality and temperature, readily available feeds and labour, infrastructure, and access to markets.

Of the almost 90 species and subspecies of abalone, only about 15 are of commercial significance in the fishery, and only about half of these are cultured commercially. As with any product, supply and demand regulate prices and in recent years production has increased substantially in response to demand. This increase in production, coupled with substantial illegal poaching of wild stocks has created a downward price trend in recent years. Primary suppliers of abalone to world markets include Australia, Chile, China, Japan, Korea, Mexico, New Zealand, South Africa, Taiwan, and the United States of America. Abalone producers worldwide must work to minimize production costs to remain competitive, especially with the dramatic increase in fuel prices and the high cost of pumping water, transporting feed, and getting product to market.

Total world fisheries production of abalone declined from 19,720 mt in 1970 to 14,830 mt in 1989. This decline continued and in 2002 landings were 10,146 mt. Since then, landings have stabilised somewhat with estimated harvest in 2007 of 9,200 mt. Poaching remains a serious problem and around 3,700 mt/yr. is illegally harvested primarily in Australia (1,000 mt), South Africa (850 mt), Mexico (550 mt), Japan (536 mt), New Zealand (400 mt), and the US (250 mt). In the future, farmed production will continue increasing to meet market demand and growers will strive to reduce production costs through science and technology. This will include improvements in nutrition, systems design, and selective breeding for improved growth and disease resistance.

REPRODUCTION AND BROODSTOCK

Abalone are dioecious and the sexes are easily distinguished when abalone are reproductively mature. Males have a cream or pale yellow coloured gonad and the female gonad is green. Abalone are broadcast spawners and females release millions of eggs which are fertilised by sperm released synchronously by males. Fertilised eggs hatch in 24 hours. The reproductive cycles of abalone are generally seasonal and related to water temperature. In temperate species gonad development and reproductive maturity increase with seasonal temperatures and in tropical species, gonad development is reduced, but not absent at the warmest times of year. Spawn induction is generally easier in smaller animals. Many hatcheries have also noted that first generation hatchery reared abalone, are easier to spawn than wild broodstock. However, it is often difficult to manage cultured abalone broodstock for synchronous reproductive maturity. Nonetheless, high fecundity, and fertilisation rates usually greater than 85%, coupled with high larval survival have resulted in relatively modest requirements for broodstock management. Wild populations continue to supplement hatchery broodstock which maintains genetic diversity in cultured stocks. Even though abalone are highly fecund, in hatchery spawnings unequal spawn success may result in inadvertent selection at critical life stages (larval rearing, settlement, juvenile and adult survival and growth). Small numbers of broodstock required for abalone hatchery production could result in inbreeding and genetic drift. For these reasons, domestic breeding programs to produce desirable traits such as accelerated growth, increased survival and disease resistance are critical to enhance production in the abalone aquaculture industry. Genetic improvements achieved by ploidy manipulations, selection, and biotechnology all need to be researched for improved performance of abalone in culture systems.

LARVAL REARING AND SETTLEMENT

Larval rearing for the first 24 to 36 hours following fertilisation is usually done in a static system. During this time the larvae develop to the trochophore stage and hatch out of the egg membrane. The remainder of the larval rearing is done using either flow through or static systems incorporating tanks of a variety of sizes and shapes, usually varying between 20 to 500 litres in relation to production requirements. Abalone larval development is temperature dependent and the swimming planktonic stage lasts for five to seven days. Most temperate abalone species are reared at 13 to 15 ºC and tropical species are reared at 23 to 26 °C. If bacterial colonies appear in the larval rearing container, the larvae are collected on screens and transferred to a clean rearing tank. Healthy abalone larvae swim upwards, then drift down, and swim upwards again in a spiral fashion. Survival through the larval stages is typically around 70%. At the end of the larval rearing period abalone larvae are competent to settle and occupy a benthic habit after metamorphosis from the swimming planktonic form to the benthic crawling form. Morphological changes include development of the radula, protrusion of the sensory cephalic tentacles, and loss of the swimming organ, the velum. Behavioural changes include intermittent swimming and crawling behaviour, and settlement at the water line of the rearing container. When these changes are observed, the larvae are ready to settle into tanks used for their early growth and feeding.

LARVAL SETTLEMENT AND NURSERY REARING

Indoor and outdoor settlement tanks are used for abalone larvae. Settlement may be induced using gamma aminobutyric acid (GABA), diatom inoculations, or mucous trails of adult abalone. The young abalone are very active crawlers and begin feeding soon after settlement. Diatom cultures are maintained at some commercial farms. Other farms supply seawater to tanks with newly settle abalone and allow natural diatom populations in the sea water to settle and grow on tank walls. Benthic diatom growth is managed by regulating light intensity with shade cloth covers put over the tanks to discourage excessive growth or removed to provide full light and encourage diatom growth. The correct diatom species and thickness of the diatom film on the tank walls is critical to early survival and growth. Young abalone are maintained in these systems for about 8 months depending on individual farm practices. Within this time frame the young abalone grow to around 8 mm in length and have developed respiratory pores. They are then transferred to circular or rectangular tanks that vary from 180 to 10,000 l. In addition to the tank wall, nearly all nursery systems have additional vertical substrates in each tank, usually made of fibreglass or PVC. The Japanese developed a series of plates that are held in a frame that is suspended in large tanks and this or similar systems are widely used throughout the world (Fig. 1).

Fig. 1. Settlement plates used for small abalone.

Abalone are maintained for approximately 4 to 6 months in the nursery area of the farm. Tanks are drained and rinsed every 1 to 3 weeks depending on the abalone grazing rates and diatom growth. The tanks are gently rinsed with seawater and any abalone washed out of the tank is returned, after being captured on screens at the outflow. At the end of the nursery rearing period abalone are 8 to 10 mm in shell length and undergo a nutritional transition. They now have a radula sufficiently large and strong to consume macroalgae or prepared diets. This dietary transition may be completed in intermediate systems or directly in the nursery system. If abalone are transferred to intermediate systems, they usually consist of baskets suspended in large production tanks. Abalone are stocked at high densities, about 2500, per basket (0.2 m^3), and the baskets are packed with macroalgae, placing the abalone is close proximity to the new food source. Availability of these small abalone seed is not an industry constraint.

GROWOUT SYSTEMS

Some farms are exclusively growout operations that purchase seed abalone from hatcheries. Growout systems are located on land with tanks and seawater systems or they are ocean based facilities with long lines or rafts supporting cage culture systems. Land based growout facilities usually utilise tanks constructed of concrete or fibreglass. Like the nursery systems, additional surface area is provided in the water column by using vertical panels, PVC pipe sections or other substrate placed in the tanks. Some growout tanks have "V" shaped bottoms or false bottoms to allow rapid removal of faeces and detritus. Abalone are fed once or twice a week based on seawater temperatures and season. Growout tanks are drained and rinsed as needed to remove excess faecal material and detritus. Cages or barrels deployed in the ocean are also fed once or twice a week and contain additional vertical substrates. Macroalgae and formulated feeds are used in abalone growout systems.

A variety of macroalgae are used but the giant kelps *macrocystis, nereocystis, undaria*, and *laminaria* comprise the bulk of abalone algal diets. In areas where sufficient macroalgae is unavailable, prepared diets are increasingly being used to feed cultured abalone as a primary or supplemental diet in a number of countries. This is especially true where kelp might be limited or harvest is restricted, or where seasonal conditions like El Nino warm the water and cause significant die-back of kelp. Land based nursery and growout systems use aeration to maintain oxygen concentration which is critical as abalone will crawl out of tanks with reduced oxygen. Abalone are also highly sensitive to hydrogen sulphide so it is imperative that tanks be kept clean and any build-up of uneaten food or detritus is cleaned from the tank. Growout systems involve substantial amounts of labour, and feed whether they are land or ocean based. Land based systems also have significant power requirements for pumping water. Though specific requirements differ between the two systems, the time involved and investment in land based facilities or boats and work barges is substantial. Abalone are held three to four years in production systems depending on the species, growth rate, and market demands

HEALTH MANAGEMENT

As is the case in all animal agricultural production, abalone are subject to environmental and pathogenic stressors and in combination, these can often prove fatal. Careful management of environmental variables and provision of a nutritional diet will help to maintain animal health. Strict health management and biosecurity programs should be in place to avoid problems associated with known pathogens like the herpes virus that recently decimated Australian abalone populations, sabellid worm infestations, and the rickettsial bacteria that causes withering syndrome. Biosecurity programs will also minimize risk of contamination with new pathogens, or known pathogens that might evolve to have increased virulence.

FUTURE OPPORTUNITIES AND NEEDS

Abalone markets are strong and will continue to grow although competition in the marketplace will continue to constrain margins. China, as the largest producer and consumer of abalone in the world will continue having a significant impact on the availability and price of abalone. Entrepreneurs interested in abalone culture must develop a rigorous analysis of a number of factors to evaluate their competitive advantage and likelihood of success. This analysis should include availability of land and water of suitable quality and temperature to support good growth year around. Species selection should be evaluated to identify abalone species demonstrating optimum growth and performance under prevailing culture conditions. In areas with relatively higher production costs, aggressive marketing must create markets that support sustainable industry development.

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Giant barnacle "picoroco" culture in Chile

DANIEL LOPEZ

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Distribution of the giant barnacle "picoroco" *Austromegabalanus psittacus* ranges from southern Peru, along the coast of Chile and southern Argentina. It is a traditional fisheries product exploited on a small-scale by local fishermen in Chile. Extraction has shown a downward trend (200 ton average). Cultures have been developed on a semi-industrial scale in southern Chile, incorporating four stages: 1) spat collection from the environment, 2) growth, 3) products, 4) market and commercialisation. Certain characteristics of the "picoroco" favour culture practices, such as: successful settlement in several substrates; maximum recruitment in short periods of time (spring); it is a sessile, filter feeder and a gregarious species; high growth rates; it is a functional hermaphrodite with early sexual maturity; high fecundity; high resistance to manipulation; simple, low cost culture technologies. Semi-intensive culture has been carried out (floating system), using both cultch (a single substrate for spat collection and growth) and "cultchless" (different substrates for spat collection and growth) systems, in addition to intensive pond cultures, with and without artificial food.

Different technology designs have been used and evaluated. The best results were obtained in suspended systems using the same substrate for spat collection and growth (Fig. 1 & 2 next page). In systems located superficially in the water column, an average growth of 3.4 ± 0.25 cm carinorostral length was reached in 28 months, while at 6 m depth, average size was 3.50 ± 0.20 cm over 22 months. Maximum biomass production was 0.75 g/cm/day. Results indicate that the commercial size can be reached from 18 months onwards. Using long lines in an area of 1 ha, it is possible to reach a biomass production of up to 50 gross tons.

Market studies have been oriented principally towards the Japanese market, as a fugitsubo equivalent (*Balanus rostratus*), with prices of over 15 US$/kg. At present 3 technology packages are available (spat collection; growth, and commercialisation), in addition to a commercial brand (*Sea Parrot picoroco*) and products (frozen with shells, tinned and live). "Picoroco" culture has the following success indicators: viable seed production on an industrial scale; technology system with economically viable results; unsatisfied market demand interested in these products.

Fig. 1. "Picoroco" spat collection system, with attached specimens (above), and "Picoroco" tubular growth system, with commercial-sized specimens (below), from a suspended culture system in southern Chile.

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The current state and potential of sea urchin aquaculture

GERASIMOS MOUZAKITIS

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Sea urchins are consumed for their roe (or gonads) worldwide. Currently, there is no widely used commercial aquaculture method and the only source of sea urchins is wild stocks. Due to the high demand for sea urchin products, over-harvesting has led inevitably to a steady decline in wild stocks. As the sea urchin market can be clearly described as high demand and diminishing (wild) supply, there is a real and immediate need for sea urchin aquaculture.

MARKETS & TRENDS

World sea urchin production peaked in 1995 with just over 115,000 metric tonnes (mt). In 2006 (the latest year for which official figures are available from the FAO) world fishery production of sea urchins was 67,500 mt, a decline of 42% in 11 years. From a commercial perspective these figures indicate that there is worldwide market gap in sea urchin products of over 47,000 mt per year. Interestingly, since 2003 China has been reporting a very large fishery production of sea urchins. From a baseline of 200 mt in 2002, Chinese authorities reported a production of 9,980 mt in 2006; a 50-fold increase in four years. Assuming these figures can be taken as accurate, world sea urchin production in 2006 stood at 77,500 mt; a decline of 33% from the world peak in 1995.

As with fishery production, the value of the sea urchin industry has also experienced a decline. The import value of sea urchin commodities has dropped from a maximum of US$350 million in 1995 to US$200 million in 2006, a decline of 42%. The decline is sea urchin stocks, is also clearly seen in the production figures from individual sea urchin producing countries. Eight countries make up approximately 97% of world sea urchin production. In seven of the eight major sea urchin producing countries (the eighth being China), sea urchin harvests have experienced a sharp decline. Chile, the largest producer with 45% of world production, has experienced a decline of 42%. Other countries, such as Japan, U.S.A. and Canada have experienced reductions of over 60%.

The largest consumer of sea urchin products is by far Japan. In 2006, Japan imported over 97% of all sea urchin exports. There are two major trends in the international sea urchin markets. First, wild stocks and fishery production is clearly declining everywhere (except China). Secondly, since around 2000 there have been a large volume of sea urchins originating from a Russian fishery centred on the Kurile Islands. This fishery has been described as IUU (Illegal, Unregulated and Unreported) and by its sheer volume and very low price for live sea urchins has had a very negative effect on both the Canadian and Japanese industries. In Europe, the major sea urchin is *Paracentrotus lividus* (also called the european edible sea urchin or the purple sea urchin). It can found all along the Mediterranean from Greece to Portugal and in the Atlantic coast as far north as Ireland. It is also a native species of the Azores. Officially, Spain is the only European sea urchin producing country, with approximately 450 mt per year (FAO). There are no exporting values from any European countries, although a proportion of European production is clearly exported to Japan *via* French markets (pers. comm. BIM, Irish Sea Fisheries Board).

There are two general issues concerning the European sea urchin markets. First, in the author's opinion, there is a large, untapped market for sea urchins in the Mediterranean. In all European Mediterranean countries there is a long tradition of consuming sea urchins (e.g. Greek achinosalata, Italian "Frutti di Mare" and various French sauces, omelettes and soups) and it is a highly prized seafood delicacy. Other than Japan, any production of the European sea urchin should be directed to this region. Secondly, as the European market is completely focused on the native species, it is not affected by the Russian IUU market flooding.

LIFE CYCLE & AQUACULTURE STRATEGIES

This section aims to provide the background for understanding the two major aquaculture strategies for sea urchins. It is not intended as a comprehensive review of the sea urchin life cycle. Adult, mature sea urchins spawn according to environmental cues, such as change in water temperature and photoperiod. Following fertilisation and various developmental stages, the developing sea urchin reaches the pluteus free-swimming stage, consuming diatoms and micro-algae in the water volume. After approximately nine to 12 weeks, the pluteus undergoes metamorphosis and settlement, developing into the general shape of an adult sea urchin (although less than 1 mm in shell diameter). The juvenile consumes feed by grazing and its shell increases in diameter typically in the region of one to two mm per month. Adult mature sea urchins would be considered animals with a shell diameter of over 45 to 50 mm. These animals undergo an annual (or biannual) cycle. Following spawning, there is an increase in the amount of roe in the animal. At this point the roe is firm and very well defined. In response to environmental cues, gametogenesis (the process of making eggs and sperm) is induced in the roe. With the onset of gametogenesis, the roe becomes soft, "runny" and "milky". The animals undergo spawning and cycle is repeated. For the market, the best animals are those in the stage just before gametogenesis, which contain a large amount of firm, well-defined, non-milky roe. Due to these requirements, sea urchins are only acceptable for the market in a specific seasonal window, typically three to four months.

In the commercial life cycle of the sea urchin, there are three general stages:

- Hatchery/nursery stage, encompassing spawning of broodstock, culture of the pluteus stage, metamorphosis/settlement and culture of settled larvae to approximately 10 to 20 mm
- An on-growing stage in which juveniles are grown to >45 mm in shell diameter
- A Roe Enhancement stage in which the roe of (wild or farmed) market-sized animals in increased by culture

Roe enhancement of sea urchins typically requires 12 weeks and it simply involves maintaining market-size animals under conditions that increase roe content but do not induce gametogenesis (i.e. water temperature and perhaps photoperiod). Importantly, it is a value-added activity; it increases the value of existing sea urchin stocks, not their number. The major commercial aim of roe enhancement is to provide sea urchin roe outside the wild seasonal window and hence attain a premium on price.

The second aquaculture strategy is full farming and it involves on-growing juveniles (from 10-20 mm) to market size. Based on work from out laboratory, the time for on-growing should be less than two years. Unlike roe enhancement, full farming increases the number of sea urchins available to the market. Given the worldwide trend in diminishing wild stocks, complete farming of sea urchins appears to be the only solution.

AQUACULTURE SYSTEMS

Culturing sea urchins is very simple. The animals are hardy and due to their sedentary nature do have great requirements for aeration and water flow. Based on our experience, the aquaculture parameter that most affects culture is high stocking density. Both in the wild and in laboratory/tank conditions, high stocking densities result in cannibalistic behaviour.

Since the 1970s there have been a range of attempts to develop commercial methods for sea urchin culture. At the moment, there are only two commercially-available systems: the land-based UrchinPlatter™ System developed in our laboratory and the sea-based SeaNest system developed in Norway. It is important to note that the aim of sea urchin aquaculture is to provide consistency. Seafood buyers and distributors demand consistency of supply. Aquaculture can provide consistency a much higher level than harvesting animals from the wild. Additionally, markets require consistency of quality. Similar to all other farming operations, both agriculture and aquaculture based, sea urchin aquaculture will result in consistent product quality.

The SeaNest system is composed of patented, self-interlocking boxes that are attached to a longline. A boat, fitted with a SeaNest platform, follows the longline. Each set of boxes is brought up into the platform (through a hole in the boat under the platform) using winches. The top box in the set is moved horizontally along the platform and can be serviced individually, such as feeding, etc. This first box then moves vertically forming a new set of boxes. This process is repeated until all the boxes are processed. Once processed, the new set of boxes can be lowered into the water. The boat can then move to the next set of boxes. The SeaNest system has been designed to allow for high water flow through the boxes and for automation. It is suited to large-scale start-up operations.

THE URCHINPLATTER™ SYSTEM

The UrchinPlatter™ System is a land-based method that uses cages within a raceway. This patented technology has been in development in our laboratory for over six years. It can be used for both on-growing and roe enhancement. The UrchinPlatter™ System utilises a novel feeding method for sea urchins called the Platter™. Feed, artificial or natural macroalgae, is sandwiched between a Backing plate and a highly perforated Holding plate (Fig. 1). The resulting Platter™ is a rigid surface onto which sea urchins can both attach and consume feed through the perforations in the Holding plate.

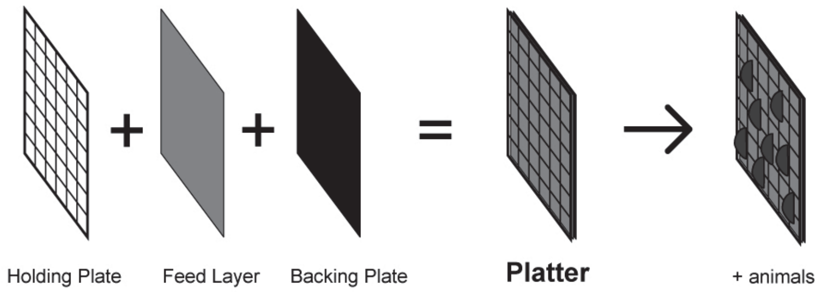

Fig. 1. Feeding method of the UrchinPlatter™ System.

The Platter™ units are used in combination with a central, perforated cage structure. The sea urchins are placed within the cage structure and tend to attach to the Platter™/feed sides. Typically, the cages are placed vertically to facilitate waste removal. Feed replenishment is performed weekly by replacing the Platters™ containing the old feed with fresh Platters™. Both artificial feeds and natural macroalgal feeds can be used. Commercially, the UrchinPlatter™ cages are called Stacks™. They are composed of a central cage structure with a 2 x 2 array of compartments. One set of Platters™ provides feed to four compartments of sea urchins. In a commercial raceway, the Stacks™ are stacked two high, forming a Column. A series of columns is then placed along the width of the raceway, forming a Set. A series of Sets can then be placed along the length of the raceway. The vertical, width-wise and length-wise stacking of Stacks™ is only possible because of the Platters™, which keep the feed, and the animals, against the sides of the Stacks™, leaving the central area free for water movement. Over the past six years we have performed a range of experiments to assess the efficiency of the UrchinPlatter™ System. Due to legal reasons involving the patent, it is only recently that we have been able to discuss this technology and submit publications to peer-reviewed journals. Research has focused on:

- Demonstration of pre-season and post-season roe enhancement
- Range of growth trials assessing on-growing of juveniles
- Assessment of use of artificial and natural diets in the UrchinPlatter™ System
- Pilot-scale assessment of on-growing

In addition to the UrchinPlatter™ System, it has been necessary to evaluate other components of commercial sea urchin aquaculture, for example, recirculation requirements and system design for intensive land-based aquaculture as well as manual and automated grading methods. As well as designing a commercial system, a major output of this work has been a "small-scale replica", a miniature of the commercial raceway that can hold approximately 100 kg of market-sized animals. The aim of this Replica is to expedite application of the UrchinPlatter™ to other countries and facilitate the assessment of both the biological and financial parameters involved in sea urchin aquaculture.

SUSTAINABLE SEA URCHIN AQUACULTURE IN THE AZORES

According to the literature, the European sea urchin, *P. lividus*, is a native of the Azores. This is very beneficial for two reasons. First, any sea urchin production in the Azores can be sold to mainland Europe. Secondly, sea urchins from mainland Europe can be brought to the Azores (e.g. broodstock or juveniles for assessing on-growing). By far, the easiest entry into sea urchin aquaculture is roe enhancement of wild stocks. Wild sea urchins would be harvested locally, enhanced to produce roe out of season over 12 weeks and sold. The basic issue concerning this strategy is whether a sufficient quantity of market-sized sea urchins can be obtained. As far as I am aware, there are no reports assessing the wild sea urchin population in the Azores. Additionally, even if sufficient stocks are available, are they accessible given the coastline characteristics of the islands? The most sustainable strategy, both economically and environmentally, is complete aquaculture as it does not rely on wild stocks (except for a small number of broodstock). This strategy though would require a supply of juveniles and a 18-21 month growing cycle. The juveniles would have to be produced locally or brought in from Ireland (the only EU country with a commercial sea urchin nursery). My recommendation would be a commercially-focused assessment of the applicability of sea urchin aquaculture to the region:

Wild Stock Assessment

Assessment of sea urchin stocks in the Azores – assuming that this is not already available from local fisheries reports to which I do not have access. If sufficient stocks are available, encourage sustainable harvesting and export to EU: identify markets, build up commercial interest in sea urchins.

Sea Urchin Aquaculture

Concurrently with the wild assessment, initiate a small-scale assessment of sea urchin aquaculture. The aim of this assessment would be to determine the financial viability of sea urchin aquaculture in the region. In the author's opinion, the most important aspect of attempting to bring in new technology, and especially a new industry in aquaculture, is engagement with industry from the onset. As part of that strategy, the assessments of the technology should not be purely scientific but have clear, commercially-focused aims.

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Review of *Seriola* spp. Aquaculture

DANIEL BENETTI

Benetti, D. 2008. Review of *Seriola* spp. Aquaculture. Pp. 63-65 in: Pham, C.K., R.M. Higgins, M. De Girolamo & E. Isidro (Eds). Proceedings of the International Workshop: Developing a Sustainable Aquaculture Industry in the Azores. *Arquipélago*. Life and Marine Sciences. Supplement 7: xiii + 81 pp.

Recent progress and current status of aquaculture of three commercially important *Seriola* species are addressed: *Seriola dumerilii*, commonly known as greater amberjack, kampachi, ricciola or seriola mediterranea (Fig. 1); *Seriola lalandi*, called yellowtail kingfish, goldstriped amberjack and hiramasa; and *Seriola rivoliana (= S. mazatlana*), known as Almaco jack, Pacific yellowtail, "huayaipe" or "Kona Kampachi". Although not to the same extent as *Seriola quinqueradiata* (hamachi) in Japan, their counterpart from temperate waters, all three species have been commercially raised in Asia, Australia, the Americas and European countries. Due to favourable biological characteristics for aquaculture and high market demand and price, a great deal of effort has been made towards developing and expanding commercial production of *S. dumerilii*, *S. lalandi* and *S. rivoliana* in recent years. Technological advances on the aquaculture of these species are presented and summarized.

An important first step in setting up any *Seriola* aquaculture project is that of determining the species to be produced. Considerations must include whether to culture native/endemic or exotic/introduced species. Commercially, the species should have a high market value and be in demand. In terms of practicality, technology should already exist that would enable the development of the organism from the egg to marketable size via high performance aquaculture that optimizes growth, survival and feed conversion rates. It is crucial to account for FEC (Feed Economic Conversion) when estimating the price of feeds and the market value of the final fish product. It is also prudent to avoid competing directly with the capture fisheries sector. Consideration must be given in terms of the trade-off between culturing species that are fast growing or species with a greater economic value. Although they can be harvested and sold in a shorter period of time, faster growing species do not necessarily provide the greatest financial return on investment. It might well be more worthwhile to invest in slower-growing, more financial valuable species.

Seriola spp. are generally cultured in large (50-80 ton) independent, environmentally controlled recirculation systems. Temperature control is key for natural spawning (cycle, trigger, maintain) and differs from species to species, e.g. 26 °C *Seriola rivoliana*; 17 °C *S. lalandi*. Aquaculture of these species has benefited from improved nutrition using fish, squid, shrimp, pellets as food sources, as well as from improved handling: moving/handling is performed using clove oil (eugenol) @ 10-40 ppm. The ratio of fish can and should be monitored and adapted via the removal and/or addition of individuals (rejected fish, sex ratio). Parasite control must also be considered and can be resolved through the addition of a "cleaning station", relying on symbiosis with the neon goby (*Gobiosoma oceanops*). *Seriola* are vulnerable to a variety of diseases including: epitheliocystis (larvae/post-larvae), caligidae and copepods, lice (*Benediniella* spp.), worms (nematodes, trematodes), and bacterial infection (exophtalmia).

Various hatchery and grow-out systems are available. These range from onshore tank-based systems to highly technological sea cages and "aquapods". Some of these offshore systems have proven to be highly resilient to extreme weather conditions, withstanding storm-force and even hurricane force winds.

Expansion of marine fish aquaculture is a certainty as demand and production continue to grow. Aquaculture of high-value marine fish can produce high yields with no significant or cumulative environmental footprint, making aquaculture one of the practices with the highest yields and least impact on the environment compared with other human productive activities. Of course, the objective is to produce "high-value" carnivorous fish for high-end market, where "high-value" means high quality and price but also rich in omega-3 fatty acids (EPA and DHA) essential for human health and nutrition.

Fig. 1. Greater amberjack, hiramasa, ricciola, seriola mediterranea (*Seriola dumerilii*) at the Aquaculture Center of the Florida Keys, a commercial hatchery in Florida, U.S.

Industry development will bring enormous social, economic and technological benefits but contentious issues will need to be addressed: use of native species (no GMO's); use of probiotics; use of approved chemicals/drugs; whether to establish facilities in exposed sites and open ocean; selection of efficient feeds, determination of low FCR, means to reduce use of fish meal; avoidance of the use of drugs, chemicals, ATB's, hormones, pigments opting instead for all-natural production; aiming to produce an "organic" product; etc. Nonetheless, both *Seriola lalandi* (primarily in Australia) and *S. rivoliana* (mostly in Hawaii, U.S.A. and Ecuador, South America) have been produced commercially from egg to market during the last decade. In spite of recent progress with hatchery technology of *S. dumerilii* in Malta and Greece, there is still shortage of commercial quantities of fingerlings available for stocking growout cages. Hatchery technology still needs to be perfected before commercial aquaculture of *S. dumerilii* can be developed in Western countries. Evidence indicates that this species is more difficult to produce than other *Seriola* species.

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Red porgy (*Pagrus pagrus)* culture in the Canary Islands

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Domínguez, L.M., L. Robaina & H.F.-P. Barber 2008. Red porgy *(Pagrus pagrus)* culture in the Canary Islands. P. 66 in: Pham, C.K., R.M. Higgins, M. De Girolamo & E. Isidro (Eds). Proceedings of the International Workshop: Developing a Sustainable Aquaculture Industry in the Azores. *Arquipélago*. Life and Marine Sciences. Supplement 7: xiii + 81 pp.

Nowadays aquaculture is a consolidated sector, increasing approximately 9% annually. Marine aquaculture concentrates production in a few species, being necessary a species diversification. Candidate species must achieve some economical and biological points. Considerable research about this subject is currently underway in many producing countries. Aquaculture production increases quickly in Canary Islands from 300 mt in 1998, to 9600 mt in 2007, however it must face different limiting factors in order to continue its evolution. One of them is the need of species diversification.

Red porgy *Pagrus pagrus*, is one of the marine fish species candidates to the aquaculture diversification in the Mediterranean and Mid Atlantic coasts, due to its biological characteristics and the market price (around 10 €/kg). This specie is characterised by a natural pink skin coloration being that an important quality parameter by its consumer acceptance. However in culture conditions this colour related to its natural feeding, changed notably. Fish are unable to synthesise carotenoids de novo and optimum skin coloration similar to wild specimens depend on the adequate carotenoids included in diets. Moreover this species have reported to require high protein dietary content. Studies on diets and carotenoid alternative sources have been done by GIA (Group of Research in Aquaculture) in order to improve feed formulation and skin colour. At these moments in Canary Islands some commercial tests have been done to check the sustainability of red porgy culture in the islands conditions.

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Review of tuna research by the Inter-American Tropical Tuna Commission at the Achotines laboratory

VERNON SCHOLEY, D. MARGULIES, J. WEXLER & M. SANTIAGO

Scholey, V., D. Margulies, J. Wexler & M. Santiago 2008. Review of tuna research by the Inter-American Tropical Tuna Comission at the Achotines laboratory. Pp. 67-68 in: Pham, C.K., R.M. Higgins, M. De Girolamo & E. Isidro (Eds). Proceedings of the International Workshop: Developing a Sustainable Aquaculture Industry in the Azores. *Arquipélago*. Life and Marine Sciences. Supplement 7: xiii + 81 pp.

The Inter-American Tropical Tuna Commission (IATTC) operates Achotines Laboratory in the Republic of Panama, where captive yellowfin tuna (*Thunnus albacores*) have been spawning almost daily since 1996. The principal duties of the IATTC are to study the biology of tuna and related species in the Eastern Tropical Pacific (ETP) with a view to determining the effects that fishing and natural factors have on their abundance and recommend appropriate conservation measures so stocks can be maintained at sustainable yields. In the early 1980's the IATTC decided a field laboratory was needed to study the early life history of tuna and selected a site in Panama which was purchased in 1984. Research activities were initiated in 1985 and a large expansion of laboratory infrastructure occurred from 1993-1996. Wild-caught yellowfin tuna moved to a large (1300 Mt) broodstock tank in June 1996 began spawning in October of 1996. Eggs, larvae and juveniles resulting from those spawns are used for a variety of studies including investigations of the effects of various environmental and biological factors on growth and survival. Research focuses on areas of tuna ecology and biology that will provide important information for population estimates and management of the stocks but additional areas of research are also ongoing. Researchers from other institutions carry out investigations at Achotines Laboratory as it is the only facility with near year round availability of tuna eggs and larvae for research purposes.

During the presentation a description of the Achotines Laboratory facilities and a review of past, present, and future research at this facility was given. Some of the areas of research that are of great interest in studying the ecology and biology of wild tuna, as well as having potentially important applications in the culture of domesticated tuna, include:

GENETICS

By reducing the number of yellowfin tuna in a tank to a single spawning pair it was possible to use the resulting eggs and larvae to confirm Mendelian inheritance of ribosomal protein gene intron variations in that species. Using the same samples Mendelian inheritance of four microsatellite DNA markers was confirmed which could be useful for registration of parents, kinship, and tracing released tuna fingerlings in an ocean enhancement program or aquaculture project. Weekly larval (offspring) samples were taken from the main broodstock tank at Achotines Laboratory and DNA profiles compared with the DNA profiles of the broodstock yellowfin tuna. Results indicated that individual females were capable of spawning almost daily for extended periods of time.

VISION STUDIES

A micro-spectrophotometer was used to analyse the eye structure of different life stages of yellowfin tuna. Juvenile and adult fish exhibited two peaks in spectral sensitivity – one in the blue-green range, and another in the violet range. Larval yellowfin showed a wide range of sensitivity, with peaks in the violet, blue-green, and green wavelengths, which is probably adaptive for eating plankton. Spectral characteristics of two types of fluorescent lights used at Achotines Laboratory were compared to examine the match, or mis-match, of larval visual pigments with the spectral characteristics of the lights. These fluorescent lights exhibited different spectral peaks which may or may not match the visual pigments of yellowfin larvae suggesting spectral characteristics of culture system lighting for tuna larvae must be analysed prior to their use.

TURBULENCE STUDIES

Microturbulence studies were undertaken to develop estimates of the optimal amount of turbulence for survival of yellowfin larvae during the first-feeding stages. Microturbulence was measured on a very fine scale with a micro-acoustic Doppler velocitometer in experimental tanks culturing larval yellowfin tuna. Results of the experiments were analysed to determine the effects of microturbulence on survival of yellowfin larvae. Moderate turbulence levels were found to give the best survival rates and tank turbulence rates were converted by a physical oceanographer to equivalent surface wind speeds needed to generate similar ocean turbulence at 0-20 m depth. Estimates of optimal wind speeds for yellowfin tuna larval survival range from 2.0 to 4.5 m/sec.

DENSITY-DEPENDENCE STUDIES

For the past several years a series of experiments have examined the effect of tank stocking densities of larval yellowfin tuna on growth rates during the first 3 weeks of feeding. It was found that higher growth rates in both length and weight are associated with the lowest densities. A 4-fold difference in larval densities during the first week of feeding (a plankton diet) resulted in growth deficits up to 45%. These magnitudes of growth deficits during the first 3 weeks of feeding could have a substantial effect on pre-recruit survival due to stage prolongation.

For those interested in learning more about tuna culture the IATTC and the University of Miami holds a yearly workshop entitled “Physiology and Aquaculture of Pelagics with Emphasis on Reproduction and Early Developmental Stages of Yellowfin Tuna” at Achotines Laboratory. International researchers, industry professionals and students gather to combine advanced technologies and improve methods for raising larval tuna and other species of marine fish.

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ROUND-TABLE THEMES AND DISCUSSIONS

Session 1: Structure of Stakeholder Involvement for Aquaculture Development in the Azores

Chairpersons: DORIS SOTO & WILLIAM FAIRGRIEVE.

The group (about 20 people) addressed the following questions with a facilitation process which allowed everyone to participate. Brainstorming techniques were used such that each participant proposed the elements (stake-holders/entities) that they perceived as most important. Selection of elements was made in phases ranging from “most important” to “least important”. Participants included invited aquaculture experts, scientists, university students, and fishermen.

Question 1.1: Which are the present organisations, entities, bodies that should be involved in the aquaculture governance and whose opinions should be considered at a first stage?

At least 13 organisations were considered as relevant. Highly relevant criteria were assigned to elements that received three or more votes in the first phase of selection. * indicates elements that were considered to be Highly Relevant.

Selected Elements:

1. Regional Directorate of Science and Technology (Belonging to the Secretaria Regional da Educação e Ciência)
2. Civil Protection
3. Labour/workers Office
4. Municipal Offices
5. Regional Directorate of Tourism (Belonging to the Secretaria Regional da Economia)
6. Universities and other research and training institutions, including DOP – Departamento de Oceanografia e Pescas (Department of Oceanography and Fisheries) of the University of the Azores *
7. Regional Environment and Sea Office, including Regional Directorate of Fisheries and the Directorate of the Territory and Water Resources (Direcção Regional das Pescas e Direcção Regional do Ordenamento do Território e dos Recursos Hídricos, both belonging to Secretaria Regional do Ambiente e do Mar)*
8. Regional Economy Office (Secretaria Regional da Economia)
9. Private Companies
10. Fishermen associations*
11. Maritime Authority
12. Culture office (Direcção Regional da Cultura)
13. Sanitary Authority and Animal Health office (Belonging to the Secretaria Regional da Agricultura e Florestas)

Question 1.2: Which should be the functions of the leading organisation/government body? (List the functions; e.g. aquaculture zoning, licensing).

Defining the functions of such an authority took quite a bit of discussion particularly regarding the competencies of existing offices and potential relationships with other entities.

Selected Functions:

1. Define an Aquaculture Strategy, policies and plans*
2. Licensing*
3. Legislation
4. Assessment of environmental conditions
5. Definition of Aquaculture zones
6. Monitoring
7. Evaluation of compliance
8. Sanctions (punishments and penalties)
9. Grants and subsidies for small entrepreneurs (fishermen)
10. Coordination with other relevant offices or institutions, e.g. Environment and sea authorities, Maritime Authority, Animal Health authority, Human health office, Research Institutions, Transport Authority etc.
11. Ensure capacity building
12. Ensure that there are facilities and resources for adequate research
13. Guidance on marketing
14. Facilitate transport (at least initially)

Elements indicated with * (asterisk) were considered to be Highly Relevant.

Question 1.3: Is there such organisation? Or should it be created?

The general agreement was that no such organisation currently exists. Therefore, a dedicated organisation would need to be created, perhaps in association with the Regional Environment and Sea Office, including Regional Directorate of Fisheries and the Directorate of the Territory and Water Resources (Direcção Regional das Pescas e Direcção Regional do Ordenamento do Território e dos Recursos Hídricos, both belonging to Secretaria Regional do Ambiente e do Mar).

Session 2: Requirements and Priorities for Aquaculture Development: the Necessary Steps Involved in Setting up an Aquaculture Initiative in the Azores Archipelago.

Chairperson: PATRICK WHITE

Participants in this forum represented a broad range of interests including: local commercial fishers, local and international scientific researchers, aquaculturists, and private consultancies. During this session participants were asked to submit suggestions for the factors most important to establishing a successful Aquaculture venture in the Azores. The following factors were identified in order of importance: the need for more information; governmental support; access to financial resources; available space in terms of land and ocean resources; technical support; and the identification of appropriate species and infrastructure.

The main finding of Round-Table Discussion Group 2 was that there is more information needed with regard to Aquaculture in the Azores in several respects. There is insufficient information available at present with regard to suitable sites, suitable technology, ideal species (but see Session 3 which took place subsequently), and market conditions.

To date there is little information on the interests of the local government with regard to their commitment to and priorities for development. It was therefore suggested that the local government provide a Mission Statement in this respect. A further requirement by the government is the provision of guidelines in terms of licensing requirements for potential investors in this sector. It was felt that without clear licensing guidelines it would be difficult to attract private investment in any Aquaculture venture.

The group agreed that if the Regional Government wants to make some investment in aquaculture, a portion of this money should be made to perform a cursory appraisal of the ecosystem with the intention of creating an Aquaculture Business Plan for the region, using the services of external consultants and local knowledge and expertise. Part of this assessment should include preliminary geographic surveys, oceanographic and hydrodynamic assessments etc. The business plan should identify potential markets, realistic costs and also assess the steps needed to secure a profit. It was foreseen that this initial evaluation should take the form of a short-term plan of about 9 months in duration, costing in the region of €200,000 (Benetti, White, Agius).

In terms of Research & Development (R&D), it was concluded that a dedicated Aquaculture Development Centre should be established for the Azores. Feelings were mixed regarding the priorities for research, whether they should focus on land-based hatchery facilities for the provision of eggs and fingerlings, or if an experimental sea-based cage system should be the first step towards Aquaculture research in the region (for further discussions see Session 4). R&D programs should promote greater interaction and cooperation between local and foreign institutions for consultation purposes as well as the transfer of knowledge. Funding for R&D could be secured from scientific funding bodies or from local government under other research initiatives in addition to those aimed specifically at Aquaculture. Such R&D should only be undertaken following the completion of a Business Development Plan and should include training of personnel, detailed environmental appraisal to determine sites and potential technology and the establishment of experimental aquaculture facilities (see Figure 1). Only through demonstration of a successful Aquaculture initiative could private parties be encouraged to invest in Azorean Aquaculture.

Identification of potential investors will be crucial to the development of commercial aquaculture in the region. It was suggested that diverse sources of public (local, national and European) funding should be tapped to support such initiatives, e.g. rural development funds. Specialist financial institutions willing to provide venture capital and conditions suitable to the initiation of Aquaculture, e.g. agricultural banks, should be explored.

Finally a greater understanding of public support, especially support from the Fishing Sector, should be obtained. Expertise of local fishers is essential to the establishment of both aquaculture trials and commercial aquaculture activities. Additionally, information on potential markets, training, transport etc. should be gathered.

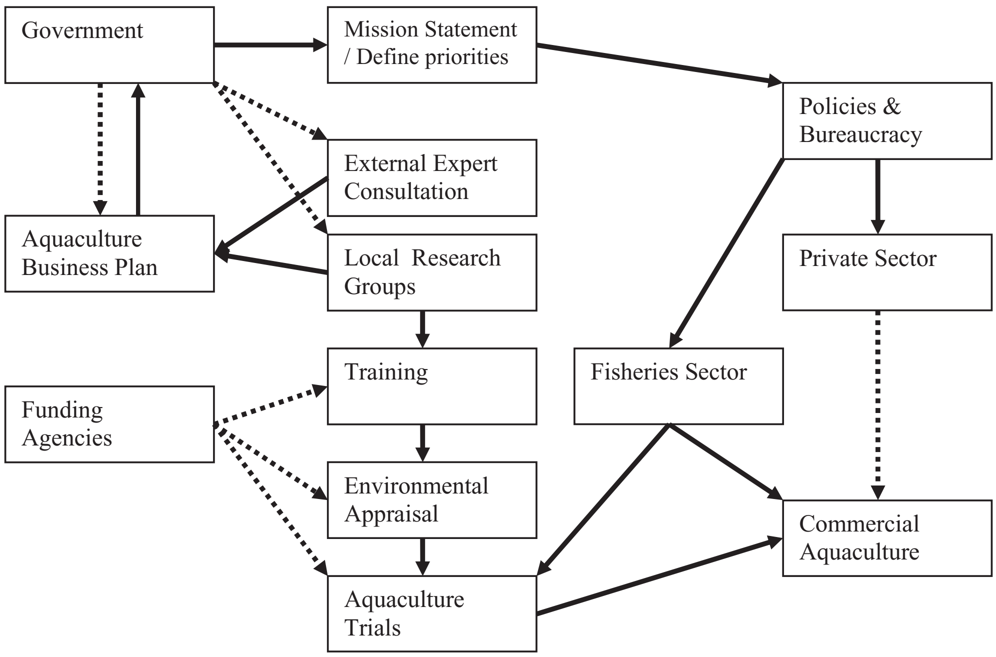

Fig. 1. Structure of steps needed for Aquaculture development. Black arrows represent transfer of information and knowledge. Dotted arrows indicate financial investments.

Recommendations of the Group

The following recommendations were made on how to implement this.

Government should try to undertake the following:

- Aquaculture Development Plan for the Azores
- Further support for the Institute for marine Research for further research and development
- Source funding for a new Aquaculture Research and Development Centre
- Capacity building within the relevant Government departments

Aquaculture Development Plan for the Azores
The government should find funding for a comprehensive study of the potential for aquaculture development in the Azores. They should set up an *ad hoc* committee comprising:

- Government representatives
- Local Scientists
- Industry representatives
- Fishermen
- Scientists from aquaculture centres in the Canaries and Azores
- Foreign specialists

This committee should undertake the following action plan:

- Prepare terms of reference for study
- Select specialists to undertake the study
- Hold a consultation workshop with all coastal stakeholders to identify the issues

The scope of the study should be to review and analyse:

- Legislation
- Regulations
- Permitting
- Licensing
- Government agencies involved
- Sources of funding
- Potential sites and their integration within existing plans of regional territorial order
- Potential species
- Potential technologies
- Potential markets
- Risks
- Competitors

Then make recommendations regarding:

- Any necessary changes in regulations
- Identification of the lead agency for aquaculture development
- Fast tracking permitting process
- Most suitable sites
- Most suitable species
- Most suitable technology
- Most suitable markets
- Feasibility of the selected species and technologies
  - – Capital costs
  - – Operating costs
  - – Profitability
- Training needs
- R&D priorities
- Form of government support required

This study should cost around €200,000 to undertake and would require 3 months preparation plus 9 months to undertake the study.

Further financial support to Institute of Marine Research (IMAR/DOP) for aquaculture research and development.

This would include funding for:

- Hydrodynamic data collection for sites
- Baseline environmental surveys of potential sites
- Exchange of scientists with Canaries and Madeira and with EU & U.S.A.
- Writing research proposals to EU and/or U.S.A. for further research funding

Government capacity building:

- Review of agency scope, jurisdiction and overlap
- Review of regulations
- Review of permitting process
- Identification of other funding sources (Axis 4)

Development of a new Aquaculture Research and Development Centre

Find funding to establish a new Research and Development Centre that has the capability for onshore small scale assessment of aquaculture potential. This facility should be multi-species (fish, crustacean and mollusc) and flexible. Facilities should include:

- Broodstock facilities
- Pilot marine hatchery
- Recirculation
- Flow through

Funding required for this research and development centre is estimated at around Euro 2.2 million, based on a similar facility recently constructed in Cyprus.

Session 3: Selection of Focal Species for Aquaculture in the Azores.

Chairperson: DANIEL BENETTI

This session was attended by representatives of local government, commercial fishers, local and international researchers, as well as private sector consultants.

Assuming the existence of support from governmental bodies, academia, commerce, fishermen and other stakeholders; and assuming the completion of a strategic plan with regard to resources, sources of funding and a time-frame within which Aquaculture should be established; short-, medium- and long-term goals were listed and subsequently linked to potential species.

Three destinations were defined with regard to cultured fish and invertebrates: (1) local market, (2) local re-stocking, and (3) export of eggs, fingerlings and adult marine organisms. The risks associated with culturing native as opposed to exotic species were discussed, particularly given the popularity of cod/"bacalhau" in Portugal. It was decided, however, that it would be more practical to concentrate on native species.

Table 1. Recommended species to be prioritised for Aquaculture development in the Azores.

Priority	Common English Name	Local Name	Scientific Name	Phase
1	Giant Azorean Barnacle	Craca	*Megabalanus azoricus*	1
2	Limpets	Lapas	*Patella aspera / P. candei*	
3	Abalone	Lapa burra	*Haliotis tuberculata coccinea*	
4	Sea Urchin	Ouriço	*Paracentrotus lividus*	
5	Greater Amberjack	Írio	*Seriola rivioliana*	2
6	Grey Triggerfish	Peixe porco	*Balistes carolinensis*	
7	Common Seabream	Pargo	*Pagrus pagrus*	
8	Tuna	Atum	*Thunnus* spp.	
9	Guelly Jack	Encharéu	*Pseudocaranx dentex*	
10	Wreckfish	Cherne	*Polyprion americanus*	

Two phases of Aquaculture development were recommended, the first concentrating on species that are well-known to aquaculture and are therefore simpler and less risky to produce. First phase species also require lower initial investments in terms of infrastructure, etc. being species that can be cultured with relative ease in a land-based facility (See Table 1). Second phase species were those that required greater initial investment but that would also provide greater return. These species are more complex to produce and require more specialist knowledge and more sophisticated facilities for production See Table 1). There was also some discussion regarding the production of ornamental marine species for the aquarium trade. Although this approach could prove to be a profitable longer-term plan (Molina) it was suggested that it should not be a priority for the Azores.

Session 4: Selection of Potential Technologies for Aquaculture in the Azores.

Chairperson(s): CARMELIO AGIUS

It was apparent from the beginning of the workshop that there were two major potential approaches to developing Aquaculture in the Azores: land-based facilities or sea-based structures. This forum was charged with the task of determining the advantages and disadvantages of each approach.

Initially this session identified the need for research facilities in the Azores region to be strengthened and for the launch of new programs and lines or research specifically focussed on Aquaculture. Further supporting mechanisms also need to be put in place with regard to support services to an Aquaculture industry, including disease control, etc.

The primary advantages to setting up a land-based Aquaculture facility are the ease and relative inexpensive costs of setting up such a facility. Additionally, land-based Aquaculture would be weather-independent and risks of losing equipment and components during storms would be greatly reduced. A disadvantage of a land-based facility is the global rise in energy costs, a factor that would impact sea-based Aquaculture to a lesser extent.

The findings of the working group on aquaculture technology are summarised as follows:

1. Freshwater aquaculture
It was agreed that there was little future in this sector.

2. Land-based aquaculture
There were two differing opinions. One school of thought was that land-based facilities could give the opportunity for a quick start. On the other hand there were serious concerns about:

a) spiralling fuel costs which is causing much concern in fisheries and agriculture sectors
b) shortage of suitable land areas near the foreshore
c) potential conflicting users
d) declining prices of abalone (one of the most promising species for this type of culture) and the excessive time it takes to reach first harvest.

There was agreement that serious consideration needs to be given to a land-based, high technology but low volume activity as described by Mr Patrick White for the Isle of Man. Essentially this would act as a bank supplying biological material of a specialised nature such as fertilised eggs, juveniles, selected broodstock, etc.

3. Offshore aquaculture

There was general agreement that a pilot cage culture project could be initiated to prove the viability of offshore finfish cage culture in the Azores. This should involve one or two cages and employ a species that is indigenous. It should have external technical input for the first six months to ensure its success. Fingerlings should be imported at a fair size and the grow-out initiated at the start of the summer season so that the net mesh size would offer least resistance during the winter months. This will convince local investors of the viability of such a venture and hatchery facilities can then follow within two to three years to further support such a development.

4. Research Facilities

It was agreed that research programmes currently under way should be strengthened both within the existing facilities and preferably by setting up a dedicated Aquaculture Research, Development and Training facility.

This should aim to:

a) pursue current work programmes e.g. barnacle farming
b) provide support services such as disease management
c) initiate new applied research programmes such as breeding of potential candidate species for restocking and cage aquaculture.

5. Regional Aquaculture Plan

It was agreed that a Regional Aquaculture Plan needs to be drawn up by an expert group comprising local and foreign counterparts that will chart the way for aquaculture developments over a five-year period. This plan should be carefully integrated within other Regional plans of order (e.g. territorial order plans). All the above activities can then be planned and executed within this framework of development. Mr Patrick White gave a comprehensive review of the "Terms of Reference" that such a plan might incorporate.

FINAL SESSION DISCUSSIONS

The final session of the workshop was intended as a discussion forum during which the conclusions of each Round-Table Discussion group were presented.

In response to priority species:
AGIUS: Stated that Maltese attempted to grow *Seriola dumerili* but they only grew successfully for half of the year. He also stressed the time-scale needed for the resources to meet the market.

MOUZAKITIS: Expressed concern about the market opportunities for species of only local importance.

KYRIACOU: Suggested that because land resources in the Azores are limited, investing in the culture of abalone for example might not be a lower investment than sea-based units.

WHITE: Stressed the importance of perfecting an aquaculture technique with a relatively simple, resilient, starter-species.

FAIRGRIEVE: Insisted to keep in mind the monetary value of the species cultivated as the purpose of the endeavour is to make a profit and attract more investors. He agreed with the strategy defined by Round-Table Discussion Group 3 - Benetti.

FEIO: Stated that more than a plan is needed in the Azores. The government has the will to start putting money into an initiative. It is best to concentrate on improving know-how while promoting species that are already undergoing trials for aquaculture. The government wants a solid plan but also to start simply.

BENETTI: Stressed that at this stage, it is crucial to bring external experts to advise government and other interested parties.

BAPTISTA: Stated that additional costs are not being considered. Neither are the fishermen. The costs of transport for example are one of the greatest costs to local fishers.

RODEIA: Remembered the importance of scale. Small scale strategic investment is the best start. The production of a species such as *Seriola*, for example, would need to be an industry driven process. It is too big a venture to begin on a local scale.

MOUZAKITIS: Stated that in Ireland, the use of an Aquaculture Development Officer, working in the government has proved very successful. He acts as an anchor between many sectors. This should be a person who knows the markets and knows the value and risks associated with any given species.

In response to requirements for development in the Azores:
AGIUS: Reminded timescale to be very important. Parallel development strategies should not be ruled out. Research must be relevant to industry.

KYRIACOU: Insisted that a hatchery is not an essential first step in setting-up aquaculture. Efforts should be directed to sea farming in cages.

BENETTI: Replied to Kyriacou saying that starting with cages is too risky given the conditions in the Azores.

AGIUS: Argued that without a cage experiment, there is no future for aquaculture in the Azores. If experts are brought in early on and insurance is taken out at the beginning, risks can be reduced. Initiating communication between the insurer and the manufacturer of the cage equipment can facilitate arrangements.

KYRIACOU: Suggested that money for a pilot project should be derived from other sources, other than the obvious.

AGIUS: Reminded that a pilot project should not be stocked to capacity as its role is for demonstration purposes only.

Final comments:
LACERDA: Stated that on behalf of the fishermen, they will support the culture of invertebrates; they will support the culture of finfish for restocking purposes, but will categorically not support the culture of fish to directly compete with the existing commercial fishery.

Unidentified participant: Reminded fishermen that wild cages frequently attract greater numbers of wild fish and could therefore provide a further resource to them.

LACERDA: Insisted that fishermen only support development of species that do not compete with or threaten the economic value of their most important species

WORKSHOP CONCLUSIONS

The very first stage of aquaculture development in the Azores region must be the fortification of relationships between interested parties and shareholders. A primary recommendation of this workshop was that a special Aquaculture Committee comprised of local and foreign experts should be established ("Selected Elements", p. 69) with the express objective of moving this interest forward. The role of the committee would be to undertake a comprehensive evaluation of aquaculture in the Azores with the goal of developing a clear strategic plan for future expansion.

Although the remit of the Aquaculture Committee would be broad ("Selected Functions", p. 70), a key role of the Aquaculture committee would be to initiate a survey and evaluation of the area for aquaculture. The initial assessment should include an analysis of current legislation, regulations and permit requirements as well as determining the agencies that should be involved. Further aims of the evaluation include not only the identification of the best sites and technology for the area, but also potential investors, markets, etc. (see "Aquaculture Development Plan for the Azores", p. 73), including proposals for the conciliation of this plan for the development of a new economic activity with other plans and activities. About this, Azorean fishermen have expressed strong signals of concern.

Two very clear options were proposed for the first aquaculture facility in the Azores: an experimental sea-cage facility or a land-based on-growth and hatchery facility. A sea-cage facility would essentially be a pilot project aimed at proving the potential of finfish aquaculture in the area with the intention of attracting more private financial resources and investors. A land-based system, on the other hand, would produce more simply cultured invertebrate species with a good market value. The best approach, however, will be that decided by the Aquaculture Committee as many factors need to be taken into account, not least the best and most profitable species (See Table 1, p. 75) but so too the funds available for its execution.

It will be mandatory, however, to establish an Aquaculture Research and Development Centre, focussing on one or more of the species mentioned in Table 1 (p. 75). Research is central to the development of any aquaculture venture and work already underway by local private enterprises as well as by IMAR/DOP (University of the Azores) can be considered a starting point to further research in the field of aquaculture. Funds for research can be sought from Regional Government-independent sources, nationally and at the EU or international (e.g. U.S.A.) level in order to begin strengthening and improving expertise of local researchers.

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c) Article from a journal:

Bentley, M.G., P.J.W. Olive, P.R. Garwood & N.H. Wright 1984. The spawning and spawning mechanism of *Nephtys caeca* (Fabricius, 1780) and *Nephtys homebergi* Savigny, 1818 (Annelida: Polychaeta). *Sarsia* 69: 63-68.

d) Electronic article, from online-only Journal:

Woo, K.L. 2006. Testing Visual Sensitivity to the Speed and Direction of Motion in Lizards. *Journal of Visualized Experiments* [Internet]. Available from: http://www.jove.com/index/details.stp?id=127 (cited 18 February 2007).

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