Interactions between

Aquaculture and the Environment

1 Guide for the Sustainable Development of Mediterranean Aquaculture

feap
Federation of European Aquaculture Producers

MINISTERIO DE AGRICULTURA, PESCA Y ALIMENTACIÓN
SECRETARÍA GENERAL DE PESCA MARÍTIMA

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1

Guide for the Sustainable Development of Mediterranean Aquaculture

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Table of Contents

Annexes

Foreword

Aquaculture currently faces a significant challenge: how to fulfil the expectation of alleviating the pressure that fishing fleets exercise on fish populations and the increasing demand of sea products in local and international markets without leading to environmental problems. Particularly, aquaculture is expected to develop widely in the near future, in the Mediterranean's European, Southern and Eastern countries. In order to avoid potential environmental disruption issues, it is important that the aquaculture sector is provided with clear, user friendly and scientifically-based guidelines to ensure its sustainable development.

The Marine Programme of the World Conservation Union (IUCN) has been promoting best practices in the aquaculture sector. The IUCN and the Federation of European Aquaculture Producers (FEAP) signed a common agreement to cooperate in the development of sustainable aquaculture in 2005. Within this framework, IUCN and the General Secretariat for Fisheries of the Ministry of Agriculture, Fisheries and Food of Spain (MAPA), signed an agreement to cooperate and develop "Guidelines for Sustainable Development of Mediterranean Aquaculture". The objective of these guidelines is to propose recommendations for responsible and sustainable aquaculture, giving support to decision makers, aquaculture producers and stakeholders in the Mediterranean region. The guidelines will be made up of a number of individual guides. These guides will address the following issues, amongst others: The Interaction between Aquaculture and Environment; Site Selection; Species and Products Diversification; Animal Welfare and Sanitary-Ethic Aspects; Social Aspects; Food Origin and Quality; Market Aspects; Aquaculture Management.

The working group, originally named "Aquaculture and Environment", was set up in 2004 by IUCN's Centre for Mediterranean Cooperation, and is composed of aquaculture specialists from around the Mediterranean region, with differing areas of expertise. After an initial meeting in 2004, the group organised a workshop with the Algerian Ecologic Movement (MEA) and the Algerian Ministry of Fisheries, in Algiers (June 2005). Later, there was a meeting in Barcelona (November 2005) designed to push forward work on the results obtained from the Algerian workshop and plan future activities.

This document belongs to a collection of guides that together will make up the guidelines for the development of sustainable aquaculture; this first one is devoted to the interaction between aquaculture practices and the environment. The document does not address interaction with other human activities taking place in the same environment. Neither does it cover fresh water aquaculture, although some examples are taken from this activity. It addresses finfish and shellfish culture, but mainly focuses on finfish aquaculture, and specifically cage culture.

The present document is the result of a three-day workshop held in Las Palmas de Gran Canaria (26-28 October 2006) and organised by BIOGES (University of Las Palmas de Gran Canaria). This workshop gathered 26 participants from most of the Mediterranean countries. There were scientists and aquaculture producers, as well as representatives of governmental and environmental organisations (the participants list can be found in Annex). The compilation of data and drafting of this document have been done by Alex Makol and Ricardo Haroun (BIOGES), with the participation of all workshop participants, and under the coordination of Javier Ojeda (APROMAR/FEAP) and François Simard (IUCN).

Executive Summary

Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated.

Most of the potential environmental impacts of aquaculture can be managed and minimised through the understanding of the processes, responsible management and the effective siting of farms. Therefore, sustainable management guidelines are essential tools for policy makers, administrators, aquaculture producers and other stakeholders. This guide is devoted to the interaction between aquaculture practices and the environment, in particular:

Guide A: Domestication

Guide B: Introduced Marine Species

Guide C: Capture of Wild Stocks for Aquaculture Needs

Guide D: Feed Ingredients

Guide E: Organic Matter in the Effluents

Guide F: Pathogen Transfer

Guide G: Therapeutic and other Products

Guide H: Antifouling Products

Guide I: Effects on Local Flora and Fauna

Guide A Domestication

Principle

The domestication of species for aquaculture is necessary. The interaction of these domesticated organisms with their wild counterparts should not have negative effects.

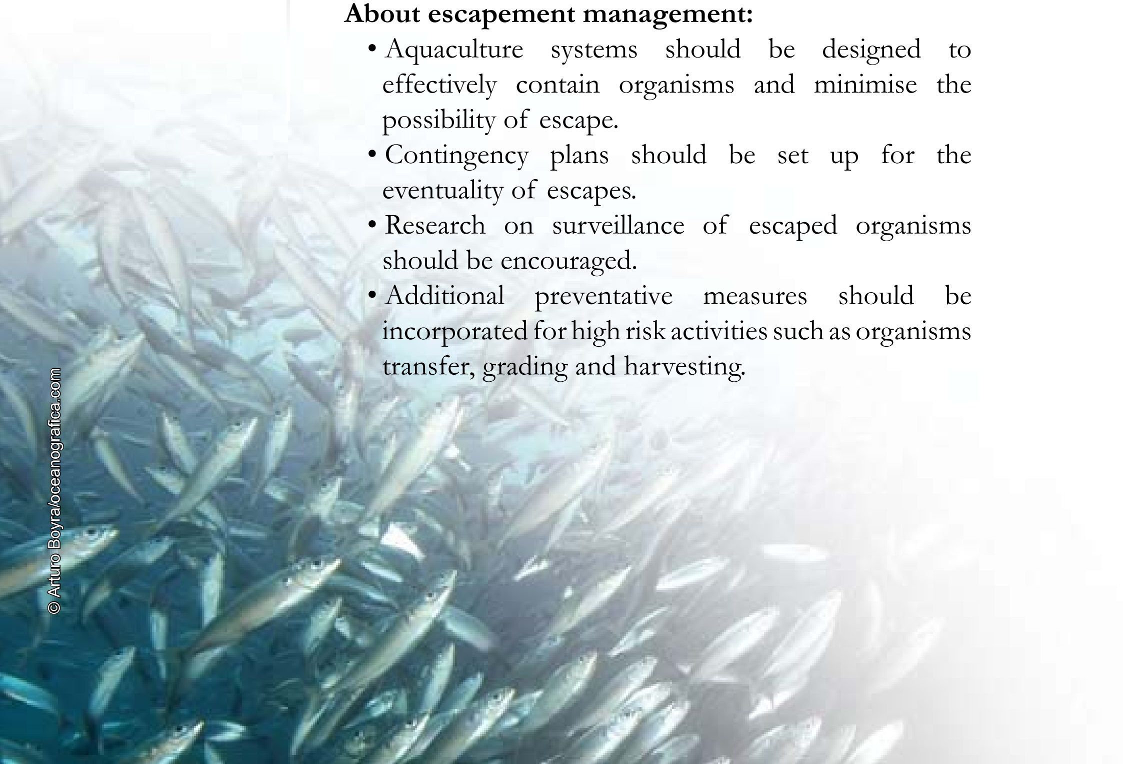
Guidelines

About the development of domestication:

- Domestication of aquacultured organisms should be encouraged.
- Selective breeding of aquacultured organisms should be designed to reduce their capacity to survive or reproduce in the wild.
- Research for domestication should be encouraged and supported.
- The creation of gene banks of wild species should be encouraged as a reservoir of genetic sources.

About escapement management:

- Aquaculture systems should be designed to effectively contain organisms and minimise the possibility of escape.
- Contingency plans should be set up for the eventuality of escapes.
- Research on surveillance of escaped organisms should be encouraged.
- Additional preventative measures should be incorporated for high risk activities such as organisms transfer, grading and harvesting.



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Guide B Introduced Marine Species

Principle

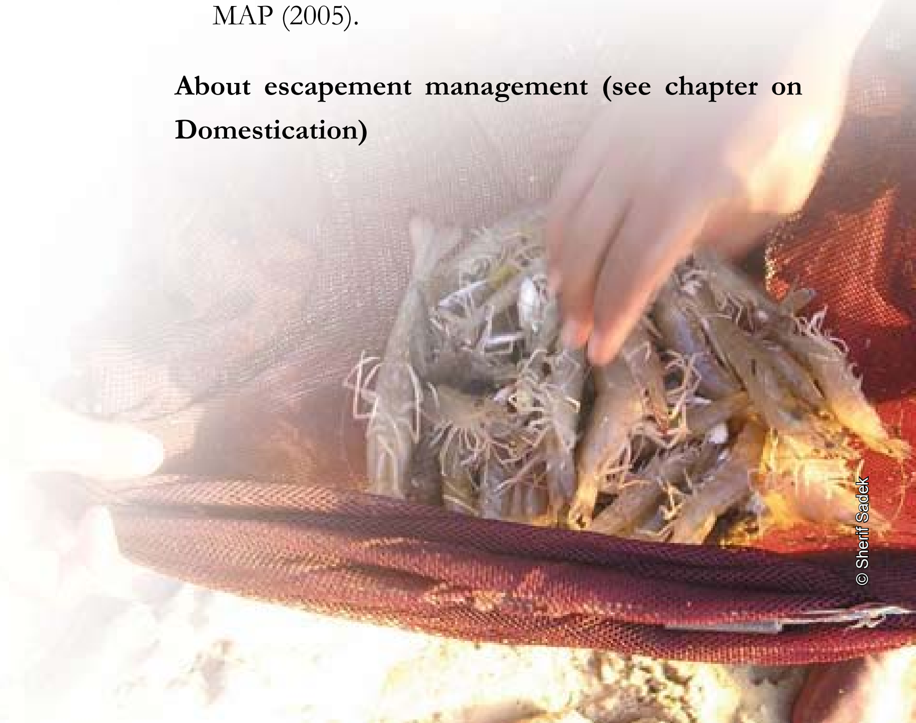
In aquaculture the use of introduced species is highly risky. The precautionary principle should be applied. Introduction of species should be carried out only in special cases and taking all required precautions.

Guidelines

About introduction of species

- Native species should be cultured whenever feasible.
- The recommendations developed in the ICES Code of Practices on the Introductions and Transfers of Marine Organisms (2005) as well as the considerations and suggestions of the report on Alien Species in Aquaculture by IUCN (2006) should be followed.
- Regional and international collaboration should be supported to address transboundary biodiversity impacts of introduced species as stated in UNEP/MAP (2005).

About escapement management (see chapter on Domestication)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Guide C

Capture of Wild Stocks for Aquaculture Needs

Principle

The stocking of aquaculture farms should not affect the natural status or viability of wild populations, their ecosystems or biodiversity in general.

Guidelines

- It is preferable that organisms to be raised in aquaculture farms should have been produced in hatcheries.
- Research on the closing of the life cycles of aquacultured species should be encouraged in order to be able to produce hatchery reared organisms.
- Research on the fish life cycle and functioning of the ecosystem should be encouraged.
- The sourcing of individuals for stocking the aquaculture farms done through their capture from wild stocks should be exercised in a sustainable manner.
- The capture of specimens to be used as broodstock in hatcheries should not distort wild populations.
- Wild stocks from endangered species should not be used, except for rehabilitation or recovery plans, in order to maintain biodiversity.

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Guide D

Feed Ingredients

Principle

The production of aquafeeds should be a sustainable activity. The sourcing of these raw materials should be environmentally acceptable, and should not have negative impacts on the ecosystems from which these ingredients are harvested.

Guidelines

About the origin of raw materials:

- The origin of raw materials should be certified as sustainable.

About the use of feeds and technology:

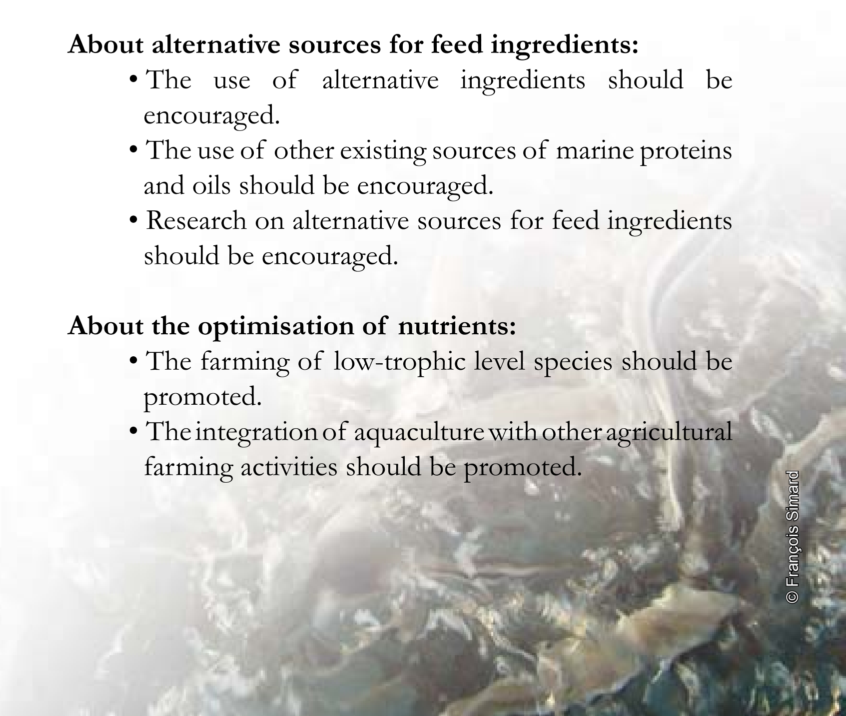
- The use of formulated feeds should be recommended.
- Feed management should be improved.
- Feed production technologies and feed quality should be improved.

About alternative sources for feed ingredients:

- The use of alternative ingredients should be encouraged.
- The use of other existing sources of marine proteins and oils should be encouraged.
- Research on alternative sources for feed ingredients should be encouraged.

About the optimisation of nutrients:

- The farming of low-trophic level species should be promoted.
- The integration of aquaculture with other agricultural farming activities should be promoted.



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Guide E Organic Matters in the Effluents

Principle

The organic matter provided by aquaculture farms effluents should, in quantity and quality, be capable of assimilation by the ecosystem, thereby not producing negative effects on the local environment.

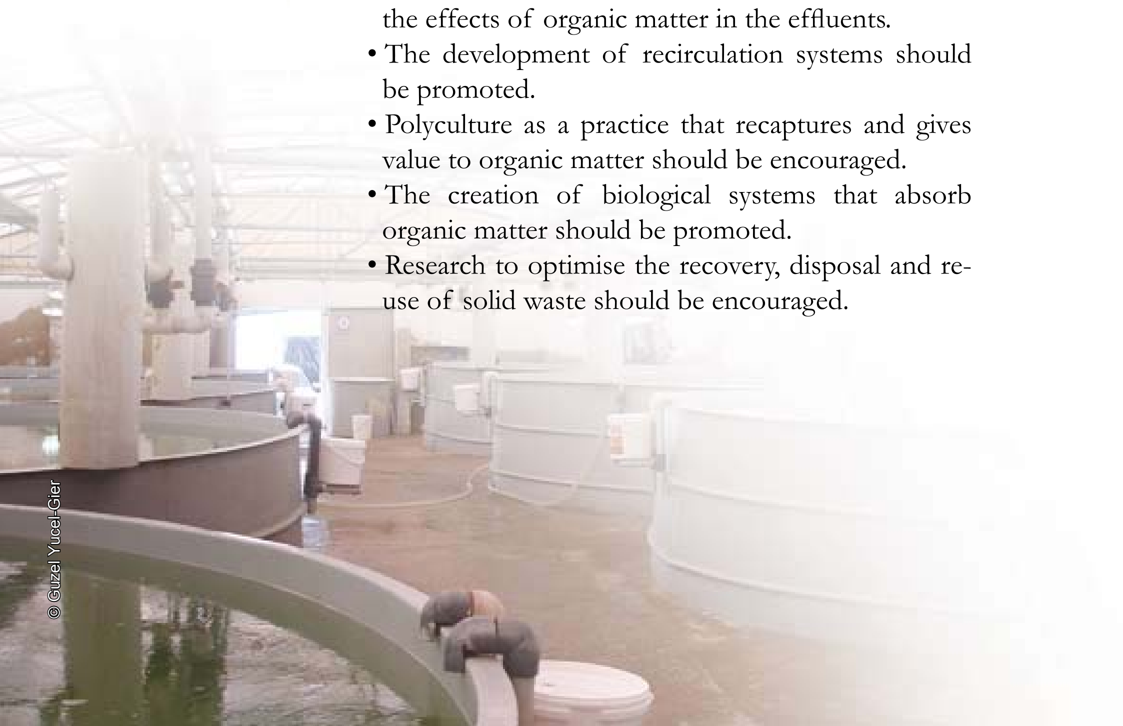
Guidelines

About farm management:

- Farms should be managed in order to control the organic matter effluents from their facilities.
- Feed quality should be understood as essential for organic matter control.
- Best feeding practices should be applied.
- Fish mortalities should be disposed of properly.

About mitigating the organic effluents and benefiting from organic matter:

- Siting of aquaculture farms should take int account the effects of organic matter in the effluents.
- The development of recirculation systems should be promoted.
- Polyculture as a practice that recaptures and gives value to organic matter should be encouraged.
- The creation of biological systems that absorb organic matter should be promoted.
- Research to optimise the recovery, disposal and re-use of solid waste should be encouraged.



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Guide F

Pathogen Transfer

Principle

The possible transfer of pathogens between farmed organisms and wild stock populations should be minimised.

Guidelines

- Aquacultured organisms should be kept in the best possible health.
- Disease outbreaks in aquaculture farms should be prevented, contained and managed.
- Precautionary measures should be implemented to prevent disease transfer.
- Special biosecurity measures to limit the introduction of pathogens in hatchery systems should be implemented.
- The research and monitoring of diseases in wild populations in the vicinity of aquaculture areas should be encouraged.

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Guide G Therapeutic and other Products

Principle

The use of therapeutants should be managed correctly to minimise possible detrimental effects on the natural environment.

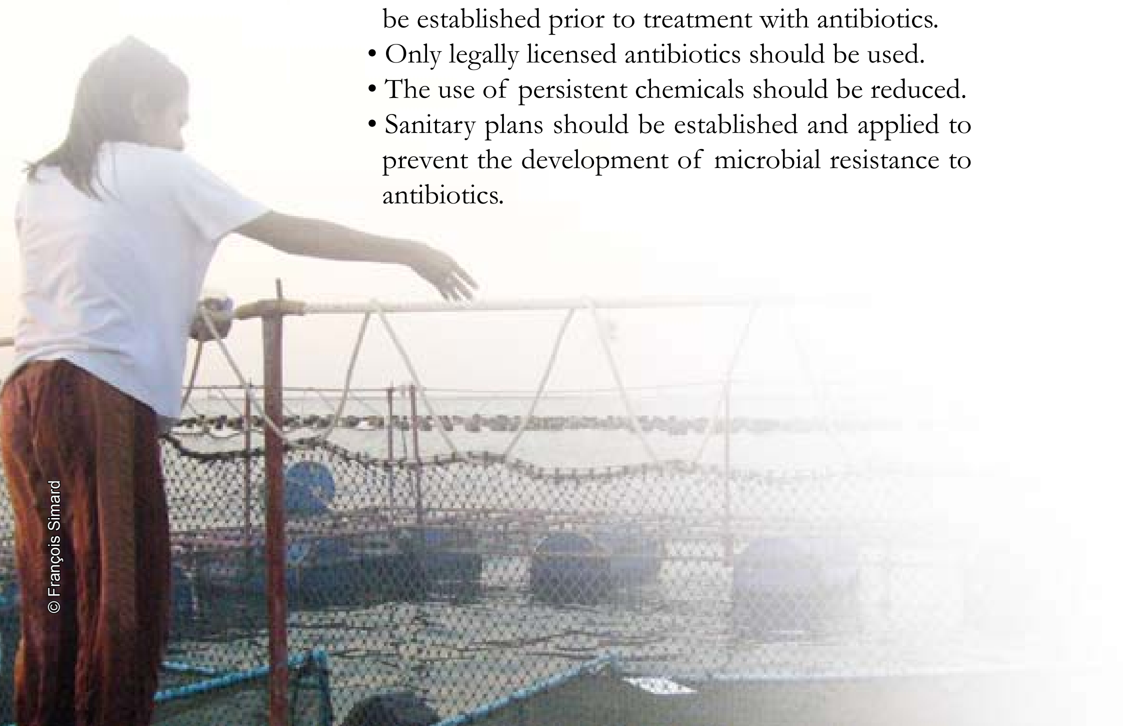
Guidelines

About the reduction of the use of therapeutants:

- Aquaculture sanitary policies should be based on appropriated preventative and prophylactic measures.
- The use of antibiotics as a prophylactic method should be avoided.
- More effective and safer veterinary medicines should be made available to the aquaculture industry.

About the proper management of therapeutic and other products:

- A precise laboratory diagnosis of the diseases should be established prior to treatment with antibiotics.
- Only legally licensed antibiotics should be used.
- The use of persistent chemicals should be reduced.
- Sanitary plans should be established and applied to prevent the development of microbial resistance to antibiotics.



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Guide H Antifouling Products

Principle

Antifouling products used in aquaculture should have no perceivable toxic effects on non-targeted organisms of the surrounding ecosystems.

Guidelines

- Eco-friendly antifouling coatings and products should be used.
- Environmentally friendly procedures for preventing or eliminating biofouling should be encouraged.
- The use of antifouling products based on heavy metals should be avoided.

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Guide I

Effects on Local Fauna and Flora

Principle

The negative impacts of interaction between aquaculture and local fauna and flora should be avoided, whilst the positive effects should be exploited.

Guidelines

About the effects of aquaculture on benthic communities

- Environmental Impact Assessments should be carried out to detect any possible effect on the wild ecosystem.
- Decisions to develop or stop further deployment of aquaculture facilities should be managed case by case.
- Hydrodynamic and ecological studies should be conducted as part of the process of site selection.
- Areas which contain significant communities of seagrass meadows should be considered as incompatible with the establishment of aquaculture facilities.
- The settlement of cages in exposed areas, located away from the coastal shore, should be encouraged.

About attraction of fauna

- The attraction of local fauna by the aquaculture structures should be considered in the management of farms.
- The attraction of predators and scavengers should be properly managed.

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Introduction to the Guides

During the last decade there have been increasing efforts to address the sustainable development of human activities, understanding this as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*", as defined by the World Commission on Environment and Development (WCED) in 1987.

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Aquaculture has attracted the attention of governmental authorities and non-governmental sectors, and a more specific definition was proposed by the Food and Agriculture Organization of the United Nations (FAO) in relation to agriculture and fisheries: "*Sustainable development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable*" (1997).

The development and intensification of aquaculture has revealed a broad spectrum of associated environmental issues. Fish and crustaceans are fed diets with high contents of protein and oils, mainly fishmeal and fish oil. Seed and broodstock are sometimes obtained from wild stocks, due to the difficulty of raising them in captivity, thereby increasing the pressure on wild fish populations. Another problem is the chemical interaction produced by the discharge of water effluents from aquaculture facilities, which may contain residues of therapeutic products, antifouling agents or uneaten fish feed. If improperly managed, this can lead to antibiotic pathogen resistance, water eutrophication, oxygen depletion and other problems that could damage the environment. Biological interaction caused by the unintentional release of farmed organisms, or the introduction of non-indigenous species into the environment, may cause alterations in the genetic pattern of wild populations. Such organisms may compete with native species for food and space, and might also transfer diseases and parasites. Although bacteria, viruses and other pathogens occur naturally, disease outbreaks are more likely to occur in farmed animals, and bidirectional transfers of pathogens between farmed and wild organisms might take place. All these aspects should also be taken into account when considering the relation of aquaculture with the other human activities in coastal areas. This is the case of the interaction between aquaculture and capture fisheries also in terms of environmental interaction within marine and coastal ecosystems.

Most of the potential environmental impacts of aquaculture can be managed and minimised through the understanding of the processes, responsible management and the effective siting of farms. Therefore, sustainable management guides are essential tools for policy makers, administrators, aquaculture producers and other stakeholders.

In its Communication to the Council and the European Parliament "A Strategy for the Sustainable Development of European Aquaculture" (Commission of the European Communities, 2002), the European Commission addressed the environmental effects of aquaculture and identified this as a key issue.

The Federation of European Aquaculture Producers (FEAP) produced a Code of Conduct (2000) that promotes responsible development and management for the European aquaculture industry, in order to guarantee high quality levels in food production and respect for the environment.

General Situation of Aquaculture

Worldwide demand for fishing products tripled between 1961 and 2001 as a result of the human population increase and the rise of consumption per person from 11 Kg./person/year in 1970 to 16,2 Kg./person/year in 2002 (FAO, 2004b). Fisheries products are at present one of the most important animal proteins in the world, representing 25% of the ingested protein in developing countries and 10% in Europe and North America.

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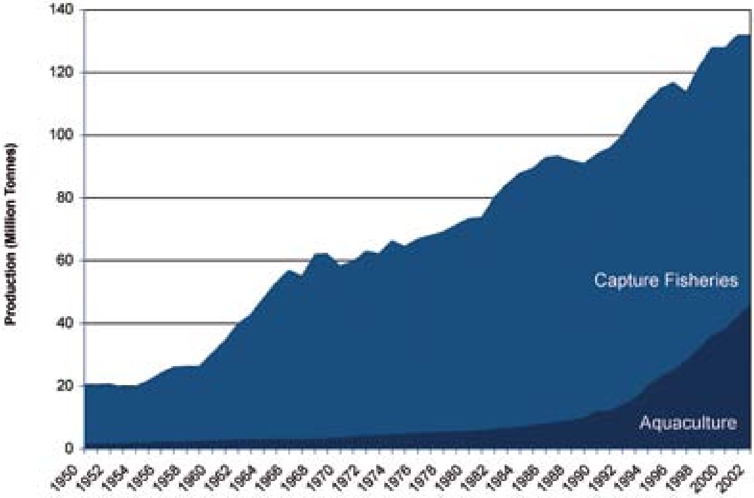
Aquaculture and extractive fishing are complementary activities that must face the challenge of this increasing demand for marine products. The production of extractive fishing reached its highest levels at the end of the 1980s, and since that time has fluctuated around the same level (90-95 million tonnes), indicating that the oceans are being exploited near to their maximum production. The improvements in the management of fishing resources will result, at best, in the maintenance of current fishing levels. As FAO confirms (FAO, 2004b), future increases in the production of fishing products can only come from aquaculture, as has been happening over the last 15 years.

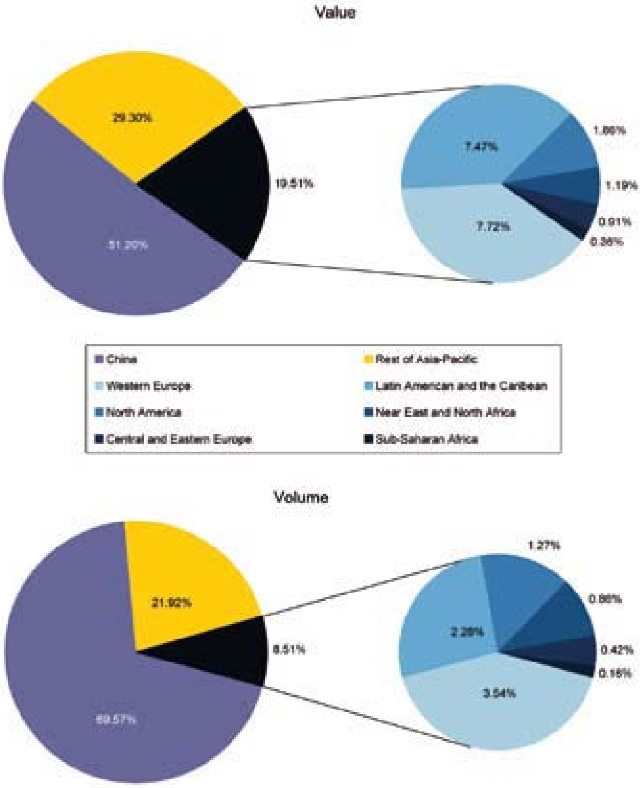
Figure 1. Evolution of the fisheries production (capture fisheries and aquaculture) in the world duing the period 1950-2003 time frame (FAO, 2004b).



Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated.

Aquaculture has a history of 4,000 years, but it is only in the last 50 years that it has become a socioeconomic activity of importance, giving employment to 9.8 million people around the world (FAO, 2004b). Its contribution to the world's fish, crustacean and mollusc supply is growing every year. According to FAO (FAO, 2004b), contribution of aquaculture to world supply has increased from 3.9% of the total fishing production (in weight) in 1970, to 29.9% in 2002, with a forecast of 50% in 2025. However, in 2006 aquaculture already provided almost half of fishing products for direct human consumption.

Figure 2. World aquaculture production in 2004 by region with China disaggregated from the rest of Asia (FAO, 2006a).



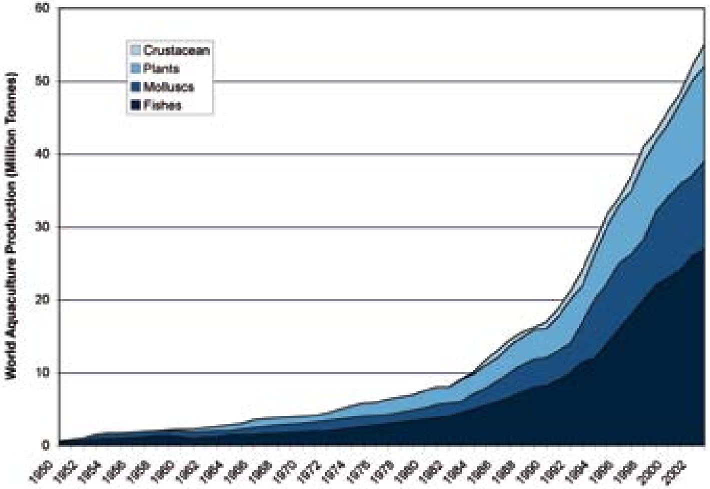
Aquaculture grows faster than other animal-origin food production sectors. On a world scale, the sector has grown with in average of 8.9% per year since 1970, in contrast with the 2.8% in meat terrestrial production systems.

More than 90 % of aquaculture production comes from Asia (mainly China), 3.5% comes from Western Europe, 0.4% from Central and Eastern Europe, 2.3% from Latin America and the Caribbean, 1.3% from North America and 0.9% from the Near East and North Africa, with the remaining 0.2% coming from sub-Saharan Africa (Figure 2).

Aquaculture is an activity that includes very diverse practices and a wide range of production species, systems and techniques. Its economic dimension offers new socioeconomic opportunities in the regions where it settles thanks to job creation, the more efficient use of natural resources and the promotion of local and international trade. The success of modern aquaculture is based on the control of the reproduction of species, a better knowledge of biology, technological innovations and the development of safe and high quality food products.

In 2003, half of global aquaculture production was fish, but the increase of production refers to all species groups (FAO, 2006a).

Figure 3. Evolution of the world aquaculture production by group. 1950-2003 (FAO, 2006a).



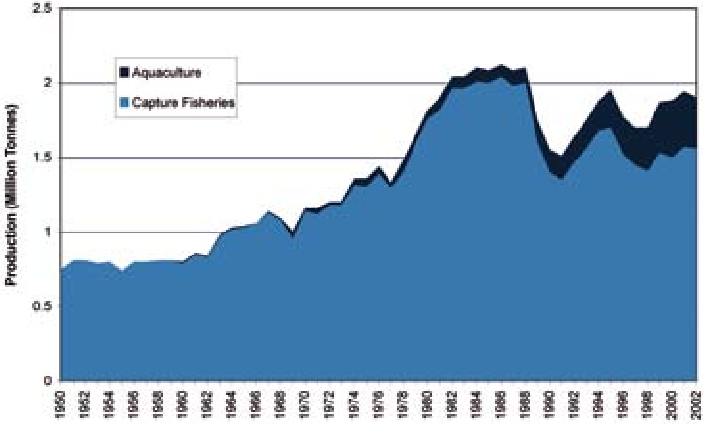
The main species cultivated worldwide are omnivorous and herbivorous finfish. These are produced mainly in developing countries, with production close to seven times that of carnivorous finfish, which are primarily cultured in developed countries.

In contrast with terrestrial agriculture and fishing exploitation systems, in which the majority of production is obtained from a reduced number of animal and plant species, more than 210 aquatic animal and plant species were being grown around the world in 2003. This diversity is due to the high number of aquatic organisms that can adapt to controlled production systems and conditions.

During the last thirty years, aquaculture has grown and diversified, and has registered enormous technological improvements. The potential of these improvements for socioeconomic welfare – both in developed and developing countries - for the enhancement of the quality of life and for the increase of food security, have been acknowledged by FAO in its Bangkok Declaration and Strategy (2000). This highlights the need to continue its development until it can display its full potential to humankind.

In the Mediterranean region, aquaculture has rapidly expanded over the last two decades, with an annual growth rate rising from 4% in 1980 to 13% in 2000, and with a trend towards the diversification of cultured species which facilitates the growth of the sector.

Figure 4. Fisheries and Aquaculture Production in the Mediterranean (FAO, 2006a)



Although Mediterranean aquaculture production was focussed mainly on mollusc farming during the mid 1990s, the share of finfish culture continues to increase.

Comparing the total Mediterrean aquaculture production from 1994 to 2003, a significant increase in finfish production has been registered in the Mediterranean aquaculture (almost three times higher); mollusc farming has also increased (Figure 5).

Figure 5. Aquaculture in the Mediterranean. Production by major groups (FAO, 2006a)

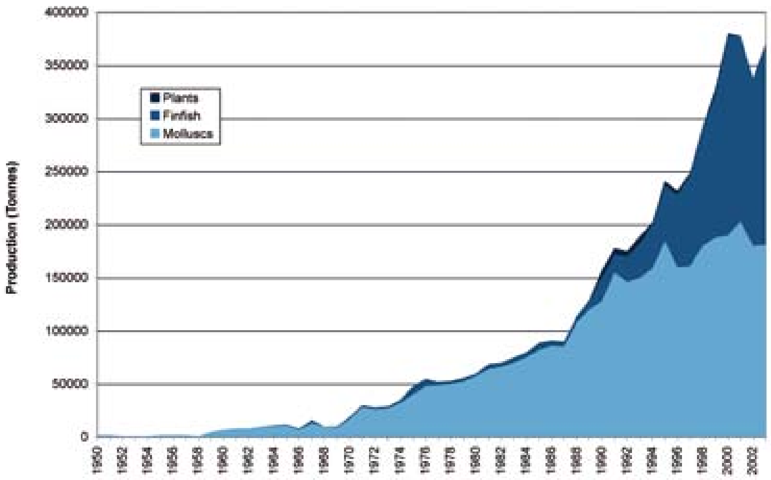


Table 1. Aquaculture in the Mediterranean. Production by species (FAO)

Mediterranean mussel *(Mytilus galloprovincialis)*	147,920t.
Gilthead seabream *(Sparus aurata)*	74,078t.
European seabass *(Dicentrarchus labrax)*	43,804t.
Flathead grey mullet *(Mugil cephalus)*	42,546t.
Japanese carpet shell *(Ruditapes philippinarum)*	25,000t.
Other seabass	20,982t.
Pacific cupped oyster *(Crassostrea gigas)*	8,608t.
Other marine fish	4,894t.
Trout *(Salmonids)*	1,194t.
Red drum *(Sciaenops ocellatus)*	438t.

Domestication

This Guide addresses the environmental aspects of species domestication for aquaculture purposes. Domestication in aquaculture is the acclimatisation to captive conditions, the total control of the life cycle and the manipulation of breeding in captivity of aquatic organisms (Hassin *et al.*, 1997).

Current situation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Domestication can contribute to sustainable aquaculture since it avoids the need to capture wild stocks for on-growing. Furthermore, thanks to domestication, the potential impact on the wild ecosystem of fish escapes can be minimised since cultured organisms can be selected to be unable to survive in wild conditions, dying in a short period of time and with a high percentage of organisms unable to reproduce (sterile organisms).

Some characteristics that determine the suitability of a species for domestication are: better growth (quantity and quality); better resistance to stress situations that may occur in aquaculture farms; high economic value; acceptance of aquafeeds; and ability to reproduce in captivity.

The obstacles to domesticating species are associated with the difficulties affecting some fundamental principles of aquaculture, such as captive breeding, biological growth and health conditions. Experience indicates that limiting factors include the inhibition of reproduction or lack of reliable mass-seed production in captivity; the inadequate supply of specific high quality artificial aquafeed suitable to cover all nutritional and physiological requirements; and the reduction of welfare and immunisation, which may lead to disease outbreaks.

Some negative effects associated with domestication are related to the emergence of genetic drift and inbreeding problems (Falconer, 1989; Agnese *et al.*, 1995), due to the fact that normally in captivity, only a small population of parents is maintained. Moreover, in the case of the escape of farmed organisms obtained from domesticated parents, the local ecology mtight be imbalanced and dislodged through interactions between domesticated and wild organisms, eventually resulting in reductions in the size of wild populations, and negative consequences on their genetic variability. Salmon culture is one of the most important cases where detrimental effects on the genetic integrity and diversity of wild stocks has been reported (Allendorf, 1991; Thorpe, 1991; Guillen *et al.*, 1999; Muir & Howard, 1999) due to the significant differences shown between the offspring of domesticated and wild parents (Lachance & Magnan, 1990; Berejikian, 1995).

Current scientific knowledge

Research is carried out to obtain species which are completely acclimatised to captivity, with faster growth rates, and resistance to stress conditions and diseases. Therefore, the process of domestication in the Mediterranean region is at present focused on large numbers of species in order to diversify aquaculture products, as well as to improve husbandry of current cultured species (Mylonas *et al.*, 2004; Papandroulakis *et al.*, 2005; Agulleiro *et al.*, 2006). Part of the research efforts are centred on methods and techniques to produce non-viable varieties of species, in order to make them sterile, unable to survive in wild conditions, and incapable of reproduction and cross-breeding with wild stocks (Brake *et al.*, 2004; Omoto *et al.*, 2005; Cal *et al.*, 2006; Gagnaire *et al.*, 2006). Modern genomic technologies can help traditional selective breeding techniques by accelerating the procedures (Howard *et al.*, 2004).

Justification

The advantages of domesticating organisms are: to secure seed supply and improve production efficiency through the mastering of breeding and feeding to select organisms that can grow faster; to achieve better feed efficiency; and therefore to alleviate the pressure on fishes used as feed. It will also minimise the potential negative impacts on wild stocks by trying to make cultured organisms unable to live in the wild ecosystems.

However, domesticated animals become significantly different over time from their wild counterparts, both genetically and physically. The escape or release of strongly domesticated organisms into the environment can lead to unpredictable effects on the ecosystems, both on wild populations of the same species and/or other organisms. In the case of aquaculture, the risk posed by the escape of domesticated organisms is far greater than that of terrestrial animals or plants in similar circumstances, because of their ability to disperse and the difficulty of recapture.

Principle

The domestication of species for aquaculture is necessary. The interaction of these domesticated organisms with their wild counterparts should not have negative effects.

Guidelines

About the development of domestication:

- **Domestication of aquacultured organisms should be encouraged**. The domestication of organisms in aquaculture is key for its sustainability. It also might avoid the need to capture wild specimens and might improve the efficiency of production by reducing the need for raw materials, mainly feed, by increasing disease resistance, etc.

- **Selective breeding of aquacultured organisms should be designed to reduce their capacity to survive or reproduce in the wild**. When cultured organisms are not able to survive or reproduce in wild conditions, the potential environmental effects due to escapes are minimised. Therefore, the use of deeply domesticated organisms seems to be the best option to minimise these potential effects.

- **Research for domestication should be encouraged and supported**. These efforts should also include, besides improving productivity or disease resistance, methods for reducing fertility and making farmed organisms unable to live in the wild. Modern genomic technologies can help traditional selective breeding techniques by accelerating trials and procedures.

- **The creation of gene banks of wild species should be encouraged as a reservoir of genetic sources**. The preservation of genetic values is essential for conserving biodiversity, and so a secured source of genes would help in the future to restore affected populations. On the other hand, and for production purposes, biological traits not sought today might be needed in the future, and a recovery path must be left available.

About escapement management:

- **Aquaculture systems should be designed to effectively contain organisms and minimise the possibility of escape**. The design of aquaculture facilities should consider the need to prevent escapes, not only because of the economic loss that these mean for the producers, but also for environmental reasons.

- **Contingency plans should be set up for the eventuality of escapes**. Domesticated organisms do not tend to disperse quickly after escaping. For this reason, there is a period of time in which the recapture of the organisms is feasible, and after which this task becomes almost impossible. In order to take action as soon as an escape takes place, detailed contingency plans must exist and personnel must be properly trained.

- **Research on surveillance of escaped organisms should be encouraged**. More knowledge is needed concerning the quantitative and qualitative effects of escapes on local populations. Also, because the escape of cultured organisms has an important cumulative effect, producers should report to the competent authorities the occurrence of such escapes in order to better understand their effects.

- **Additional preventative measures should be incorporated for high risk activities such as organisms transfer, grading and harvesting**. When transferring cultured organisms to different containments, when harvesting or with any other routine that implies movements, there is the potential risk of escapes. Therefore, in those conditions, stricter measures should be applied to minimise risks.

Genetically Modified Organisms (GMO)

The desired genetic improvements of aquacultured organisms are sought by means of traditional breeding procedures. The use of genetic engineering techniques (gene transfer technologies) to produce Genetically Modified Organisms (GMO) for aquaculture is not in the consideration of producers in the Mediterranean region. According to FAO (2006a), the use of genetically modified organisms is controversial in most regions due to concerns about environmental and human health risks.

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Introduced Marine Species

Biological invasion has been one of the most serious ecological problems of the 20th and 21st centuries. Since the 1950s, world trade has increased 14-fold; during this same period, biological invasions in terrestrial, freshwater and marine habitats has increased exponentially (Ruesink *et al.* 1995; Ruiz *et al.*, 1997; Nordstrom & Vaughan, 1999). Efforts have been made internationally and domestically to prevent, eradicate and control introduced species. However, new pathways and new invasions are still being discovered in diverse coastal areas, often at a stage when invaders are already well established and the response to date has been inadequate, and much remains to be done (Doelle, 2003; McNeely & Schutyser, 2003).


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Scientists and policy makers increasingly see the introduced species invasion as a major threat to marine biodiversity and a contributor to environmental change (Bax *et al.*, 2001, Hewitt *et al.,* 2006). Introductions of species in the marine environment can result from numerous human mediated activities that are typically driven by global trade and human movement. Marine introduced species are moved by human activities to an area outside their natural range, and might threaten human health, economic or environmental values. The introduction of marine species might be a major threat to the marine environment when they become invasive (Carlton, 1992; Naylor *et al.,* 2001; UNEP/MAP, 2005) and adversely affects economically important marine-based activities and uses. Impacts of invasive marine species can be dramatic and are usually irreversible. Introduced invasive marine species might have consequences as negative as collapsing fisheries, destroying aquaculture stock, increasing production costs, threatening human health and altering biodiversity. But not all introduced species become invasive; many of them just settle in their new ecosystem and participate in its development (Wabnitz *et al.*, 2003).

Introductions can be either accidental or intentional, and arise from a wide range of practices. Globally, at any given moment, some 10,000 different species are being transported between bio-geographic regions in ballast tanks. Fortunately, most potential invaders die before they can establish because environmental conditions at the receiving ecosystem are not suitable. Even when they establish, at first most do not become invasive.

As stated in a recent report of the European Environmental Agency (EEA, 2006), biological invasions in the Mediterranean Sea are a matter of concern. There is a high number of introduced marine species which are increasing, mainly in ports and lagoons. Transportation via the Suez Canal is also important; hence the greater number of alien species in the eastern basin (UNEP/MAP, 2004).

- Over 600 marine exotic species have been recorded in the Mediterranean Sea.

- The rate of introduction of exotic species in the Mediterranean Sea peaked in the 1970–1980 period, and since then has remained stable or kept increasing for most groups, especially for the bottom-living animals.

- An average of one introduction every four weeks has been estimated over the past five years.

The mode of introduction is different between the two basins. Whereas in the eastern Mediterranean, penetration via the Suez Canal is the main mode of introduction, in the western Mediterranean, shipping mainly and/or aquaculture are responsible for the great majority of exotic species. Lagoon ecosystems in the northern Adriatic and the south of France (with 70 and 96 exotic species respectively, mostly introduced via aquaculture) are considered hot-spot areas for exotic species (EEA, 2006).

Current situation

Although the main vectors of introduced marine species are ballast water and fouling, aquaculture has also been pointed out as an important vector for the arrival of alien species to coastal areas. Approximately 17 percent of the world's finfish production is due to alien species. Production of the African cichlid tilapia is much higher in Asia (greater than 700,000 metric tonnes in 1996) than in most areas of Africa (39,245 metric tonnes). Introduced salmonids in Chile support a thriving aquaculture industry that is responsible for approximately 20 percent of the world's farmed salmon and directly employs approximately 30,000 people (FAO, 2003). Three species of introduced macroalgae have become invasive in Hawaii: *Hypnea musciformis*, *Kappaphycus spp.*, and *Gracilaria salicornia*. These species were intentionally introduced on Oahu and Molokai in the 1970s for experimental aquaculture related with the agar industry. These "weedy" species have now spread from their initial sites of introduction and are competing with native marine flora and fauna (Smith, 2002). Most of introduced macroalgae populations are currently confined to discreet areas and may still be able to be controlled by removal and/or enhancement of native grazer populations.

There are two possible ways of introduction of species in aquaculture:

I. The "voluntary" introduction of a species for aquaculture purpose. It is the case, for example, of the above mentioned macroalgal species in Hawaii as well as that of the Japanese oyster *Crassostrea gigas* in the 1960s in France (Grizel & Héral, 1991). This is not a recent phenomenon, the Portuguese oyster *Crassostrea angulata* was introduced accidentally in France (Gironde estuary) in 1868, and colonised quickly all the Atlantic coast from Biarritz to Brest in less than 20 years (Héral, 1986). Other bivalves have been introduced for their culture such as the clam *Mercenaria mercenaria* in Arcachon basin in 1861 and in Seudre river in 1910 (Ruckebusch, 1949), and the Japanese clam *Ruditapes philippinarum* in 1975 (Flassch & Leborgne, 1992).

II. The "accidental" introduction of species which are associated with other desired species introduced on purpose. It is the case of several Japanese seaweeds such as *Sargassum muticum* and *Porphyra sp.* which have been introduced accidentally (Eno *et al.*, 1997). *Sargassum muticum* (also know as Japanese weed) was reported in the British Isles as

> well as in the Atlantic French coasts associated to imports of Japanese oyster seeds during the 1970s. A few years later, that seaweed appeared together with other Japanese introduced species in the Mediterranean Sea (Sète - Etang de Thau), again associated to Japanese oyster importations. Since that time, *Sargassum muticum* have extended its distribution in the Atlantic European coast from Kattegat and Belt Sea in Scandinavia down to the Portuguese coast (Haroun & Izquierdo, 1991; Eno *et al.*, 1997; Stahr *et al.*, 2000). A similar trend, related to oyster culture, was observed in the Pacific coasts of North America, where *S. muticum* colonised more than 3,000 km in a few decades (Cohen & Carlton, 1995). This brown alga has modified the ecology of intertidal and subtidal macroalgal populations both in the pacific American coast (Britton-Simmons, 2004) and in the Atlantic European coasts (Sánchez *et al.,* 2005; Thomsen *et al.,* 2006). Also some boring or parasitic invertebrates were introduced with the imported oysters such as *Petricola pholadiformis* and *Crepidula fornicata* both from North America, which are widespread in the Baltic and North Atlantic coasts (Eno *et al.,* 1997; Goulletquer *et al.,* 2002; Wolff & Reise, 2002).

According to the CIESM Atlas of exotic species in the Mediterranean Vol. 1 Fishes and Vol. 2 Crustaceans (Galil *et al.*, 2002; Golani *et al.*, 2002), there is one fish species introduced for aquaculture purposes (amongst a total of 90 species of introduced fish species), the mullet *Mugil soiuy*. This species was introduced primarily from the western Pacific in the Sea of Azov and the Black Sea, but is still very rare in the Aegean Sea. Among crustaceans, one species of shrimp, *Marsupenaeus japonicus*, escaped from aquaculture facilities in the Western Mediterranean, but is also rare. The same species has been introduced as well via the Suez Canal and is now very abundant, and commercially important for fisheries, in the Levant and southern Turkey. There are also two species of crabs, *Dyspanopeus sayi* and *Rhithropanopeus harrisii* which have been introduced with clam seed and are now common in the brackish waters of the Adriatic Sea where they are abundant and outnumber the autochthonous crabs.

For fish species, aquaculture can be a vector of introduction outside their natural range through escapes (ICES, 2004; Hewitt *et al.*, 2006).

In this sense, escapes of cultured organisms from aquaculture facilities may interact and harm local wild stocks. Some escapes may occur through normal operational “leakage” where only a few organisms are lost; large-scale escapes can occur caused by storms, vandalism, marine mammals or human error (McGinnity & Ferguson, 2003). When cultured organisms escape or are restocked they may interbreed with wild populations and change their genetic makeup, sometimes decreasing the fitness of wild populations to the natural environment (Hindar, 2001; Youngson *et al.*, 2001; McGinnity & Ferguson, 2003). When the number of escapes is higher than that of wild stocks, the native genetic makeup of wild stock can change, altering local populations (NMFS/FWS, 2000).

Justification

In aquaculture, the risks posed by the introduction of species, whether for their rearing (intentional) or as associated with aquaculture species (accidental), are important. The consequences of the releasing of those species might have major impacts on biodiversity and ecosystem.

Principle

In aquaculture, the use of introduced species is highly risky. The precautionary principle should be applied. Introduction of species should be carried out only in special cases and taking all required precautions.

Guidelines

About introduction of species

- **Native species should be cultured whenever feasible**. The use of introduced species should be reserved for special cases where the escapement of the aquaculture organism or its associated species is controlled (close system) or impossible (reservoir).

- **The recommendations developed in the ICES Code of Practices on the Introductions and Transfers of Marine Organisms (2005)**

as well as the considerations and suggestions of the report on Alien Species in Aquaculture by IUCN (2006) should be followed. In these two dedicated reports there is enough technical information to help decision-makers select the appropriate measures to prevent, eradicate or control introduced marine species when needed.

- **Regional and International collaboration should be supported to address transboundary biodiversity impacts of introduced species as stated in UNEP/MAP (2005)**. Trans-National cooperation is desirable to cope with the spread of introduced marine species in the Mediterranean marine ecosystem.

About escapement management (see chapter on Domestication)

Capture of Wild Stocks for Aquaculture Needs

In this guide, the interaction between aquaculture and the environment is focussed on the need to use stocks of wild living organisms for their later on-growing, or for reproduction purposes, in captivity.

Current situation

For many years, the collection of wild seeds or juveniles has been practised worldwide in order to stock them in aquaculture facilities for on-growing purposes. The collection of adult organisms is a special case related to the construction of captive broodstock used for breeding in hatcheries. The collection of adults is not so important quantitatively, except in recent cases of fattening, such as commercial bluefin tuna farming. The wild collection practice of fingerlings is mainly made for species whose wild stock is high enough to cover the required demand without affecting the natural populations, such as the wild spat collection of some molluscs (mussels, oysters, scallops) (Davenport *et al.*, 2003). It is also carried out for those species whose life cycles are not yet complete, with no way of accurately reproducing them in captivity. Examples include eels (*Anguilla spp.*), tuna (*Thunnus spp.*), yellowtails (*Seriola spp.*), groupers (*Epinephelus spp.*), octopus (*Octopus spp.*), rabbit fish (*Siganus rivulatus*), species of mullet, and others presenting complications, technical or economic (Hair *et al.* 2002; Ottolenghi *et al.*, 2004).

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The dependence on wild populations (larvae, juveniles or adults) as biological material for subsequent on-growing to marketable size, or fattening using captive rearing techniques, is known as capture-based aquaculture. This accounts for about 20% of the total quantity of food fish production through aquaculture – mainly molluscs, though carnivorous finfish are becoming more evident (FAO, 2004b). Nowadays, hatcheries in most countries are capable of producing good quality seeds of marine and freshwater species, gradually diminishing the dependence on wild-caught seed, limited to mature fish for breeding programmes to improve the quality of broodstock (FAO, 2006b).

In the case of the culture of molluscs, juveniles and spats are supplied from hatcheries (such as oysters) or collected from wild populations without adverse effects due to the abundance of organisms (such as blue mussel). The cultivation process mirrors closely the natural mechanisms.

In developing countries, capture-based aquaculture constitutes an alternative livelihood for local coastal communities, and can contribute significant economic returns in those regions with depressed marginal economies (Ottolenghi *et al.*, 2004).

The interaction between Aquaculture and capture fisheries are widely dealt with in the GFCM Studies and reviews N.78 (Cataudella *et al.*, 2005) in which the relationship between the two sector is discussed following a systemic approach, for each of the different dimension of fisheries sector (governance, ecological economic and social).

The main problem of capture-based aquaculture, as described by Nash *et al.* in 2005, is the increase of fisheries pressure on such species (Figures 6 & 7) that may lead to stock depletion, stock collapse or other related problems. In addition, the by-catch of non-targeted species and the destruction and disturbance of habitats should be noted (FAO, 2004a), although Nash *et al.* in 2005 presented evidence of the by-catch produced being small.

Sadek & Mires (2000) have reported their concern about wild fry collection in the Mediterranean Sea, and the possible negative effect that the continuation of such practices can have on wild genetic resources and their environment. Already, in some countries, the current heavy fishing pressure on these resources does not meet aquaculture requirements.

This deficiency only encourages the selective mass transplantation of genetic stocks from one region to another, the continuation of which could eventually endanger some endemic stocks.

As an example, there is the mullet culture in Egypt, which produced 133,000 tonnes in 2004, representing around 38% of the total Egyptian aquaculture production. Meanwhile, Egypt is annually collecting 100 to 135 million mullet species fry from the wild for the mullet culture (GAFRD, 2004).

It can be argued that the early transplantation of wild fry to controlled and protected aquaculture environments only has a negligible effect on wild fish stocks, since only a very small percentage would have naturally survived and reproduced. Nevertheless, nothing can justify mismanagement of fishing practices and transport that cause unnecessary wastage. In the long run, there can be no doubt that aquaculture will have to become self sufficient in this t and more fish hatcheries will have to be built.

Figure 6. Global trends in the total bluefin tuna catch (1991-2000) (FAO, 2004b)

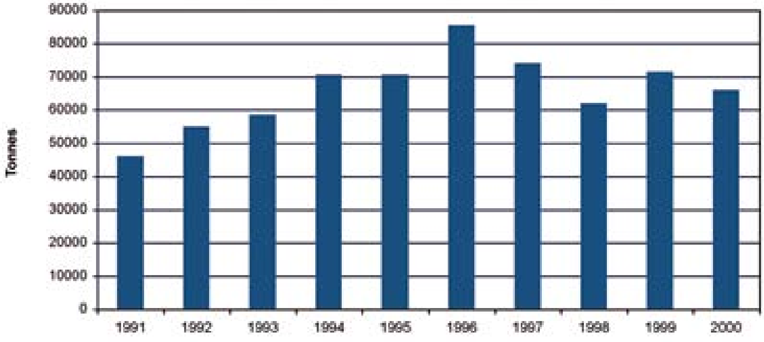
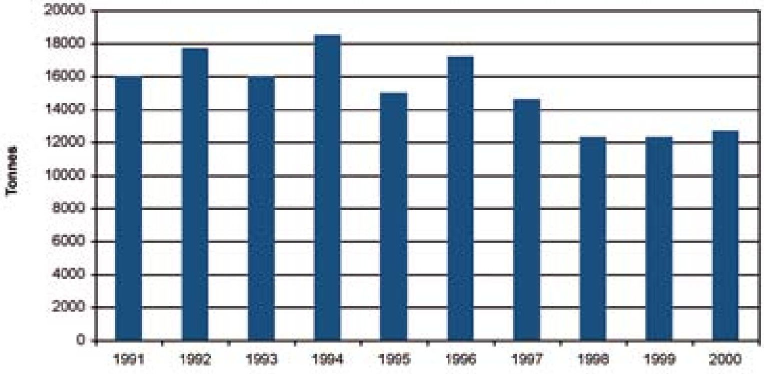


Figure 7. Trends in the global eel catch (1991-2000) (FAO, 2004b).



The estimates of capture-based aquaculture production in 2000 of the main species, such as eels, groupers, yellowtail and bluefin tuna are shown in Table 2. Eels are the main species produced from this type of aquaculture method, where the larval sources are dependent on wild stock.

Table 2. Estimates for capture-based aquaculture production of different species in 2000 (FAO, 2004b).

Species group	Estimated production (thousands tonnes)
Eels	288
Groupers	15
Bluefin tunas	10
yellowtails	136

In the case of bluefin tuna (Table 3), fisheries will collapse if pressure on wild stocks is maintained (Lleonart & Majkowski, 2005; Lovatelli, 2005). The over fishing of adult groupers would result in a decline in the capture-based juveniles available for farming, while the over-fishing of juveniles could have a much more lasting impact, not only on the adult fishery, but to the supply of juveniles for farming (Ottolenghi *et al.*, 2004).

Table 3. Estimates of Bluefin tuna annual catches (in tonnes) by country and year (FAO, 2005b).

	1996	1997	1998	1999	2000	2001	2002	2003	2004
France	9,680	8,470	7,713	6,471	7,321	6,748	5,87	6,443	7,028
Spain	1,657	1,172	1,573	1,504	1,676	1,453	1,686	2,521	--
Italy	--	--	--	--	--	3,255	3,245	--	--
Greece	0	0	0	0	0	0	0	0	--
All EU Countries	11,337	9,642	9,286	8,245	8,997	11,456	10,801	8,964	7,028
Cyprus	0	0	0	0	0	0	0	0	
Turkey	--	--	--	--	--	--	2,3	3,3	1,09
Croatia	--	1,105	906	970	930	903	977	--	--
Libya	--	--	--	--	--	--	200	905	--
Morocco	1,621	2,603	3,028	2,825	2,923	3,008	2,986	2,557	--
Total	12,958	13,350	13,220	12,040	12,850	15,367	17,264	15,726	8,118

Current scientific knowledge

Research is focussed on breeding technologies to close the life cycles of these groups to avoid the dependence of their culture on wild stock populations. Many such technologies have been achieved in experimental conditions, but have not yet been obtained in commercial conditions – such breeding technologies are not yet considered effective for mass production, and are not yet cost efficient on a large-scale (Marino *et al.*, 2003; Iglesias *et al.*, 2004; Mylonas *et al.*, 2004; García *et al.*, 2005; Van Ginneken & Maes, 2005; Jerez *et al.*, 2006). In these cases, aquaculture still relies on the capture of wild juvenile stocks to cover the market demand.

As an example, in the case of reef fish, more than 99% of larvae will disappear within one week, mainly due to predation (Planes & Lecaillon, 2001; Doherty *et al.*, 2004). By collecting a small percentage of these post-larval reef fish before this high mortality phase, the impact of collection on future fish stocks will be negligible (Bell *et al.*, 1999). An innovative technology, the CARE system (Collection by Artificial Reef-Ecofriendly, developed by Ecocean Inc.), currently undergoing trials in the Mediterranean region, enables the collection of undamaged post-larval fish. Once sorted, these post-larval fish are grown-on in tanks or sea cages to provide food-fish fingerlings for local aquaculture or for the restocking of marine protected areas.

This type of trap limits environmental impact. For example, in Moorea (French Polynesia), the traps have collected on average 1000 post-larvae per night. Compared to the 2 million that arrive on the reef each night, this proportion is insignificant ($P< 0.05\%$).

Justification

Worldwide aquatic wild stocks and their ecosystems are in a fragile state. The growing importance of aquaculture production should not increase the pressure already exercised by capture fisheries on wild stocks. Rather the opposite, aquaculture should be a way to relieve this pressure on wild stocks and foster the maintenance of biodiversity whilst satisfying the growing market demand for aquatic products.

Principle

The stocking of aquaculture farms should not affect the natural status or viability of wild populations, their ecosystems or biodiversity in general.

Guidelines

- **It is preferable that organisms to be raised in aquaculture farms should have been produced in hatcheries**. The mastery of the complete life cycle of the species produced in aquaculture should be a priority. This knowledge enables the decoupling of the production in aquaculture from the situation of wild stocks.

- **Research on closing the life cycles of cultured species should be encouraged in order to be able to produce hatchery organisms**. When life cycles of farmed aquatic organisms are not closed, their reproduction or later on-growing depends on the capture of wild stocks. Therefore, to minimise the interaction of capture-based aquaculture and the ecosystem, there is the need for research about how to close the life cycles of the organisms we want to farm in captivity.

- **Research on the fish life cycle and functioning of the ecosystem should be encouraged**. A better understanding of the ecosystem as a whole would allow us to understand what would be the possible catches of larvae and juveniles (size and period) that can be made without negative consequences on the functioning of the ecosystem.

- **The sourcing of individuals for stocking the aquaculture farms done through their capture from wild stocks should be exercised in a sustainable manner**. In the case of molluscs (such as mussels), and also some finfish (like mullets), where aquaculture relies on the capture of wild specimens (generally spats and juveniles), no detrimental effects seem apparent. For other aquaculture species, such as tuna, amberjack and eels, which also rely on the capture of specimens from the wild ecosystem, this capture must be sustainable, and strict measures to assure this sustainability must be implemented, both in reference to the wild population of the same species and to the ecosystems.

- **The capture of specimens to be used as broodstock in hatcheries should not distort wild populations**. Even though, thanks to domestication, aquaculture will rely in time more on cultivated specimens to act as breeders, the need to introduce some wild individuals into the breeding programmes will continue to be necessary. In the case of collecting mature wild stock during the reproductive season, it is important to ensure that this will not distort wild populations in order to allow the reproduction of wild stocks in the ecosystem.

- **Wild stocks from endangered species should not be used, except for rehabilitation or recovery plans, in order to maintain biodiversity**. Endangered species are protected by regulations due to their biologically fragile status. Therefore, any capture activity of these species is forbidden. However, when the aim of their culture is for restock purposes, aquaculture practices are sometimes allowed by Governments.

Tuna farming

In the case of tuna farming, and in the context of a sustained increase in fishing and farming overcapacity, all attempts to achieve a real regional management of this key Mediterranean fish resource have resulted in failure (WWF, 2006).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As described by FAO (2005b), the farming of Atlantic Bluefin Tuna (BFT) in the Mediterranean Sea should be considered as an activity clearly overlapping between capture fisheries and aquaculture. The potential of BFT, all the perceived risks associated with it, and all matters relevant to the sustainability of this recent commercial activity, clearly encompass issues specific to both the fisheries and aquaculture sectors. In this document, the potential sustainability of BFT farming is linked also to research advances in the successful "domestication" of the species. Although considerable progress has been made in this regard, the economically feasible "closed cycle" production of BFT has not yet been achieved.

The expansion of tuna farming activities in the Mediterranean has generated a growing demand for wild fish specimens. Hence, one of the main concerns about this demand is the current and potential pressure to increase fishing. An important step towards responsible and sustainable fishing is to enforce the conservation and management measures of the regional fisheries management organisations, particularly ICCAT and GFCM.

The problem of tuna fattening is not only that we do not know how to produce tuna larvae and juveniles in quantity, but also that the fattening activity is by definition based on wild stocks. Fattening is a special aquaculture case that involves only a short period of the life span of the fishes. The basic concept is to keep live fishery products in captivity for a while in order to give them an added value. In the case of tuna, most of the animals that fatten in the cages are adults that have spawned several times and are part of a fisheries quota. Therefore knowing how artificially to produce tuna seeds might create a new production (aquacultured tuna) in the future, but would not automatically replace the tuna fattening which is something different.

There is an ongoing debate about whether or not tuna fattening is considered as an aquaculture activity. In any case, this activity has to be sustainable from the point of view of tuna stocks (quotas, etc.) and feed fish stocks, as well as economically (to be based on one market on the other side of the world is questionable for sustainability) and socially, e.g. resources being utilised by one type of dominant fishery (Seines) to the detriment of other smaller fishing methods such as the traditional fixed trap net (almadraba).

Ongoing tuna fattening in the Mediterranean is raising a number of issues regarding sustainability: the lack of available data to assess the status of the stock; the difficulty of management organisations to set strong management measures; the use of feed fish from all around the world; the equitable use of resources; the impact on the local environment; the compliance with regional regulations; and others. A clear and drastic recuperation plan, and a clear management plan, will probably need to be enforced quickly if the collapse of the resources wants to be avoided. The management plan might set up a kind of secondary quota, part of the fisheries quota, for the tuna that can be put into the fattening process.

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Feed Ingredients

Aquaculture organisms reared in captivity must be fed in order to enhance their productivity. Some filter feeder species, such as mussels, clams or oysters, take their food directly from the surrounding water column. However, in most cases (all finfish and crustaceans) feed must be supplied by the farmer.

Feed is the main exogenous input into the aquaculture system, and the quantity of feed required is, in general, two or three times the volume of the output produced. For the manufacturing of these feeds, large volumes of natural raw materials are needed.

This Guide deals with the effects on the environment of the use of natural resources for the production of feeds for aquacultured species.


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Current situation

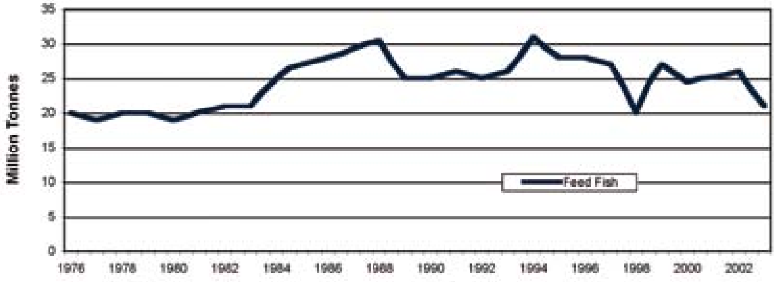
Aquacultured species must be fed according to their intrinsic nutritional and physiological requirements. Marine finfish and crustacean species, such as those present in the Mediterranean Sea, generally have a carnivorous diet. This is identical to the diet of species in other seas and oceans, and is due to the fact that marine trophic chains are far more complex than terrestrial ones. Marine large algae or plants are only found in the bottom of shallow coastal areas. In the open sea, and in the water column of coastal waters, the sole existing vegetables are microalgae that because of their microscopic size can only be eaten by zooplankton and not by finfish.

Although herbivorous species can be produced in aquaculture, generally in freshwater, and although they encompass the most important aquacultured finfish in the world (e.g. tilapia and carp), they do not normally have a high commercial value. On the other hand, there is a growing worldwide demand, mainly in developed countries, for the consumption of carnivorous species such as salmon, trout, shrimp, turbot and cod.

The main aquacultured species in the Mediterranean region are Gilthead seabream (74,078 mT), European seabass (43,804 mT) and Flathead grey mullet (42,546 mT) (FAO, 2003). Although the mullet is an herbivorous/ omnivorous species, both Gilthead seabream and European seabass are carnivorous animals that feed on other fish, molluscs, crustaceans and worms in the wild. Historically, therefore, the main ingredients in the feeds for aquacultured fish have been fish meal and fish oil, produced from wild fish that are caught all over the world.

Fish meal and fish oil are commodities whose commercialisation has been subject to globalisation. They are produced by fishing fleets and processing plants dedicated specifically to this task. The wild fish caught for this purpose are generally small and bony oily fish, for which there is little or no demand either for human consumption or for other uses, or by recycling the trimmings from food fish processing.

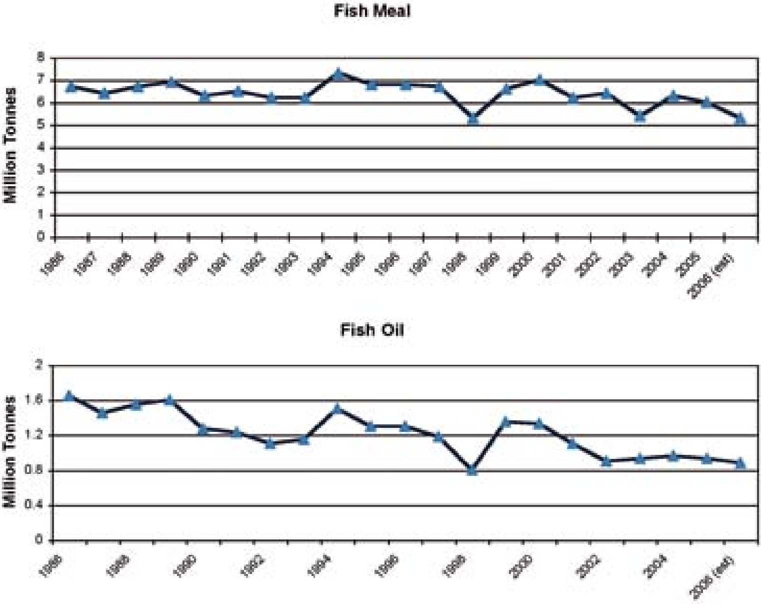
Figure 8. World feed fisheries landings (FAO, 2005a)



The fish meal and fish oil used in fish feeds for aquaculture in the Mediterranean come mainly from the Pacific coast of South America,

but also from the North East Atlantic and the North Sea. The main species of fish that are processed into fish meal and fish oil are anchovy, jack mackerel, horse mackerel, sand eel, sprat, blue whiting, capelin and herring.
At present, around 28 million tonnes of fish (30% of the world catch) and 5 million tonnes of trimmings from food fish are processed annually into fish meal and fish oil (IFFO 2002). The average annual worldwide production of fish meal is 6.3 million tonnes, and fish oil is 1.1 million tonnes. These production figures (figure 9) have been relatively stable in recent decades, although it hasn't been until the last few years that efforts have been made to certify the sustainability of these stocks. It must be kept in mind that these fish have short life cycles that enable quick annual stock recoveries.

Figure 9. World production of fish meal and fish oil (IFFO, 2006)



However, although it seems possible to guarantee the maintenance of current worldwide production volumes of fish meal and fish oil, there is an increasing demand for their use by both terrestrial and aquatic animals.

The use of fish meal and fish oil is advantageous for the feeding of aquatic, and even terrestrial, organisms, because they produce optimal growth and animal health benefits, and are affordable. They provide balanced and easily digestible feeds that are high in proteins, lipids, minerals and a range of micronutrients.

The aquafeed industry consumes nearly 50% of the total worldwide production of fish meal, and more than 80% of total fish oil production. These percentages are projected to continue growing into the future, as shown in Figures 10 and 11.

Figure 10. Reported global fish meal and fish oil usage in 2002 (Pike, 2005)

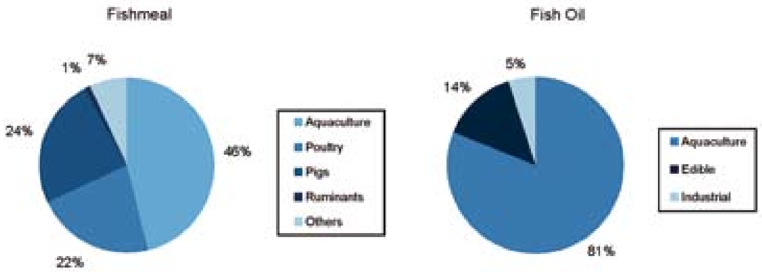
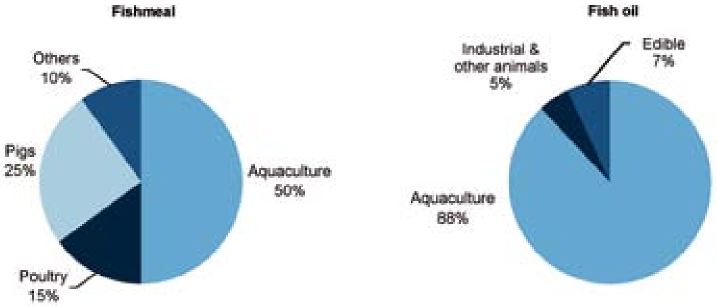


Figure 11. Projected global fish meal and fish oil usage in 2012 (Pike, 2005)



Due to the rapid expansion of the aquaculture industry, there is an urgent need to reduce the dependence of the aquaculture industry on marine wild capture fisheries.

Current scientific knowledge

Manufacture of mono-ingredients fish feed is no longer the case for the aquafeed industry. The formulation of fish feeds is becoming more complex with time, and their composition is multi-ingredient. No single raw material will, by itself, be able to replace fish meal and fish oil. This new formulation principle implies balancing nutritional values at complex molecular levels, and using small quantities of very different ingredients. Research should be encouraged to determine the suitability of diverse raw materials.

Many studies have been conducted to identify alternative protein and lipid sources. Research is ongoing, the main objective being to find possible sustainable substitutions for fish meal and fish oil sources, without compromising the growth, quality and welfare of the cultured organisms. This would allow an appropriate growth of the aquaculture industry in the future. Tested ingredients are plant and animal oils and meals, which may reduce both the pressure on wild pelagic fish stocks and the cost of the feed (Sabaut, 2002; Bell *et al*, 2003). However, low–cost feeds will not necessarily reduce the cost of production for farmers, if the growth of the fish is less satisfactory, and the feed conversion ratio is impaired, such that more feed is needed per kilogram of fish produced.

The complete substitution or replacement of fish meal by more sustainable and renewable protein sources, like oilseeds or vegetable meals, has in the past brought up several issues, partially because of an inappropriate amino-acid balance and poor protein digestibility (Sargent & Tacon, 1999; Webster *et al.,*1999; Bell *et al.*, 2002; Martínez, 2005).

The best results have been obtained in omnivorous and herbivorous finfish and crustaceans (carps, tilapia, channel catfish, pacific white shrimp and others), where total fish meal and fish oil replacement did not affect their growth or feed efficiency (Davis *et al.*, 2004; Muzinic *et al.*, 2004; Yu, 2004).

In carnivorous species such as seabream and seabass, it has been shown that fish oil can be substituted (up to 60%) by a range of vegetable oils (soybean, rapeseed and linseed oils), without any negative effects on fish performance and flesh quality. Furthermore, even with high levels of substitution, the beneficial health effects of consuming aquacultured fish, such as reducing heart problems and lowering cholesterol levels, are maintained (Izquierdo *et al.,* 2003).

Other possible options include the use of fishery and agricultural food-processing by-products that have been successfully recycled and used for aquafeeds. Examples include rendered fish/crustaceans meals and oils produced from by-catch; brewers grains and extracted yeast products from brewing/fermentation products; and broken rice, rice and wheat bran from cereal/milling by-products (New *et al.*, 1995; Tacon, 2004).

Justification

The future development of aquaculture is strongly linked to the possibility of providing sustainable aquafeed ingredients. The current marked increase in aquaculture production has to take into account that fish meal and fish oil are worldwide limited resources. If the aquaculture of carnivorous species wishes to continue further growth, improvements must be achieved in the feeding of these animals, and alternative raw ingredients for aquafeeds must to be found.

Principle

The production of aquafeeds should be a sustainable activity. The sourcing of these raw materials should be environmentally acceptable, and should not have negative impacts on the ecosystems from which these ingredients are harvested.

Guidelines

About the origin of raw materials

- **The origin of the raw materials should be certified as sustainable.** Certification of sustainability of the sourcing of raw materials for the production of aquaculture feeds is one of the most important measures to ensure sustainability of aquaculture at a global level. This type of certification is probably not achievable today, but should be targeted for the future. This certification should not be restricted only to the fish stocks captured for fish meal and oil; other ingredients, including agricultural products, should also be subject to this certification.

About the use of feeds and technology

- **The use of formulated feeds should be recommended**. Formulated feeds, generally in the form of dry pellets, provide better performance than other types of feeds in relation to nutritional benefits, animal health and food safety. This recommendation is not intended to apply to filter feeders that take their feed directly from the local environment.

- **Feed management should be improved**. The way feed is delivered to the aquatic organisms is important, in order to optimise feed utilisation and reduce feed losses. Improvements in the use of feeds will contribute to optimising the use of wild fish for the fabrication of meal and oil. Special efforts should be put into the training of farm personnel at all levels on this topic.

- **Feed production technologies and feed quality should be improved**. New fabrication technologies should be promoted to improve the quality of the feeds, and therefore their efficiency.

About alternative sources for feed ingredients

- **The use of alternative ingredients should be encouraged**. These ingredients should meet standard requirements of food safety, profitability, animal health and welfare, be sustainably produced and provide good nutritional value for consumers. These alternative ingredients include vegetal proteins and oils, as well as processed terrestrial by-products, fermented yeast and others.

- **The use of other existing sources of marine proteins and oils should be encouraged**. The world's seas and oceans still contain untapped resources that could be used as ingredients for the fabrication of aquaculture feeds. In some cases, these could be obtained from the wild with all necessary precautions in a sustainable way, such as krill, or the use of trimmings from the processing industry, giving at the same time an added value to these by-products. In other cases, these raw materials could be cultured for this purpose, such as algae, worms or molluscs.

- **Research on alternative sources for feed ingredients should be encouraged**. In particular, cooperation between scientists, aquafeed manufacturers and aquaculture producers should be promoted.

About the optimisation of nutrients

- **The farming of low-trophic level species should be promoted**. The production of low-trophic level species, herbivorous or omnivorous, would reduce the percentage of fish meal and fish oil, and is more ecologically efficient. Fish such as mullet, carp or tilapia, or molluscs such as mussels, clams or oysters, can utilise readily available nutrients in the waters to grow. In the case of the finfish, nevertheless, if reasonable output is to be achieved, some form of feed must be supplied or fertilisation of the culture waters be achieved. However, there is a reduced commercial market for herbivorous finfish in some Mediterranean countries.

- **The integration of aquaculture with other agricultural farming activities should be promoted**. By integrating aquaculture production with other agricultural or stockbreeding activities, the use of natural resources becomes more efficient.

What food for which fish?

"Turning carnivorous fish species into vegetarians" (Powell, 2003) has recently been suggested as a more sustainable solution. It has its own challenges, but in the face of the increasing costs of carnivorous fish production and the ecological implications of wild stocks decline, this seems to be one possible way to go (New & Wijkstrom, 2002).

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The conversion of finfish from carnivorous to vegetarian is concerning. At present, partial replacement of fish meal and fish oil in the diets of aquacultured fish by vegetable proteins and oils is taking place. Over time, the percentage of this substitution will probably increase for the sake of sustainability. There is an apparent collision of ethical concepts between what is believed to be "natural" and what is considered to be "sustainable".

Food safety concerns exist in relation to the inclusion of processed terrestrial animal proteins into the feeds of aquacultured fish. The use of blood meal, generally porcine, in feeds for carnivorous fish has existed worldwide for decades because of its high quality. After the Bovine Spongiform Encephalopathy (BSE) crisis started in 1986, the use of these proteins was forbidden in the European Union as a precaution. In 2003, after the scientific committees of the European Commission demonstrated the complete safety of these ingredients, the use of non-ruminant blood meal in fish feeds was authorised. Nevertheless, the use of these proteins in fish feeds in Europe today is small, because of worries within the aquaculture sector about its image. At the same time, they are widely used in Asia and America.

The use of genetically modified organisms (GMOs) as ingredients could be a solution for aquaculture feeds. Genetically engineered plants producing oils with tailored composition profiles could be the ultimate solution to the fish oil shortage. Nevertheless, their application in Europe will require solid proofs of food and environmental safety, and a major change in the attitude of consumers and legislators towards GMOs.

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Organic Matter in the Effluents

This guide deals with the environmental effects of the organic matter contained in the effluents of aquaculture facilities. These effluents include uneaten feed, metabolic excretions, faeces and dead fish, and they consist of both organic solid wastes and dissolved organic and inorganic nutrients. If the flux of these compounds into the environment surpasses the natural assimilation capacity of the ecosystems, severe impacts, such as eutrophication, oxygen depletion and alteration of local biodiversity, can occur both in the water column and in the bottom substrate.


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Current situation

There are many chemical compounds that aquaculture may release to the surrounding marine environment; some as particles and others in soluble form. The largest fluxes of chemical compounds released are carbon [C], nitrogen (N) and phosphorus (P), which are by-products of fish metabolism and there is a concurrent large uptake of dissolved oxygen by the respiring fish and flora/fauna associated with the farm. If farm sites are properly selected, in areas with reasonable current flow, problems associated with oxygen depletion would not be anticipated, unless there are other farms or oxygen-demanding activities upstream or downstream of the site. However, this topic will be addressed in detail in the future review on “site selection”. Most of the carbon released is excreted as CO2, which may, in theory, affect the pH of the seawater. But again, if the site is selected properly, this should not occur, and there are no known cases where fish farms caused a dramatic drop in pH. The other major form of carbon that is released from fish farms is organic C that originates in waste food, fish faeces, mucus excretions, scales, dissolved organic compounds and dead fish. The dominant form of N released from fish cages is ammonia and a small fraction of N is released as dissolved and particulate organic N compounds. Unless there is strong bacterial nitrification activity taking place in the vicinity of the fish cages, the levels of nitrate and nitrite are generally very low. Phosphorus is excreted by the fish as dissolved orthophosphate or as organic P compounds, and we often see a peak in sedimentary phosphorus around fish farms, partially related to the abundant P in fish meal and fish bones. In open-cage aquaculture C, N and P enter into the natural ecosystem without prior treatment, whereas in land-based facilities nutrients may be stripped from the effluents prior to discharge to the sea to reduce or minimise effluent nutrient levels. Solid and dissolved effluents can cause several problems, such as eutrophication, oxygen depletion and alteration of local biodiversity, in the water column and on the seafloor. In order to enhance the sustainability of aquaculture activities, the influence of farm effluents on pelagic and benthic systems needs to be reduced.

There is increasing public and scientific awareness and concern regarding sustainability of this expanding industry in many countries, as shown by the recent publication of a special issue of The Handbook of Environmental Chemistry devoted entirely to the environmental effects associated with marine finfish aquaculture (Hargrave, 2005). The magnitude of the ecological impact will depend on the physical and oceanographic conditions of the site, seawater temperature and assimilative capacity of the environment, farm management (husbandry), farm size, stocking density, duration of farm operation, digestibility of the food, disease status, etc.

Two general types of waste are produced from feed by-products:

- Particulate matter, including settleable and suspended solids which may include faeces, uneaten feed, organic matter, and nitrogen-phosphorous containing compounds.

- Soluble material, including dissolved organic and inorganic compounds, mainly nitrogen and phosphorous, released from fish and shellfish metabolism (such as ammonia, urine) and the breakdown of solid wastes (solid material).

The solid waste discharges from fish cages affect the abundance and composition of endemic bacterial, floral and faunal populations. The benthic community structure beneath fish farms is often modified due to the alteration of the physical structure (changes in grain size distribution, texture porosity, etc.) and chemical (hypoxia, anoxia, pH, sulfides, porewater nutrients levels, etc.) and biological composition of the sediments (Costa-Pierce, 1996; Burd, 1997; Boesch et al., 2001; Vezzulli et al., 2002). High concentrations of suspended solids may reduce sunlight penetration into the water column altering photosynthetic activity and affecting macrophyte and seagrasses. The extent of the impacted seafloor area varies considerably as a result of hydrography, bathymetry, seafloor depth, and additional factors, but overall, most studies show clear impact in the range of 50-150 m from the point source (Angel et al., 1995, Beveridge, 1996; EAO, 1998; Pearson & Black, 2000; Chelossi et al., 2003; Sarà et al., 2004; Porrello et al., 2005).

Cages with high biomass of fish, often close to shore and in shallow water, can lead to changes in water quality and the underlying sediments, both in the region adjacent to the fish farm and up to a certain distance away. The extent of the effect of fish farms is generally limited in space (Pearson & Black, 2000); however, the role of local hydrodynamics (dispersant forces) should be taken into consideration (Sarà et al., 2004, 2006). Widespread environmental effects such as oxygen depletion and nutrient enrichment (from waste feed, fish faeces and excretory products) may occur in coastal areas with poor flushing. Moreover, poorly-flushed sites may experience benthic accumulation of particulate organic matter, followed by sediment anoxia and the build-up of hydrogen sulphide in the sediments. These phenomena have been studied in great detail in cold northern and southern waters (Norway, Chile, Ireland, Canada, Scotland, USA, Australia and New Zealand), related to the culture of salmonids that occurs mainly in productive waters. Studies on the environmental effects of warm-water aquaculture, as in the case of oligotrophic waters of the Mediterranean and Red Seas are more recent (Angel et al., 1995, Karakassis et al., 2000; Kovac et al., 2004), and primarily relate to collaborative multinational research projects (e.g., MARAQUA, BIOFAQs, MEDVEG, ECASA, etc.). Despite the differences in the environments and cultured species, many of the environmental effects and trends (processes) are quite similar.

Current scientific knowledge

One of the difficulties in studying the impacts of N and P discharges from aquaculture farms on the receiving waters is that nutrient discharges can also come from other sources (river run-offs, sewages). In nutrient-limited waters, modest additions of nutrients may increase the productivity and biodiversity in an area, and could lead to eutrophication if flushing (nutrient dispersal) rates are not high.

Several studies and large scale projects (MEDVEG, MERAMED, etc.) have indicated that benthic effects from aquaculture are limited to within a short distance of the cages, normally not exceeding 30-50 m from the fish farms. There are signs that pelagic fish, invertebrate and seagrass communities may be affected to a large distance (Dimech et al., 2000; Pergent-Martini et al., 2006). It is well known that fish farming releases a substantial amount of nutrients into the marine environment and therefore it would be reasonable to expect effects at larger spatial scales, particularly when a group of farms is established in a coastal bay. Data arising from large scale projects (including MARAQUA, BIOFAQs, AQUCESS, ECASA) indicate that such changes may also affect benthic and fish communities in the vicinity of aquaculture development zones and particularly in oligotrophic environments, like the Mediterranean Sea, where nutrient scarcity limits productivity.

The estimated time for the benthos to recover its species abundance, richness and biomass after fish farming ceases has been reported from a few months to five years, depending on the scale and duration of the fish farming activity and the geography of the area (Angel et al., 1998, Burd, 1997; Mazzola et al., 2000; McGhie et al., 2000; Pohle et al., 2001; Pergent-Martini et al., 2006). The high organic matter supply under and close to fish cages resulted in a slight decrease of benthic meiofauna biomass and the impoverishment of species diversity. The abundances of the main meiofaunal groups (Nematoda, Harpacticoidea, Polychaeta, Turbellaria, Bivalvia) gradually increased from the fish farm in the direction of unaffected area. Diversity increased from a low level under the cages to a higher level at 200 m from the cages (considered as control site).

In addition to solid waste discharges, the benthic efflux of dissolved inorganic nutrients to the overlying water, following organic matter decomposition, is an important source of N and P to the surrounding waters. Excess nitrogen and phosphorus can lead to eutrophication, which is expressed as an increase in primary production, changes in algal composition, algal blooms (that could be toxic) and, when the algae decompose, hypoxia and anoxia often ensue (McClelland and Valiella 1998; Gismervik et al., 1997; Worm et al., 1999; GESAMP, 1990; Worm and Lotze, 2000; Worm et al., 2000). Studies carried out on shellfish farming indicate that the extent of effect of nutrients (decomposition of biodeposits) is related to oceanographic and biological parameters of the area. Those studies showed different effects in the benthic environment, ranging from no appreciable effect (Hostin, 2003), small (Buschmann et al., 1996; Crawford et al., 2003; Miron et al., 2005; Da Costa & Nalesso, 2006) and important (Mirto et al., 2000; Chamberlain et al., 2001; Christensen et al., 2003; Smith & Shackley, 2004). In the Bay of Fundy, increased zinc concentrations were found in intertidal sediments located more than 1 km from the nearest salmon fish farm; thus the dissolved fraction could also travel that far. At the same time, an increase of green algal (Ulva-dominated) population biomass was observed. The algal mats negatively affect clam recruitment and behaviour (i.e. growth and survival), and consequently, the annual beach crop of this bivalve (Robinson et al., 2005). The study of Kovac et al. (2004) in the Bay of Piran (Northern Adriatic Sea, Slovenia), demonstrated the long-term impact of fish farms on meiofauna communities.

Various measures have been proposed to mitigate inorganic and organic matter enrichment near or under fish-farm cages, which can be classified under 2 main types:

- **Biofilters**
  Plastic benthic artificial reefs were proposed by Angel & Spanier (2002) to enhance the growth of biofouling organisms (mainly tunicates and bryozoans) near fish-farm cages to filter and retain particulate (and dissolved) matter falling from the cages. In order to reduce the flux of dissolved nutrients from aquaculture to surrounding waters, seaweed and various other biofiltering organisms may be used to capture ammonia and phosphorus, and to oxygenate aquaculture ponds (Krom et al., 1995; Troell et al., 1997; Chopin et al., 1999; Soto & Mena, 1999; Jones et al., 2001; Marinho-Soriano et al., 2002; Neori et al., 2004).

- **Integrated aquaculture**
  Recent studies demonstrate the potential for integrated aquaculture techniques (polyculture) for capturing and capitalising on the flux of particulate and dissolved nutrients from land-based cultures or fish-farm cages (Chopin et al., 2001; Hussenot, 2003; Neori et al., 2003;

Troell et al., 2003; Angel, 2004; Viera et al., 2006). This approach is being tested in various countries, including Canada, Scotland, Israel, South Africa, Australia, Spain and Chile. Variations on this theme have been in use for many years in Asia, including China and Vietnam, where polyculture aquaculture is a traditional practice (Alongi et al., 2000).

Justification

Aquaculture feed by-product may affect water quality by increasing turbidity or by altering the concentrations of dissolved nutrients and suspended solids, and may affect the underlying benthos in a variety of ways. There are various means to reduce these water quality and benthic impacts, but current technologies are generally expensive and have not been sufficiently tested for their environmental, practical and economic feasibility.

Principle

The organic matter in the effluents from aquaculture farms should, in quantity and quality, be capable of assimilation by the ecosystem, thereby not producing negative effects on the local environment.

Guidelines

About farm management

- **Farms should be managed in order to control the organic matter effluents from their facilities**. Appropriate management is critical to controlling organic matter production. The main input of organic matter comes through fish feeds. Feed quality and feeding practices are therefore key to this issue. Whenever possible (e.g. land-based facilities), organic matter should be retrieved from the effluents.

- **Feed quality should be understood as essential for organic matter control**. Feed composition (types and digestibility of proteins and oils), feed fabrication technology (e.g. extrusion), appropriate pellet size (according to fish species and sizes) and presence of feed dust, should be taken into account. Moreover, feed should be of a high standard and not contain harmful elements such as heavy metals or other undesirable compounds.

- **Best feeding practices should be applied**. This includes appropriate rations (according to the fish stock), distribution methods (be spread as evenly as possible throughout the culture system), and feed storage conditions (maintaining the nutritional quality and palatability of feed). Farm feeding personnel should receive proper training.

- **Fish mortalities should be disposed of properly**. The carcasses of fish from routine mortality should be retrieved from the culture enclosures and disposed of properly.

About mitigating the organic effluents and using the benefits of this organic matter

- **Siting of aquaculture farms should take into account the effects of organic matter in the effluents**. Local currents and water depth play a crucial role in the capacity of dispersal and absorption of organic matter by the ecosystem. Decision-making over farm site selection must consider these hydrodynamic conditions together with the projected production.

- **The development of recirculation systems should be promoted**. In land-based facilities, partial or complete recirculation of the culture water allows for both the reuse of the water and the elimination of organic matter.

- **Polyculture as a practice that recaptures and gives value to organic matter should be encouraged**. Polyculture systems can be a useful tool for mitigating the input of nutrients into the environment in which at the same time another valuable crop is produced.

- **The creation of biological systems that absorb organic matter should be promoted**. Physical structures constructed in the vicinity of fish farms can encourage vegetal and animal filter-feeding communities to flourish; these retain particles and use the organic matter for their own subsistence. Artificially created marshes or reefs can serve this purpose.

- **Research to optimise the recovery, disposal and re-use of solid waste should be encouraged**. Treatment and waste recuperation methods need to be improved. Added value can be found for the re-use of waste products, such as for example in the agro-industrial sector.

Fallowing the waters

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The practice of rotating production between several sites is known in aquaculture as fallowing. Leaving a site with no production for a reasonable length of time gives the local ecosystem the opportunity to assimilate accumulated organic matter and to restore the location to its initial conditions. At the same time, this procedure breaks the life cycles of potential pathogen organisms and contributes to securing a healthy status on the next generation of aquacultured organisms in that site.

Fallowing is a normal procedure in northern European countries, but this is not the case in the Mediterranean region. Important legal limitations exist in most countries for the possibility of having several available sites for one single aquaculture farm. At the same time, more research is needed to prove the usefulness of this practice in warmer waters where biochemical reactions in the organic matter take place at higher speeds.

Pathogen Transfer

This Guide deals with the interaction between aquaculture and the possible pathogen transfer to and from the natural environment.

Current situation

Pathogens, as part of the natural ecosystem, do not cause disease outbreaks unless major environmental changes occur (Winton, 2001). In aquaculture facilities, however, sub-optimal environmental conditions and poor management practices (overcrowding, overfeeding or nutritional imbalances) can induce stress, making these animals more susceptible to disease outbreaks (Verschuere *et al.*, 2000; Winton, 2001; Weber, 2003; Schulze *et al.*, 2006).

Diseases pose a significant constraint on finfish and shellfish aquaculture production (Verschuere *et al.*, 2000; Schulze *et al.*, 2006), leading to economic losses, and thus affecting the aquaculture sector's sustainability. At the same time, imported diseases can affect wild populations and can cause alterations in the ecosystem equilibrium.

Diseases of aquatic organisms generally move into the production system from an environment where such pathogens exist at sub-lethal concentrations, and affect fish stocks that might be under stressful conditions. Rare cases have also been mentioned of disease transfer by un-processed fish used as feed for aquaculture (Anon, 2005). However, as the fish used for this are usually frozen, it is only viruses and a few bacteria that can survive under such conditions (Goodwin *et al.*, 2004).

On the other hand, no known record of contamination from reared to wild species has yet been documented in the Mediterranean. The potential disease impacts from farmed organisms to wild stocks have been determined to have low incidence and little risk (Waknitz *et al.*, 2002; Gardner *et al.*, 2004). However, very different is the case of the introduction of alien species that have been proven to be responsible for spreading various diseases around the globe.

Open aquaculture systems are more exposed to pathogens from the aquatic environment than closed systems, and the control of this risk is difficult. Nevertheless, this risk can be reduced through proactive measures such as careful site selection, the choice of species cultured, appropriate culture systems, contingency plans and monitoring systems (Mcvicar, 1997; Myrick, 2002).

Current scientific knowledge

Blazer & LaPatra (2002) identified three potential forms of pathogen transmission: first of all, the introduction of new pathogens to an area via the importation of alien organisms for culture; secondly, the introduction of new pathogens or new strains of pathogens via the movement of cultured organisms (native and alien); and thirdly, the amplification of pathogens that already exist in wild populations and their transmission between wild and cultured populations via intensive culture, which can destroy raising conditions.

Recently it has been emphasised that the possible introduction into the ecosystem of pathogens could be associated with the unintentional release of infected farmed organisms (native or exotic). However, there is no scientific data to demonstrate pathogen transfer between stocks (De Silva *et al.*, 2006).

Currently, research is focused on determining the situation of the transfer of diseases from farmed stocks to the wild. However, this causality is difficult to identify or correlate because it might be associated with other factors.

Justification

Aquaculture farms are generally open systems in which pathogens can flow in and out, and interact with wild populations. Although cases of pathogen transfer between wild and aquacultured organisms, and vice-versa, are rare in the Mediterranean, the growing importance of aquaculture increases the risk of this happening in the future. Nevertheless, this risk is certainly high in the case of the introduction of alien species that might transfer diseases especially virulent for the local species.

Principle

The possible transfer of pathogens between farmed organisms and wild stock populations should be minimised.

Guidelines

- **Aquacultured organisms should be kept in the best possible health**. Animals in good health are less likely to suffer disease and to transfer pathogenic organisms to the wild populations. At the same time, they are less susceptible to the effects of pathogens imported from the environment.

- **Disease outbreaks in aquaculture farms should be prevented, contained and managed**. This may be done through the application of measures such as health status monitoring, quick disease diagnosis, and the application of appropriate treatments under veterinary prescription and supervision when disease outbreaks occur.

- **Precautionary measures should be implemented to prevent disease transfer**. These measures can include assuring that stock captured and introduced into aquaculture systems is healthy and its origin known, that quarantine periods are implemented, that cultured organisms are separated by age classes and that fish are vaccinated. These measures must be especially stringent when alien species are moved into an area.

- **Special biosecurity measures to limit the introduction of pathogens in hatchery systems should be implemented**. Vertical transmission of diseases through the aquaculture cycle can potentially affect or be caused by wild populations. This path should be cut at hatchery level with actions that can include healthy broodstock, sterilisation of the water supply, control of other inputs such as feeds, minimisation of handling and stressful situations, and implementation of cleaning and disinfecting protocols.

- **The research and monitoring of the epidemiology of diseases in wild populations in the vicinity of aquaculture areas should be encouraged**. More knowledge is needed to evaluate the impact of diseases from aquaculture to the wild stocks, and vice versa.

Therapeutic and other Products

Veterinary medicines and therapeutic products are tools for animal health management. They are important for the welfare of the animals and must also be considered from the point of view of human food safety.

Most aquaculture veterinary medicines, if properly used, have minimal adverse environmental impacts. However, excessive dosage and failure to provide for adequate neutralisation or dilution prior to discharge to the natural environment could make their use unsafe and harmful to wildlife near the aquaculture facility.


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This Guide deals with the interactions between aquaculture practices, such as disease prevention and treatment, and the un-intentional release of the chemical products used into the environment.

Current situation

Therapeutic products used in aquaculture include a range of antibiotics, vaccines, pesticides, disinfectants and anaesthetics. They are used to control microbial infections, external and internal parasites, and to facilitate the handling of the cultured organisms. Few drugs and chemicals have been approved for use in aquaculture because the licensing of pharmaceutical products is expensive, and the market for these in aquaculture is small in comparison to human or other livestock needs.

Issues of concern regarding the negative environmental impacts of these products include the chemical residues in wild fauna and soil, the toxic effects in non-target species and the bacterial strains resistance that can threaten aquaculture operations, and potentially could be transferred to the human food chain (Smith *et al.*, 1994; Schmidt *et al.*, 2001).

The ecological impact of these chemicals greatly depends on the time they take to biodegrade, on the types of chemicals that are created through their disintegration, and on their tendency to accumulate in organisms' tissues.

Bacterial disease outbreaks occur mainly when aquaculture farms are not properly managed, causing the animals to suffer stressful conditions, or because of inappropriate sanitary measures. Intensive aquaculture practices pose a higher risk of stress situations which contribute to the majority of problems with cultured organisms, imposing a significant constraint on the production of finfish and shellfish (Bachère *et al.*, 1995; Verschuere *et al.*, 2000).

Pesticides are usually used to remove parasitic species, but their residues are often highly toxic and persistent in the water and sediment, killing non-target organisms and affecting the natural ecosystem, particularly crustaceans.

A number of anaesthetic agents have been used in aquaculture to sedate and calm animals for different aquaculture practices, such as vaccination, handling, sampling or transportation.

The use of pharmaceutical medicines can be reduced by good management practices and sanitary prevention measures, such as the use of vaccines and immune stimulants. The World Health Organization (WHO) recommends preventative (prophylactic) approaches to disease management, in order to avoid over costly post-effect treatments and their environmental effects, such as increased resistance of pathogens, accumulation in bottom soils and affection of non-target organisms (WHO, 2002).

The use of vaccines in aquaculture is part of health management strategies (Thorarinsson & Powell, 2006). These vaccines are being developed, and their use continues to increase (NRC, 1999), replacing the use of antibiotics. Nowadays there are vaccines against several aquaculture pathogens (Costello *et al.*, 2001). These can be administered orally, by injection, through immersion or by spraying (Avault, 1997).

Current scientific knowledge

Veterinarian research in aquaculture is focused on the production of vaccines for every known disease, and for the use of biosafe chemicals. The development of probiotics and immunostimulants agents is one of the latest research areas which are obtaining success due to their capability to enhance the immune status of the cultured organisms (Dugenci, 2003; Rodríguez *et al.*, 2003; Torrecillas *et al.*, in press). At the same time, the use of new anaesthetics is also being investigated, to reduce the detrimental effects on the cultured organisms and the natural ecosystem.

Guichard & Licek (2006) have recently established the number of antimicrobial agents that currently possess MA for use in aquaculture in 31 counties in the European region. These data are summarised in Table 4 by Pete Smith in a PANDA report.

Table 4: Number of products authorised for aquaculture use in European countries.

No of active substances*	Countries
0	9
1	7
2	5
3	8
4	2
5	0

* active substances that demonstrate high levels of cross-resistance (such as flumequine and oxolinic acid) are grouped together and are treated as a single agent in this Table.

This summary table simply indicates that urgent measures need to be taken to facilitate broader availability of veterinary drugs and vaccines in the fast growing European aquaculture industry on the grounds of fish welfare, sector sustainability and the establishment of a plain field between Member states without trade barriers. Current complicated licensing procedures and the small size of the aquaculture industry have discouraged pharmaceutical companies from investing in the sector for licensing new products.

Justification

As with all livestock production, the aquaculture industry is susceptible to disease outbreaks, and so the use of veterinarian medicines is needed. These chemical compounds may have a negative impact on the surrounding environment if misused. Therefore, in order to minimise detrimental effects in the cultured organisms and the wild environment, prevention measures and treatments should be put in place.

Principle

The use of therapeutants should be managed correctly to minimise possible detrimental effects on the natural environment.

Guidelines

About the reduction of the use of therapeutants

- **Aquaculture sanitary policies should be based on preventative and prophylactic measures**. Good management practices, attention to aquatic animal welfare, vaccination and the strengthening of the immune system should be used to minimise the possibility of disease outbreaks and the subsequent need for antibiotics.

- **The use of antibiotics as a prophylactic method should be avoided**. These could only be acceptable as part of carefully planned treatment strategies, following antibiogram and veterinary prescription.

- **More effective and safer veterinary medicines should be made available to the aquaculture industry**. Research and licensing of new vaccines, and more effective and safer antibiotics, should be encouraged.

About the proper management of therapeutants and other products

- **A precise laboratory diagnosis of the diseases should be established prior to treatment with antibiotics**. A sound recommendation for disease treatment should be produced at laboratory level (antibiogram) before applying therapeutic agents, in order to use antibiotics in a responsible manner.

- **Only legally licensed antibiotics should be used**. These should only be used under the guidance of a qualified professional.

- **The use of persistent chemicals should be reduced**. Biodegradable chemicals will be recommended when available.

- **Sanitary plans should be established to prevent the development of microbial resistance to antibiotics**. Several different antibiotics should be available to fight each disease, and an appropriate alternation in their use should reduce the risk of the appearance of resistances.


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Antifouling Products

Marine biological fouling, usually termed marine biofouling, is the undesired accumulation of microorganisms, plants, or animals on the surface of structures submerged in the sea water. It is a complex and recurring problem in aquaculture that affects immersed structures such as cages, netting and pontoons; equipment and structures such as pipelines, pumps, filters and holding tanks; and even farmed species such as mussels, scallops or oysters. Such damage subsequently adds weight to floating structures, reduces water flow, and consequently increases production costs due to losses in productivity and elevated maintenance costs. Different procedures are used to fight biofouling, the traditional one being the coating of immersed surfaces with antifouling paints similar to those used in the shipping industry.


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The objective of this Guide is to analyse the interaction between antifouling procedures and the ecosystem.

Current situation

The main damage biofouling causes to aquaculture systems is the clogging of nets and pipes that causes a reduction in the amount of dissolved oxygen available for the organisms, an increase in carbon dioxide concentration in the culture waters, and the worsening of the dispersal of ammonia, uneaten feed and faeces. At the same time it adds weight to the structures reducing physical resistance to marine forces, such as storms and currents. Another important consequence of biofouling is that aquaculture structures can act as reservoirs for disease-causing organisms which can affect the cultured organisms (Tan *et al.*, 2002). However, the acuteness of the problems associated with biofouling depends on its intensity, and this intensity is site specific, depending on geographical location, environmental conditions and season of the year.

The most common way for preventing or delaying the fixation of fouling organisms onto submerged structures is their coating with chemical antifouling products. Besides their antifouling properties, these products protect materials from the negative effects of exposure to sunlight (e.g., ultraviolet degradation of nets and ropes).

Antifouling products used in the past were based on heavy metals such as tin or chrome. Today, copper is the main active substance, even though several studies show the detrimental effects that copper has on marine microorganisms and molluscs (Manley, 1983; Viarengo, 1989; Elfwing & Tedengren, 2002). Copper is listed under the EU Dangerous Substances legislation, and its release into the natural environment may be controlled under discharge limits and further investigation (Henderson & Davies, 2000).

Nowadays, antifouling products cause less impact on the environment than in the past, due to product optimisation of the quantities used, and because they are more efficient at targeting fouling species.

Current scientific knowledge

Today, copper is the main ingredient in antifouling paints in which it is used as cuprous oxide (Cu_2O). The oxide is dissolved in a polymeric matrix that acts as a vehicle, the slow dissolution in water of which favours the gradual dispersion of the copper, thereby enhancing the antifouling effect.

Research focuses on natural repellents or on the use of biological substances that prevent the settlement of fouling organisms through the better understanding of settlement mechanisms. Investigation is also carried out on new coatings, such as silicon based fouling-releasing coatings (Baum *et al.*, 2002), on spraying with antifouling solutions (acetic acid) (Carver *et al.*, 2003), or nanotechnology applied to new materials. An entire European project has been dedicated to biofouling and its solutions, called Collective Research on Aquaculture Biofouling (CRAB, http://www.crabproject.com).

At present, the aquaculture sector is searching for alternatives to present coating products such as copper, and moving towards more environmentally friendly procedures. These include research on biological control using grazers that feed on the fouling organisms (Lodeiros & García, 2004). Grazing species might be molluscs such as gastropod snails, sea urchins, or even fish.

Justification

Antifouling products are needed in aquaculture to prevent or minimise biofouling, but they are effective precisely because of their toxic properties towards these organisms. This toxicity may harm non-targeted organisms and affect the surrounding ecosystems.

Principle

Antifouling products used in aquaculture should have no perceivable toxic effects on non-targeted organisms of the surrounding ecosystems.

Guidelines

- **Eco-friendly antifouling coatings and products should be used**. These might include silicone-based coatings, polyurethanes and enzymatic technologies.

- **Environmentally friendly procedures for preventing or eliminating biofouling should be encouraged**. Alternative ways for fighting biofouling should be applied. These can include appropriate management such as considering the natural productivity of areas when siting the farms, washing nets more frequently, or taking into consideration the life cycles of the biofouling organisms when changing nets. Other procedures for onsite biofouling cleaning can be high pressure water or drying out in the air, and new methods such as biocontrol through the utilisation of grazers.

- **The use of antifouling products based on heavy metals should be avoided**. Substances such as tin, lead or cadmium have been proven to cause severe damage to the ecosystems, so their use should be avoided.

Effects on Local Flora and Fauna

This chapter deals with the interaction between aquaculture processes and the local flora and fauna.

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Wild flora and fauna may be affected by aquaculture practices, but such interaction is not always detrimental; it can also be beneficial. Effects can be produced as a result of feeding practices, organism excretions, water outflow and escapes (issues that are addressed in separate guides). Many societal concerns come from the perceived environmental effects of finfish cages or land-based aquaculture production units on the local flora and fauna.

Current situation

Interaction between aquaculture and benthic communities, in particular seagrass meadows

Many studies have indicated that visible effects from aquaculture on the benthic environment are found within a short distance, normally not exceeding 50m from the fish farms, while the biological communities of the water column may be affected at a greater distance (Grant *et al.,* 1995; MEDVEG, MERAMED, Uriarte & Basurco, 2001; Machias *et al.*, 2005). The marine bottoms where cages are sited do not receive sunlight, due to shadowing, and this leads to disruption of the local ecosystem. In the case of seagrass meadows, shadowing disrupts the photosynthesis process, and consequently natural community modifications. This is intensified by nutrient loads and epiphyte covering. Seagrass meadows are essential ecosystems playing a major ecological role in the Mediterranean coastal zone preventing coastal erosion, supporting biodiversity and water transparency, and oxygenating water and sediments (Hemminga & Duarte, 2000). *Posidonia oceanica* meadows are considered determining elements in assessing the biological quality of Mediterranean coastal zones (EU Directive 2000/60/CE, of October 23rd, 2000), but they are highly vulnerable to human activity, such as marine aquaculture (Delgado *et al.*, 1997; Ruiz *et al.*, 2001; Pergent-Martini *et al.*, 2006). They suffer large-scale losses in response to nutrient enrichment (Ruiz *et al.,* 2001; Cancemi *et al.*, 2003) and this may continue for several years even after the cessation of activities (Delgado *et al.*, 1999). Under or near sea cages, the meadows of *Posidonia oceanica* die and the effects are not reversible, at least on a human timescale (Holmer *et al.*, 2003; Pergent *et al.*, 2006). Due to the sensitivity of seagrass meadows to aquaculture activity, vertical rhizome growth can be used as an early indicator of fish farm impacts on *P. oceanica* meadows (Marbà *et al.*, 2006).

Conversely, cages can drag along epiphytes as well as benthic and fisheries communities modifications. Setting up cages requires good planning at the ecoregional level, including bathymetric, hydrodynamic and ecological studies to avoid any detrimental effects on the nearby ecosystems. Geographic Information Systems (GIS) can provide help for decision-makers, but the management decision remains a human one based on societal choice.

Attraction of fauna by the aquaculture installations

Aquaculture facilities may attract wildlife to benefit from easy available food or shelter, altering the population structure on site. It might cause problems in farms due to predation, stress on animals, disease transfer, etc. Much wildlife (e.g., predators, scavengers) is attracted by the aquaculture structures used to culture aquatic organisms. Other fishes are the most prevalent among attracted organisms, but birds, marine mammals, sharks and turtles also visit aquaculture facilities. They are searching for food, which can be both the cultured organisms and organisms that colonise on and around the structures (Nash *et al.*, 2005). The greatest risk to any animal near to the aquaculture facility is rubbish from the site, such as plastics, feed bags or ropes, which can prove to be fatal when ingested accidentally. However, the aquaculture structure itself (e.g., ropes, lights, acoustics, buoys, nets) only poses a minimal threat to wild species thanks to the improvements that have been made in recent years (Nash *et al.*, 2005); therefore, wild populations are protected from other activities such as capture fishing, pollution, etc.

It is well known that fish farming releases a substantial amount of nutrients into the marine environment and therefore it would be reasonable to expect effects within a larger radius of the site, particularly when a group of farms is established in a coastal bay. New studies are starting to show that such changes also affect fish communities in the vicinity of aquaculture development zones, particularly in oligotrophic environments such as the Mediterranean Sea where nutrient scarcity limits productivity and fisheries production. In this sense, the release of nutrients from fish farming in nutrient-poor systems can have a positive effect on local fisheries with no visible negative change in species composition or biodiversity (Machias *et al.,* 2005).

The effects of cages and other aquaculture structures are very different and change with time. In general, the situation can be summarised as follows:

- Very strong interaction exists between aquaculture structures and local flora and fauna;
- Part of the local fauna benefits from excess food accumulated below the cages;
- Close to the cages, richness seems to decrease. However, the richness evolves when the distance from the cages increases;
- Wild fish catches and landings increase near the cages; and
- Interaction is mostly reversible, though not in the case of some very sensitive species such as *Posidonia,* or specific ecosystems.

Justification

The interaction of aquaculture with nearby wild flora and fauna is of concern in relation to its development. In some cases, aquaculture facilities, especially fish cages, have negative impacts on local fragile or sensitive species, such as seagrass meadows. On the other hand, farm operations might attract local fauna and even have positive effects on fish populations and productivity.

Principle

The negative impacts of interaction between aquaculture and local flora and fauna should be avoided, whilst the positive effects should be exploited.

Guidelines

About the effects of aquaculture on benthic communities

- **Environmental Impact Assessments should be carried out to detect any possible effect on the wild ecosystem**. The use of bio-indicator species should be preferred to the collection of more parameters.

- **Decisions to develop or stop further deployment of aquaculture facilities should be managed case by case**. It is necessary to take the ecosystem into account, as well as technical and economical considerations such as the presence of sensitive species, the number of farms, their type, their dimensions and the densities inside aquaculture structures.

- **Hydrodynamic and ecological studies should be conducted as part of the process of site selection**.

- **Areas which contain significant communities of seagrass meadows should be considered as incompatible with the establishment of aquaculture facilities**.

- **The settlement of cages in exposed areas, located away from the coastal shore, should be encouraged**. This would minimise the effects on the seabed and coastal ecosystems.

About attraction of fauna

- **The attraction of local fauna by the aquaculture structures should be part of the management of farms**. It might have positive effects on enhancing local productivity and therefore the fisheries stocks.

- **The attraction of predators and scavengers should be properly managed**. The feeding of wild fauna on aquaculture fish stocks, or any other food, is not desirable and can lead to problems. All measures should be taken to avoid the appearance of such phenomena. This includes scaring techniques and not letting feeds or carcasses outside of closed containers.

Which aquaculture for which marine protected area?

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One of the main issues concerning marine protected areas is the role that they can play in sustaining local livelihoods and alleviating local poverty issues. Small scale fisheries, ecotourism and diving activities are often presented as sustainable activities that can take place inside, or close to, marine protected areas. Aquaculture can probably play a role in this case. Aquaculture requires good quality water and a healthy ecosystem. Aquaculture is often cited as playing the role of "sentinel": if the environmental parameters become wrong, then aquaculture production will suffer as an immediate consequence. In other words, sustainable aquaculture can only take place in a healthy environment. Although the overload of organic matter created by aquaculture operations would not usually be compatible with marine protected areas, low density aquaculture might be a good solution for sustaining the livelihoods of the local population around marine protected areas.

Some types of aquaculture, such as mussel or oyster culture, have a long history, are traditional practices, and are heavily linked with the local ecosystems. In this case, some aquaculture areas would merit protection in the same way that some vineyards or olive trees fields are now protected in rural areas. Traditional aquaculture areas do have cultural values. For example, earthen pond fish farms ("*esteros*") along the South-eastern coast of Spain, which are the economic evolution of old salt pans, provide the centre of the conservation values of a local protected area ("*Parque Natural Bahia de Cadiz*"). Another example is mussel culture in the Galician *rias*, which is an important part of the local landscape. The recognition that traditional aquaculture is supporting local biodiversity, as well as landscape and seascape, is important and could help to conserve marine biodiversity. Areas where traditional aquaculture takes place could be designated as marine protected areas. In this case they would fall under IUCN category V (*Protected Landscape/Seascape: Protected area managed mainly for landscape/seascape conservation and recreation.*)

Eco-tourism on the fish farm

As with farms in rural areas, aquaculture facilities could be turned into tourist attractions. Apart from visiting the facilities and viewing the production systems, tourists could also learn about the integration of the production activity into the natural environment. The fact that numerous fishes and other animals might be attracted by the cages could also be used for tourism purposes, such as offering a diving experience based around the aquaculture cages. Consequently, tourists would get a better image of the aquaculture activity, and the producers would be encouraged to keep the farm and

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its surrounding area clean in order to transmit a positive image of their activity. Furthermore, produce from the farm could be sold directly to the tourists.

Culture density and problem density

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The density of the reared fish stocks is a major factor in relation to the effects on the bottom communities and local flora and fauna. The density is the number of fish per volume of water in one cage (or the quantity of shellfish in one structure), or the quantity of cages in a site. It is a matter of scale. In both cases, the strength of the effects is linked to the aquaculture density. Therefore, the density and the adequacy of the type of aquaculture activities have to be considered alongside the sensitivity of the local ecosystem. The optimisation of densities in cages and other rearing devices might avoid problems linked to ecosystem sensitivity. Extensive aquaculture might in many cases be a solution to avoid problems related to local flora and fauna. The concept of carrying / holding capacity is key to this issue.

Annexes

Glossary

Aquaculture

According to FAO in the Technical Guidelines for Responsible Fisheries (1997), "*Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture*".

Biodiversity

Biodiversity (short for "*biological diversity*") is a notion – a representation of the complexity or web of life, in all its forms. The Convention on Biological Diversity (CBD) defines biodiversity as "*the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and ecosystems*".

Signed by 150 government leaders at the 1992 Rio Earth Summit, the Convention on Biological Diversity is dedicated to promoting sustainable development. Conceived as a practical tool for translating the principles of Agenda 21 into reality, the Convention recognises that biological diversity is about more than plants, animals and micro organisms and their ecosystems – it is about people and their need for food security, medicines, fresh air and water, shelter, and a clean and healthy environment in which to live.

Biofouling

Marine biological fouling, usually termed marine biofouling, is the undesirable accumulation of microorganisms, plants, and animals on surfaces immersed in sea water.

Cages

According to FAO, "*Cages are a rearing facility enclosed on the bottom as well as on the sides by wooden, mesh or net screens. It allows natural water exchange through the lateral sides and in most cases below the cage*".

Carrying capacity

According to FAO, *"Carrying capacity is the amount of a given activity that can be accommodated within the environmental capacity of a defined area"*. In aquaculture: *"usually considered to be the maximum quantity of fish that any particular body of water can support over a long period without negative effects to the fish and to the environment"*.

Coastal Zone Management

Coastal zone management can be defined as "*the management of the coastal and marine areas and resources in order to have a sustainable use, development and protection*".

Domestication

According to FAO, "*Domestication is the process by which plants, animals or microbes selected from the wild adapt to a special habitat created for them by humans, bringing a wild species under human management"*. In a genetic context, the *"process in which changes in gene frequencies and performance arise from a new set of selection pressures exerted on a population*".

Exposed Aquaculture

Aquaculture is usually defined as "exposed aquaculture" when "*cage aquaculture is developed in marine areas not protected by the coastline from adverse marine conditions"*.

Fallowing

According to FAO, "*Fallowing is a process where sites normally used for production are left to recover for part or all of a growing season*".

Immunostimulants

These are molecules that have stimulatory effects on non-specific immune defences of humans and animals. These compounds are attractive for use in intensive fish and animal farming: to improve the health of the organisms and prevent disease outbreak, thereby reducing the use of antibiotics and veterinary medicines.

Integrated Aquaculture

According to FAO, "*Integrated aquaculture is an aquaculture system sharing resources such as water, feeds and management, with other activities; commonly agricultural, agro-industrial, infrastructural (wastewaters, power stations, etc.)*". Nevertheless, "*the raising of several organisms in the same aquaculture facility, where the volume of residues of one species is used as food by another species*" is accepted in aquaculture. This system reduces the total volume of residues of the aquaculture facility, increasing the total biomass production.

Intensive Culture

According to FAO, "*Intensive culture is a system of culture characterised by a production of up to 200 tonnes/ha/yr; a high degree of control; high initial costs, high-level technology, and high production efficiency; tendency towards increased independence of local climate and water quality; and the use of man-made culture systems*".

Marine Protected Area

The definition of a marine protected area (MPA) adopted by IUCN is : "*Any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment*".

Polyculture

According to FAO, "*Polyculture is the rearing of two or more non-competitive species in the same culture unit*". There is no competition for food or habitat, but neither are there any trophic benefits due to the interaction.

Ponds

According to FAO, "*Ponds are a relatively shallow and usually small body of still water or with a low refreshment rate, most frequently artificially formed, but can also apply to a natural pool, tarn, mere or small lake*".

Protected Area

The Convention on Biological Diversity defines protected areas as "*a geographically defined area which is designated or regulated and managed to achieve* *specific conservation objectives."* IUCN, the World Conservation Union (1994) defines protected areas as *"areas of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means."*

Sheltered Aquaculture

Aquaculture is usually defined as "sheltered aquaculture" when "*cage aquaculture is developing in marine areas protected by the coastline from adverse marine conditions"*.

Tanks

According to FAO, "*Tanks are a fish or water holding structure, usually above ground, typically with a high water turnover rate and highly controlled environment*".

General Bibliography

This bibliography may not be directly quoted in the text but includes basic documents about aquaculture:

Asociación Empresarial de Productores de Cultivos Marinos (APROMAR), 2005. *La Acuicultura Marina de Peces en España*. 39 pp.

Asociación Empresarial de Productores de Cultivos Marinos (APROMAR), 2006. *La Acuicultura Marina de Peces en España*. 52 pp.

Black, K.D. (Ed.), 2001. *Environmental Impacts of Aquaculture*. Academic Press, Sheffield, UK, 214 pp.

Beaz, D., Beaz, V., Dürr, V., Icely, J., Lane, A., Thomason, J., Watson, D. and Willemsen, P.R., 2005. Sustainable Solutions for Mariculture Biofouling in Europe. ASLO Meeting, Santiago de Compostela, Spain, 19th June 2005.

Bostick, C., Clay, J.W., McNevin, A.A., 2005. Aquaculture and the Environment. A WWF Handbook on Production Practices, Impacts, and Markets.

Dunham, R.A., Majumdar, K., Hallerman, E., Bartley, D., Mair, G., Hulata, G., Liu, Z., Pongthana, N., Bakos, J., Penman, D., Gupta, M., Rothlisberg, P. & Hoerstgen-Schwark, G., 2001. Review of the status of aquaculture genetics. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. *Aquaculture in the Third Millennium*. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 137-166. NACA, Bangkok and FAO, Rome.

FAO, NACA, UNEP, The World Bank, WWF, 2006. International Principles for Responsible Shrimp Farming, 26 pp.

Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), 1997. Towards safe and effective use of chemicals in coastal aquaculture. IMO/FAO/UNESCO-IOC/WMO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. *Reports and Studies GESAMP*. No. 65. London, IMO. 40 pp. <http://www.fao.org/docrep/meeting/003/w6435e.htm>.

Hargrave, B., 2005. Environmental Effects of Marine Finfish Aquaculture. *The Handbook of Environmental. Chemistry*, vol. 5, Part M. Springer, Berlin.

Hasan, M.R., 2001. Nutrition and feeding for sustainable aquaculture development in the third millennium. In R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery & J.R. Arthur, eds. *Aquaculture in the Third Millennium*. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. pp. 193-219. NACA, Bangkok and FAO, Rome.

Moyle, P.B. & T. Light, 1999. Biological invasions of fresh water: empirical rules and assembly theory. *Biological Conservation*, 78: 149-161.

NACA/FAO, 2000. Aquaculture Development Beyond 2000: the Bangkok Declaration and Strategy. Conference on Aquaculture in the Third Millennium, 20-25 February 2000, Bangkok, Thailand. NACA, Bangkok and FAO, Rome. 27pp.

Naylor, R.L., Goldberg, R.J., Primavera, J.H., Kautsky, N., Beveridge, M.C.M., Clay, J., Folke, C., Lubcheno, J., Mooney, H., Troell, M., 2000. Effects of aquaculture on world fish supplies. *Nature* 405: 1017–1024.

Naylor, R., Hindar, K., Flaming, I.A., Goldburg, R., Williams, S., Volpe, J., Whoriskey, F., Eagle, J., Kelso, D. & Mangel, M., 2005. Fugitive salmon: assessing the risks of escaped fish from net-pen aquaculture. *BioScience*, 55: 427-473.

Railkin, A.I., 2004. Marine biofouling: colonization process and defenses. ISBN 0-8493-1419-4. CRC Press.

Rodríguez, C., **Carrasco, J.F., Arronte, J.C., Rodríguez, M., 2006.** Common octopus (*Octopus vulgaris* Cuvier, 1797) juvenile ongrowing in floating cages. *Aquaculture,* 256: 293-300.

Rottmann, R.W., R. Francis-Floyd, and R. Durborow, 1992. The role of stress in fish disease. Feb. 1992. *Southern Regional Aquaculture Center* Publication 474. 21May2001. <http://ag.ansc.purdue.edu/aquanic/publicat/usda_rac/efs/srac/474fs.pdf>.

Secretariat of the Convention on Biological Diversity, 2004. Solutions for sustainable mariculture - avoiding the adverse effects of mariculture on biological diversity. CBD Technical Series no. 12, 54 pp.

Tacon, A.G.J., 2004. Use of fish meal and fish oil in aquaculture: a global perspective. *Aquat. Resour. Cult. Dev.*, 1: 3–14.

Treasurer, J.W., 2002. A review of potential pathogens of sea lice and the application of cleaner fish in biological control. *Pest Management Science*, 58 (6): 546-558.

United Nations Environment Programme /Mediterranean Action Plan, 2004. *Marine pollution indicators Fact.* Document UNEP(DEC)MEDWG.264/Inf.14. http://dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id=2213

United Nations Environment Programme/Mediterranean Action Plan, 2005. *Action Plan concerning species introductions and invasive species in the*

Bibliography

Agnese, J.-F., Oteme, Z.J. and Gilles, S., 1995. Effects of domestication on genetic variability, fertility, survival and growth rate in a tropical siluriform: *Heterobranchus longifilis* Valenciennes 1840. *Aquaculture*, 131: 197-204.

Agulleiro, M.J., Anguis, V., Cañabate, J.P., Martínez-Rodríguez, G., Mylonas, C.C. and Cerdà, J., 2006. Induction of spawning of captive-reared Senegal sole (*Solea senegalensis*) using different administration methods for gonadotropin-releasing hormone agonist. *Aquaculture*, 257: 511-524.

Allendorf, F.W., 1991. Ecological and genetic effects of fish introductions: Synthesis and recommendation. *Can. J. Fisheries Aquat. Sci.*, 48: 178-181.

Alongi, D.M., Johnston, D.J. and Xuan, T.T., 2000. Carbon and nitrogen budgets in shrimp ponds of extensive mixed shrimp– mangrove forestry farms in the Mekong Delta, Vietnam. *Aquac. Res.*, 31: 387– 399.

Angel, D.L. 2004. Integrated aquaculture - variations on the theme of biofiltration. *Bull. Aquaculture Ass.Canada* 104: 20-25.

Angel, D.L. and Spanier, E. 2002. An application of artificial reefs to reduce organic enrichment caused by net-cage fish farming: preliminary results. *ICES J. Mar. Science*, 59: 324-329.

Angel, D.L., Krost, P. and Gordin, H. 1995. Benthic implications of net cage aquaculture in the oligotrophic Gulf of Aqaba. *European Aquaculture Society,* 25: 129-173.

Anon, 2005. *Risk on local fish populations and ecosystems posed by the use of imported feed fish by the tuna farming industry in the Mediterranean.* WWW Mediterranean Programme 12 pp.

Avault, J.W., 1997. Prevention of diseases: some fundamentals reviewed. *Aquaculture Magazine (March/April)*: 78-83.

Bachère, E., Mialhe, E., Noël, D., Boul, V., Morvan, A. and Rodrigues, J., 1995. Knowledge and research prospects in marine mollusc and crustacean immunology. Aquaculture, 132: 17–32.

Baum, C., Meyer, W., Fleischer, L.G. and Siebers, D., 2002. Biozidfreie Anti-fouling Beschichtung, EU Patent EP1249476A2.

Bax, N., K. Hayes, A. Marshall, D. Parry, and R. Thresher, 2001. *Man-made marinas as sheltered islands for alien marine organisms: Establishment and eradication of an alien invasive species. Turning the tide: the eradication of invasive species.* IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. pp 26-39.

Bell, J., Doherty, P. and Hair, 1999. Capture et élevage du poisson de récif coralline au stade post-larvaire: des débouchés pour les nouvelles entreprises artisanales. Ressources marines et commercialisation. *Bulletin de la CPS*, 6: 31-34.

Bell, J.G., Henderson, R.J., Tocher, D.R., McGhee, F., Dick, J.R., Porter, A.,

Smullen, R.P. and Sargent, J.R., 2002. Substituting fish oil with crude palm oil in the diet of Atlantic salmon (*Salmo salar*) affects muscle fatty acid composition and hepatic fatty acid metabolism. *American Society for Nutritional Sciences*: 222-230.

Bell, J.G., McGhee, F., Campbell, P.J. and Sargent, J.R. (2003) Rapeseed oil as an alternative to marine fish oil in diets of post-molt Atlantic salmon (Salmo salar): changes in flesh fatty acid composition and effectiveness of subsequent fish oil _wash out_. *Aquaculture*, 218: 515–528.

Berejikian, B.A., 1995. The effects of hatchery and wild ancestry and experience on the relative ability of steelhead trout fry (*Oncorhynchus mykiss*) to avoid a benthic predator. *Can. J. Fisheries Aquat. Sci.*, 52: 2476-2482.

Beveridge, M.C.M. 1996. *Cage Aquaculture*, 2nd ed. Edinburgh, Scotland: Fishing News Books: 346.

Blazer, V.S. and LaPatra, S.E., 2002. Pathogens of cultured fishes: potential risks to wild fish populations. Pages 197-224. In: J. Tomasso, ed. *Aquaculture and the Environment in the United States*. U.S. Aquaculture Society, A Chapter of the World Aquaculture Society, Baton Rouge, LA.

Boesch, D.F., R.H. Burroughs, J.E. Baker, R.P. Mason, C.L. Rowe, and R.L. Siefert, 2001. *Marine Pollution in the United States: Significant Accomplishments, Future Challenges.* Pew Oceans Commission, Arlington, Virginia.

Brake, J., Davidson, J. And Davis, J., 2004. Field observations on growth, gametogenesis, and sex ratio of triploid *Mytilus edulis*. *Aquaculture*, 236: 179-191.

Britton-Simmons K.H. 2004. Direct and indirect effects of the introduced alga *Sargassum muticum* on benthic, subtidal communities of Washington State, USA. *Mar Ecol Prog Ser*, 277: 61-78.

Burd, B., 1997. B.C. *Salmon Aquaculture Review Interim Draft Report. Key Issue C: Waste Discharges.* British Columbia Environmental Assessment Office. 157 pp.

Buschmann, A.H., Lopez, D.A. and Medina, A., 1996. A review of environmental effects and alternative production strategies of marine aquaculture in Chile. *Aquacult. Eng.*, 15, 397– 421.

Cal, R.M., Vidal, S., Gómez, C., Álvarez-Blázquez, A., Martínez, P. and Piferrer, F., 2006. Growth and gonadal development in diploid and triploid turbot (*Scophthalmus maximus*). *Aquaculture*, 251: 99-108.

Cancemi, G., de Falco, G. and Pergent, G., 2003. Effects of organic matter input from a fish farming facility on a *Posidonia oceanica* meadow. *Estuarine, Coastal and Shelf Science*, 56: 961-968.

Carlton, J.T., 1992. Introduced marine and estuarine mollusks of North America: an end-of-the-20th-century perspective. *J. Shellfish Res.*, 11: 489-505.

Carroll, M.L., Cochrane, S., Fieler, R., Velvin, R. and White, P., 2003. Organic enrichment of sediments from salmon farming: environmental factors, management practices, and monitoring techniques. *Aquaculture*, 226: 165– 180.

Carver, C.E., Chisholm, A. and Mallet, A.L., 2003. Strategies to mitigate the impact of *Ciona intestinalis* (L.) biofouling on shellfish production. *J. Shellf. Res.*, 22: 621-631.

Cataudella, S., Massa F., Crosetti, D., (eds), 2005. Interaction Between Aquaculture and Capture Fisheries: a methodological perspective" Studies and Review General Fisheries Commission for the Mediterranean N. 78, FAO, Rome, 229 pp.

Chamberlain, J., Fernandes, T.F., Read, P., Nickell, T.D. and Davies, I.M., 2001. Impacts of biodeposits from suspended mussel (*Mytilus edulis* L.) culture on the surrounding superficial sediments. *ICES J. Mar. Sci.*, 58: 411– 416.

Chelossi, E., Vezzulli, L., Milano, A., Branzoni, M., Fabiano, M., Riccardi, G. and Banat, I.M., 2003. Antibiotic resistance of benthic bacteria in fish farm and control sediments of the western Mediterranean. *Aquaculture*, 219: 83-97.

Chopin, T., Yarish, C., Wilkes, R. Belyea, E.,Lu, S. and Mathieson., A., 1999. Developing *Porphyra*/salmon integrated aquaculture for bioremediation and diversification of the aquaculture industry. *J. Applied Phycol.,* 11: 463–472.

Chopin, T., Buschmann, A.H., Halling, C., Troell, M., Kautsky, N., Neori, A., Kraemer, G.E., Zertuche-González, J.A., Yarish, C. and Neefus, C. 2001. Integrating seaweeds into marine aquaculture systems: a key towards sustainability. *J. Phycol.*, 37: 975-986

Christensen, P.B., Glud, R.N., Dalsgaard, T. and Gillespie, P., 2003. Impacts of longline mussel farming on oxygen and nitrogen dynamics and biological communities of coastal sediments. *Aquaculture*, 218: 567– 588.

Cohen A.N. and Carlton J.T. 1995. *Nonindigenous aquatic species in a U.S. estuary: a case study of the biological invasions of the San Francisco Bay and delta.* Report US Fish & Wildlife Service, Washington D.C. and National Sea Grant College Program, Connecticut Sea Grant, (NOAA Grant Number NA36RG0467).

Commision of the European Communities, 2002. A strategy for the sustainable development of European aquaculture. *Communication from zhe Commission to the Council and the European Parliament.* 26 pp.

Costa-Pierce, B.A., 1996. Environmental Impacts of nutrients from aquaculture: Towards the evolution of sustainable aquaculture. In: *Aquaculture and Water Resource Management,* D.J. Baird, M.C.M. Beveridge, L.A. Kelly and J.F. Muir (eds.). Blackwell Science, U.K. 81-113 pp.

Costello, M.J., Grant, A., Davies, I.M., Cecchini, S., Papoutsoglou, S., Quigley D. and Saroglia, M., 2001. The control of chemicals used in aquaculture in Europe. *J. Appl. Ichthyol.,* 17 (4): 173– 180.

Crawford, C.M., Macleod, C.K.A. and Mitchell, I.M., 2003. Effects of shellfish farming on the benthic environment. *Aquaculture*, 224: 117– 140.

Da Costa, K.G. and Nalesso, R.C., 2006. Effects of mussel farming on macrobenthic community structure in Southeastern Brazil. *Aquaculture*, 258: 655-663.

Davenport, J., Black, G., Burnell, G., Cross, T., Culloty, S., Ekaratne, S., Furness, B., Mulcahy, M. and Thetmeyer, H., 2003. *Aquaculture: the ecological issues.* British Ecological Society: Ecological Issues Series (Blackwell Science Ltd) 89 pages.

Davis, D.A., Samocha, T.M., Bullis, R.A., Patnaik, S., Browdy, C.L., Stokes, A.D. and Atwood, H.L. 2004. Practical diets for *Litopenaeus vannamei* (Boone, 1931): working towards organic and/or all plant production diets. *In* L.E. Cruz-Suárez, D. Ricque-Marie, M.G. Nieto-Lopez, D.A. Villarreal-Cavazos, U. Scholz & M.L. Gonzalez-Felix, (eds.) *Proceedings of the VII International Symposium on Aquaculture Nutrition.* Universidad Autonoma de Nuevo Leon, Mexico. Hermosillo, Mexico,

Delgado, O., Grau, A., Pou, S., Riera, F., Massuti, C., Zabala, M. And Ballesteros, E., 1997. Seagrass regression caused by fish cultures in Fornells Bay (Menorca, Western Mediterranean). *Oceanologia Acta,* 20: 557-563.

Delgado, O., Ruiz, J., Pérez, M., Romero, J. and Ballesteros, E., 1999. Effects of fish farming on seagrass (*Posidonia oceanica*) in a Mediterranean bay: seagrass decline after organic loading cessation. *Oceanologia Acta*, 22: 109-117.

De Silva, S., Nguyen, T.T., Wabery, N. and Amarasinghe, U.S., 2006. An evaluation of the role and impacts of alien finfish in Asian inland aquaculture. *Aquaculture Research*, 37: 1-17.

Dimech, M., Borg, J.A. and Schembri, P.J., 2000. Structural changes in a *Posidonia oceanica* meadow exposed to a pollution gradient from a marine fish-farm in Malta (Central Mediterranean). *Biol. Mar. Mediterr.*, 7(2): 361-364.

Doherty, P.J., Dufour, V., Galzin, R., Hixon, M.A. Meekan, M.G and Planes, S., 2004. High mortality during settlement is a population bottleneck for a tropical surgeonfish. *Ecology*, 85:2422–2428.

Doelle, M. 2003. The Quiet Invasion: Legal and Policy responses to Aquatic Invasive Species in North America. *The International Journal of Marine and Coastal Law*, 18 (2): 261-294.

Dugenci, S.K., (2003). Some Medical Plants as Immunostimulant for Fish. *Journal of Ethnopharmacology*, 88:99-106.

Elfwing, T. and Tedengren, M., 2002. Effects of copper on the metabolism of three species of tropical oysters, *Saccostrea cucullata*, *Crassostrea lugubris* and *C. belcheri*. *Aquaculture*, 204: 157–166.

EEA, 2006. *Priority issues in the Mediterranean environment.* EEA Report 4, 88 pp

Eno N.C., Clark R.A. and Sanderson W.G. 1997. *Non-native marine species in British waters: a review and directory*. Published by JNCC, Peterborough: 152pp.

Environmental Assessment Office (EAO), 1998. British Columbia. The Salmon Aquaculture Review.
<http://www.eao.gov.bc.ca/project/aquacult/salmon/report/toc.htm>.

European Commission, 2004. European Code of Practice for Sustainable and Responsable Fisheries. Luxemburgo: Official Publications Office of European Communities. 15 pp.

Falconer, D.S., 1989. *Introduction to Quantitative Genetics*, 3rd edn. Longman, New York.

Federation of European Aquaculture Producers (FEAP), 2000. *Code of Conduct for European Aquaculture*. FEAP, Brussels. http://www.feap.info/FileLibrary/6/FEAP%20Code%20of%20Conduct.pdf.

Flassch J.P. and Leborgne Y. 1992. Introduction in Europe, from 1972 to 1980, of the

Japanese Manila clam (*Ruditapes philippinarum*) and the effects on aquaculture production and natural settlement. *ICES mar. Sci. Symp.*, 194: 92-96.

Food and Agriculture Organization of the United Nations (FAO), 1997. *Aquaculture development*. FAO Tech. Guidel. Responsible Fisheries, (5):40 pp.

Food and Agriculture Organization of the United nations (FAO) 2003. Fishery Records Collections. FIGIS Data Collection. FAO - Rome. Updated Jan 31 2007. http://www.fao.org/figis/servlet/static?dom=collection&xml=dias.xml

Food and Agriculture Organization of the United Nations (FAO), 2004a. The State of World Fisheries and Aquaculture. SOFIA 2004. http://www.fao.org/DOCREP/007/y5600e/y5600e00.htm

Food and Agriculture Organization of the United Nations (FAO), 2004b. Capture-based aquaculture. The fattening of eels, groupers, tunas and yellowtails.

Food and Agriculture Organization of the United Nations (FAO), 2005a. FAO Fisheries Department, Fishery Information, Data and Statistics Unit. Fishstat Plus: Universal software for fishery statistical time series. Aquaculture production: quantities 1950–2003; Aquaculture production: values 1984–2003; Capture production: 1950–2003; Commodities production and trade: 1950–2003; Total production: 1970–2003,Vers. 2.30. www.fao.org/fi/statist/FISOFT/FISHPLUS.asp

Food and Agriculture Organization of the United Nations (FAO), 2005b. General fisheries commission for the Mediterranean international commission for the conservation of Atlantic tunas. Report meeting of the ad hoc GFCM/ICCAT working group on sustainable bluefin tuna farming/fattening practices in the Mediterranean. Rome, 2005.

Food and Agriculture Organization of the United Nations (FAO), 2006a. *State of world aquaculture: 2006*. FAO Fisheries technical paper No. 500, 145pp.

Food and Agriculture Organization of the United Nations (FAO), 2006b. *Use of fisheries resources as feed inputs to aquaculture development: trends and policy implications*. FAO Fisheries Circular No. 1018, 114 pp.

Galil B., Froglia, C. and Noël, P., 2002. *CIESM Atlas of Exotic Species in the Mediterranean. Vol.2. Crustaceans. Decapods and stomapods*. CIESM Publishers, Monaco. 192 pp.

García-Gómez, A., Díaz, M.V., de la Gándara, F., de la Serna, J.M., Belmonte, A., Ayora, E., Gordin, H., Fauvel, C., Medina, A., Bridges, C., Vassallo-Agius, R., Mylonas C. and De Metrio, G., 2005. Posibilidades de reproducción del atún rojo, *Thunnus thynnus*, en cautividad. *Actas del X Congreso Nacional de Acuicultura, Gandía (Valencia). Universidad Politécnica de Valencia*: 358-359.

Gardner, J., Peterson, D., Wood, A. and Maloney, V., 2004. *Making sense of the debate about hatchery impacts, interactions between enhanced and wild salmon on Canada's Pacific coast*. Pacific Fisheries Resource Conservation Council. Vancouver, British Columbia, 159 pp.

Gagnaire, B., Soletchnik, P., Madec, P., Geairon, P., Le Moine, O. and Renault, T., 2006. Diploid and triploid Pacific oysters, *Crassostrea gigas* (Thunberg), reared at two heights above sediment in Marennes-Oleron Basin, France: Difference in mortality, sexual maturation and hemocyte parameters. *Aquaculture*, 254: 606-616.

General Authority For Fish Resources Development (GAFRD), 2004. *Fish production statistics in Egypt for the year.* Egyptian Ministry for Agriculture and Reclamation land. 195 pp.

Golani D., Rellini-Orsi, I., Massutri, E. and Quignard, J.-P., 2002. *CIESM Atlas of Exotic Species in the Mediterranean. Vol.1. Fishes.* CIESM Publishers, Monaco. 256 pp.

Goulletquer Ph., Bachelet G., Sauriau P.G. and Noel P. 2002. Open Atlantic coast of Europe - a century of introduced species into French waters. In: Leppakoski E., Gollasch S. and Olenin S.(eds), *Invasive Aquatic species of Europe - distribution impacts and management.* Kluwer Academic Publishers, Dordrecht, Boston, London: 276-290.

Goodwin A.E., Peterson, J.E., Meyers, T.R. and Money, D.J., 2004. Transmission of Exotic Fish Viruses: The Relative Risks of Wild and Cultured Bait. *Fisheries*, 29(5): 19-23.

Grant, J., Hatcher, A., Scott, D.B., Pocklington, P., Schafer, C.T., Winters, G.V., 1995. A multidisciplinary approach to evaluating impacts of shellfish aquaculture on benthic communities. *Estuaries* 18(1A):124–144

Grizel H. and Héral M. 1991. Introduction into France of the Japanese oyster (Crassostrea gigas) J. *Cons. Int. Explor. Mer,* 47: 399-403.

Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), 1990. The state of the marine environment. *Rep. Stud. GESAMP,* (39): 111 p.

Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), 1997. Towards safe and effective use of chemicals in coastal aquaculture. IMO/FAO/UNESCO-IOC/WMO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. *Reports and Studies GESAMP.* No. 65. London, IMO. 40 pp. <http://www.fao.org/docrep/meeting/003/w6435e.htm>.

Guichard, B. & Licek, E., 2006. A comparative study of antibiotics registered for use in farmed fish in European countries. Poster. OIE Global Conference on Aquatic Animal Health, Bergen.

Guillen, I., Berlanga, J., Valenzuela, C.M. Morales, A., Toledo, J., Estrada, M.P., Puentes, P., Hayes, O. and LaFuente, J, 1999. Safety evaluation of transgenic tilapia with accelerated growth. *Mar. Biotech.*, 1: 2-14.

Hair, C., Bell, J. and Doherty, P. 2002. The use of wild-caught juveniles in coastal aquaculture and its application to coral reef fishes. *In* R.R. Stickney & J. McVey, eds. *Responsible Marine Aquaculture*, pp. 327-351. Wallingford, England, CAB International.

Haroun, R.J. and Izquierdo, M.S. 1991. Distribución de *Sargassum muticum* (Yendo) Fehnsholt en Europa. Peligros de su penetración en la Península Ibérica" *Actas V Simp. Iber. Estud. Bentos Mar.*, Vol. I: 22 – 27.

Hassin, S., De Monbrison, D., Hanin, Y., Elizur, A., Zohar, Y. and Popper, D.M., 1997. Domestication of the white grouper, *Epinephelus aeneus.* 1. Growth and reproduction. *Aquaculture*, 156: 305-316.

Hemminga, M.A. and Duarte, C.M., 2000. *Seagrass Ecology*. Cambridge University Press, Cambridge, 298 pp.

Henderson, A.R. and Davies, I.M., 2000. Review of aquaculture, its regulation and monitoring in Scotland. *J. Appl. Ichthyol.*, 16: 200-208.

Héral M. 1986, L'ostréiculture française traditionnelle. In: Barnabé G. (éd.), *Aquaculture. Vol. 1*. Lavoisier, Paris, pp. 345-390.

Hewitt, C.L., Campbell, M.L. and Gollasch, S., 2006. *Alien Species in Aquaculture. Considerations for responsible use*. IUCN, Gland, Switzerland and Cambridge, UK. viii + 32 pp.

Hindar, K., **2001**. Interactions of cultured and wild species. In: *Marine aquaculture and the environment: a meeting for stakeholders in the Northeast*. University of Massachusetts, Boston. 11–13 pp.

Holmer, M., Pérez, M and Duarte, C.M., 2003. Benthic primary producers—a neglected environmental problem in Mediterranean maricultures? *Mar. Pol. Bul.,* 46: 1372–1376.

Hostin, L.M., 2003. *Influência de cultivos de ostras (Crassostrea Sacco, 1897) nas comunidades macrobênticas de um canal de maré da Baía de Guaratuba, Paraná*. Dissertation. Biology Department, Universidade Federal do Paraná, 76 pp.

Howard, R.D., DeWoody, J.A. and Muir, W.M., 2004. Transgenic male mating advantage provides opportunity for Trojan gene effect in fish. *Proceedings of the National Academy of Sciences*, 101(9): 2934-2938.

Hussenot, J.M.E., 2003. Emerging effluent management strategies in marine fish-culture farms located in European coastal wetlands. *Aquaculture*, 226: 113-128.

International Council for the Exploration of the Sea (ICES), 2004. *Report of the Working Group on Introductions and Transfers of Marine Organisms (WGITMO).* International Council for the Exploration of the Seas, Copenhagen, Denmark, 151 pp.

International Council for the Exploration of the Sea (ICES), 2005. ICES *Code of Practice on the Introductions and Transfers of Marine Organisms*. International Council for the Exploration of the Seas, Copenhagen, Denmark. 30p.

Iglesias, J., Otero, J.J., Moxica, C., Fuentes, L. and Sánchez, F.J., 2004. The completed life cycle of the octopus (*Octopus vulgaris*, Cuvier) under culture conditions: paralarval rearing using *Artemia* and zoeae, and first data of juvenile growth up to 8 months of age. *Aquaculture Internacional,* 12: 481-487.

Ingrid, G., Andersen, T., and Vadstein, O., 1997. Pelagic food webs and eutrophication of coastal waters: impact of grazers on algal communities. *Mar. Pol. Bull.*, 33(1-6): 22-35.

International Fishmeal & Fish Oil Organisation (IFFO), 2002. Resources and Markets – The world market overview of fishmeal and fish oil, S. M Barlow, Paper presented to the 2nd Seafood By-Products Conference, Alaska in November 2002. http://www.iffo.org.uk/tech/alaska.htm

Izquierdo, M.S., Obach, A., Arantzamendi, L., Montero, D., Robaina, L. and Rosenlund, G., 2003. Dietary lipid sources for seabream and seabass: growth performance, tissue composition and flesh quality. *Aquacult. Nutr.*, 9: 397– 407.

Jerez, S., Samper, M., Santamaria, F.J., Villamandos, J., Cejas, J. and Felipe, B., 2006. Natural spawning of greater amberjack (*Seriola dumerili*) kept in captivity in the Canary Islands. *Aquaculture*, 252: 199-207.

Jones, A.B., Dennison, W.C. and Preston, N.P., 2001. Integrated treatment of shrimp effluent by sedimentation, oyster filtration and macroalgal absortion: a laboratory scale study. *Aquaculture*, 193: 155–178.

Karakassis, I., Tsapakis, M., Hatziyanni, E., Papadopoulou, K.N. and Plaiti, W., 2000. Impact of cage farming of fish on the seabed in three Mediterranean coastal areas. *ICES Journal of Marine Science*, 57: 1462-1471.

Kovac, N., Cermelj, B., Vrišer, B. and Lojen, S., 2004. The Influence of Fish Farming on Coastal Marine Sediment in Slovenia (Piran Bay, northern Adriatic) – Summary. In: UNEP/MAP/MED POL: *Mariculture in the Mediterranean*. MAP Technical Reports Series No. 140, UNEP/MAP, Athens, 2004.

Krom, M.D., Ellner, S., van-Rijn, J. and Neori, A., 1995. Nitrogen and phosphorus cycling and transformations in a prototype "non-polluting" integrated mariculture system, Eliat, Israel. *Mar.Ecol. Prog. Ser.,* 118:25-36.

Lachance, S. and Magnan, P., 1990. Performance of domestic, hybrid, and wild strains of brook trout, *Salvelinus fontinalis*, after stocking: The impact of intra- and interspecific competition. *Can. J. Fisheries Aquat. Sci.*, 47: 2278-2284.

Lleonart, J. and Majkowski, J., 2005. Summary report on bluefin tuna capture fishing for farming/fattening in the Mediterranean. In: *GFCM/ICCA ICCAT Working Group on sustainable Tuna Farming/Fattening practices in the Mediterranean*. Rome,

Lodeiros, C. and García, N., 2004. The use of sea urchins to control fouling during suspended culture of bivalves. *Aquaculture*, 231: 293-298.

Lovatelli, A., 2005. Summary report on the status of bluefin tuna aquaculture in the Mediterranean. In: *GFCM/ICCA ICCAT Working Group on sustainable Tuna Farming/ Fattening practices in the Mediterranean*. Rome, 16-18 pp.

Machias, A., Karakassis, I., Giannoulaki, M., Papadopoulou, K.N., Smith, C.J. and Somarakis, S., 2005. Response of demersal fish communities to the presence of fish farms. *Mar. Ecol. Prog. Ser.*, 288: 241-250.

Manley, A.R., 1983. The effects of copper on the behaviour, respiration, filtration and ventilation activity of *Mytilus edulis*. *J. Mar. Biol. Assoc. U.K.*, 63: 205–222.

Marbà, N., Santiago, R., Díaz-Almela, E., Álvarez, E. and Duarte, C.M., 2006. Seagrass (*Posidonia oceanica*) vertical growth as an early indicator of fish farm-derived stress. *Estuarine, Coastal and Shelf Science*, 67: 475-483.

Marinho-Soriano, E., Morales, C. and Moreira, W.S.C., 2002. Cultivation of *Gracilaria* (Rhodophyta) in shrimp pond effluents in Brazil. *Aquac. Res.*, 33: 1081–1086.

Marino,G., E. Panini, A. Longobardi, A. Mandich, M.G. Finoia, Y. Zohar and C.

Mylonas, 2003. Induction of ovulation in captive-reared dusky grouper, *Epinephelus marginatus* (Lowe, 1834), with a sustained-release GnRHa implant. *Aquaculture,* 219 (1-4): 841-858.

Martínez, S., 2005. *Contribución al estudio del crecimiento y aprovechamiento nutritivo de la dorada (Sparus aurata) alimentada con piensos con diferentes fuentes proteicas y lipídicas*. Tesis Doctoral. Universidad de Valencia: 204 pp.

Mazzola, A., Mirto, S., La Rosa, T., Danovaro, R. and Fabiano, M., 2000. Fish farming effects on benthic community structure in coastal sediments: analysis of the meiofaunal resilience. *ICES Journal of Mar. Sci.,* 57: 1454–1461.

McClelland, J.W. and Valiela, I., 1998. Changes in food web structure under the influence of increased anthropogenic nitrogen inputs to estuaries. *Mar. Ecol. Prog. Ser.*, 168: 259-271.

McGhie, T.K., Crawford, C.M., Mitchell, I.M. and O'Brian, D., 2000. The degradation of fish-waste in sediments during fallowing. *Aquaculture*. 187(3-4): 351-366.

McGinnity, P. and Ferguson, A., 2003. Accidental and Deliberate Introduction of Farmed Salmon and Result in reduced Survival and Fitness could Lead to Extinction of Vulnerable Wild Populations of Atlantic Salmon. http://130.226.135.19/fiskepleje/PDFs/Nontechnical.pdf

McNeely, J.A. and Schutyser, F., 2003. Invasive species: A global concern bubbling to the surface. *International Conference on the Impact of Global Environmental Problems on Continental and Coastal Marine Waters*. Geneva, Switzerland, 12 pp.

McVicar, A.H. 1997. Disease and parasite implications of the coexistence of wild and cultured Atlantic salmon populations. *ICES J. Mar. Sci.,*, 54: 1093–1103.

Miron, G., Landry, T., Archambault, P. and Frenette, B., 2005. Effects of mussel culture husbandry practices on various benthic characteristics. *Aquaculture*, 250: 138-154.

Mirto, S., La Rosa, T., Danovaro, R. and Mazzola, A., 2000. Microbial and meiofaunal response to intensive mussel farm biodeposition in coastal sediments of the Western Mediterranean. *Mar. Pollut. Bull.*, 40: 244–252.

Muir, W.M. and Howard, R.D., 1999. Possible ecological risks of transgenic organism release when transgenes affect mating success: sexual selection and the Trojan gene hypothesis. *Proc. Nat. Acad. Sci.*, 96: 13853-13856.

Muzinic, L.A., Thompson, K.R., Morris, A., Webster, C.D., Rouse, D.B. and Manomaitis, L., 2004. Partial and total replacement of fish meal with soybean meal and brewer's grains with yeast in practical diets for Australian red claw crayfish *Cherax quadricarinatus*. *Aquaculture*, 230: 359–376.

Mylonas, C., Papandroulakis, N. Smboukis, A., Papadaki, M. and Divanach, P., 2004. Induction of spawning of cultured greater amberjack (*Seriola dumerili*) using GnRHa implants. *Aquaculture*, 237: 141-154.

Myrick, C.A., 2002. Ecological impacts of escaped organisms. In: *Aquaculture and the Environment in the United States. U.S.*, J. Tomasso, (ed.). Aquaculture Society, A

Chapter of the World Aquaculture Society, Baton Rouge, LA. 225-245 pp.

Nash, C.E., P.R. Burbridge, and J.K. Volkman (editors). 2005. *Guidelines for ecological risk assessment of marine fish aquaculture.* U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-71, 90 p.

National Research Council (NRC), 1999. *The Use of Drugs in Food Animals: Benefits and Risks.* National Academy Press, Washington, D.C.

National Research Council (NRC), 2000. *Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution.* National Academy Press, Washington, D.C.

Neori, A, Msuya, F.E., Shauli, L., Schuenhoff, A., Kopel, F. and Shpigel, M. 2003. **A novel three-stage seaweed (*Ulva lactuca*) biofilter design for integrated mariculture.** *J. Applied Phycol.*, **15: 543-553.**

Neori, A., Chopin, T., Troell, M., Buschmann, A.H., Kraemer, G.P., Halling, C., Shpigel, M. and Yarish, C., 2004. Integrated aquaculture: rationale, evolution and state of the art emphasizing seaweed biofiltration in modern mariculture. *Aquaculture*, 231: 361–391.

New, M.B., Tacon, A.G.J. and Csavas, I. (eds.), 1995. *Farm-made aquafeeds.* FAO Fisheries Technical Paper No. 343, 434 pp., Rome.

New, M.B. and Wijkstrom, U.N., 2002. *Use of fish meal and fish oil in aquafeeds further thoughts on the fish meal trap.* FAO Fish . Circ. 975. Rome, 61 pp.

National Marine Fisheries Service/ U.S. Fish and Wildlife Service (NMFS/FWS), 2000. November 2000. Guide to the listing of a distinct population segment of Atlantic salmon as endangered. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. 21 May 2001. <http://www.nefsc.nmfs.gov/press_release/salmonguide00.01.pdf>.

Nordstrom, H., and Vaughan, S., 1999. *Trade and Environment.* Special Studies 4. Geneva: World Trade Organization.

Omoto, N., Maebayashi, M., Adachi, S., Arai, K. and Yamauchi, K., 2005. Sex ratios of triploids and gynogenetic diploids induced in the hybrid sturgeon, the bester (*Huso huso* female x *Acipenser ruthenus* male). *Aquaculture*, 245:39-47.

Ottolenghi, F, Silvestri, C., Giordano, P., Lovatelli, A. and New, M.B., 2004. *Capture-based aquaculture. The fattening of eels, groupers, tunas and yellowtails.* FAO, Rome. 308 pp.

Papandroulakis, N., Mylonas, C.C., Maingot, E. and Divanach, P., 2005. First results of greater amberjack (*Seriola dumerili*) larval rearing in mesocosm. *Aquaculture*, 250: 155-161.

Pearson, T.H. and Black, K.D., 2001. The environmental impacts of marine fish cage culture. In: *Environmental Impacts of Aquaculture*, Black, K.D. (ed.). Sheffield Academic Press, 1– 27 pp..

Pergent-Martini, C., Boudouresque, C.F., Pasqualini, V. and Pergent, G., 2006. Impact of fish farming facilities on *Posidonia oceanica* meadows: a review. *Marine Ecology*, 27: 310-319p.

Pike, I.H. 2005. Eco-efficiency in aquaculture: global catch of wild fish used in aquaculture. *Int. Aquafeed*, 8(1): 38–40.

Planes, S. and Lecaillon, G., 2001. Caging experiment to examine mortality, during metamorphosis of coral reef fish larvae. *Coral Reefs*, 20(3): 211-218.

Pohle, G., Frost, B. and Findlay, R., 2001. Assessment of regional benthic impact of salmon mariculture within the Letang Inlet, Bay of Fundy. *ICES J. Mar. Sci.*, 58: 417-426.

Porrello, S., Tomassetti, T., Manzueto, L., Finoia, M.G., Persia, E., Mercatali, I. and Stipa, P., 2005. The influence of marine cages on the sediment chemistry in the Western Mediterranean Sea. *Aquaculture*, 249: 145– 158.

Powell, K., 2003. Fish farming: eat your veg. *Nature*, 426: 378-379.

Robinson, S.M.C., Auffrey, L.M. and Barbeau, M.A., 2005. Far-Field Impacts of Eutrophication on the Intertidal Zone in the Bay of Fundy, Canada with Emphasis of the Soft-Shell Clam, *Mya arenaria. Hdb. Env. Chem.*, vol. 5, Part M: 253-274.

Rodríguez, A., Cuesta, A., Ortuno, J., Esteban M.A. and Meseguer, J., 2003. Immunostimulant properties of cell wall-modified whole *Saccharomyces cerevisiae* strain administered by diet to seabream (*Sparus aurata* L.). *Veterinary Immunology and Immunopathology*, 96: 183-192.

Ruckebusch, H., 1949. Le clam : note sur *Venus mercenaria* (L.), son introduction et son élevage dans le Bassin de la Seudre. *Rev. Trav. Off. Scient. Tech. Pêches. Mar.*, XV (1-4) (1949) 99-117.

Ruesink, J., Groom, M., Parker, I. and Kareiva, P., 1995. Reducing the risks of nonindigenous species introductions. *BioScience,* 47: 465-477.

Ruiz, G.M., Carlton, J.T., Grosholz, E.D. and Hines, A.H., 1997. Global invasions of marine and estuarine habitats by non-indigenous species: Mechanisms, extent, and consequences. *Am. Zool.*, 37: 621-632.

Ruiz, J.M., Perez, M. and Romero, J., 2001. Effects of fish farm loadings on seagrass (*Posidonia oceanica*) distribution, growth and photosynthesis. *Marine Pol. Bull.*, 42, 749-760.

Sadek, S. and Mires, M., 2000. Capture of wild finfish fry in Mediterranean coastal areas and possible impact on aquaculture development and marine genetic resources. *The Israeli Journal of Aquaculture - Bamidgeh*, 52(2), 77-88.

Sabaut, J.-J., 2002. *Feeding Farmed Fish.* President of the Interprofessional Committee for Aquaculture Products (CIPA) France.

Sanchez I., Fernandez, C., and Arrontes, J., 2005. Long-term changes in the structure of intertidal assemblages after invasion by *Sargassum muticum* (Phaeophyta). *J. Phycology*, 41: 942-949.

Sarà, G., Scilipoti, D., Mazzola, A. and Modica, A., 2004. Effects of fish farming waste on sedimentary and particulate organic matter in a southern Mediterranean area (Gulf of Castellammare, Sicily): a multiple stable isotope study (δ13C and δ15N). *Aquaculture*, 234: 199–213.

Sarà, G., Scilipoti. D., Milazzo, M. and Modica, A., 2006. Use of stable isotopes to investigate dispersal of waste from fish farms as a function of hydrodynamics.

Mar. Ecol. Prog. Ser., 313: 261-270.

Sargent, J.R. and Tacon, A.G., 1999. Development of farmed fish: a nutritionally necessary alternative to meat. *Proceeding of Nutritional Society*, 58: 377-383.

Schmidt, A.S., Bruun, M.S., Dalsgaard, I. and Larsen, J.L., 2001. Incidence, distribution, and spread of tetracycline determinants and integron-associated antibiotic resistance genes among motile aeromonads from a fish farming environment. *Appl. Environ. Microbiol.*, 67: 5675– 5682.

Schulze, A.D., Alabi, A.O., Tattersall-Sheldrake, A.R. and Miller, K.M., 2006. Bacterial diversity in a marine hatchery: Balance between pathogenic and potentially probiotic bacterial strains. *Aquaculture*, 256: 50-73.

Smith, J. and Shackley, S.E., 2004. Effects of a commercial mussel *Mytilus edulis* lay on a sublittoral, soft sediment benthic community. *Mar. Ecol., Prog. Ser.*, 282: 185– 191.

Smith, J.E., 2002. *Alien Marine Algae in the Hawaiian Islands.* www.botany.hawaii.edu/GradStud/smith/invasive/BROCHURE.htm

Smith, P., Hiney, M.P. and Samuelsen, O.B., 1994. Bacterial resistance to antimicrobial agents used in fish farming: a critical evaluation of method and meaning. *Annu. Rev. Fish Dis.*, 4: 273–313.

Soto, D. and Mena, G., 1999. Filter feeding by the freshwater mussel, *Diplodon chilensis*, as a biocontrol of salmon farming eutrophication. *Aquaculture,* 171: 65–81.

Stahr, P.A., Pedersen, M.F., Thomsen, M.S., Wernberg, T. and Krause-Jensen, D., 2000. Invasion of *Sargassum muticum* in Limfjorden (Denmark) and its possible impact on the indigenous macroalgal community. *Mar Ecol Pro Ser*, 207: 79-88.

Tacon, A.G.J., 2004. Use of fish meal and fish oil in aquaculture: a global perspective. *Aquat. Resour. Cult. Dev.*, 1: 3–14.

Tan, C.K.F., Nowak, B.F. and Hodson, S.L., 2002. Biofouling as a reservoir of *Neoparamoeba pemaquidensis* (Page 1970), the causative agent of AGD in Atlantic salmon. *Aquaculture*, 210: 49– 58.

Thomsen, M.S., Wernberg, T., Stahr, P.A. and Pedersen, M.F., 2006. Spatio-temporal distribution patterns of the invasive macroalga Sargassum muticum within a Danish Sargassum-bed. *Helgoland Marine Research*, 60(1): 50-58.

Thorarinsson, R. and Powell, D.B., 2006. Effects of disease risk, vaccine efficacy, and market price on the economics of fish vaccination. *Aquaculture*, 256: 42-49.

Thorpe, J.E., 1991. Acceleration and deceleration effects of hatchery rearing on salmonid development, and their consequences for wild stocks. *Aquaculture*, 98: 111-118.

Torrecillas, S., Makol, A., Caballero, M.J., Montero, D., Robaina, L., Real, F., Sweetman, J., Tort, L. and Izquierdo, M.S., 2007 Immune stimulation and improved infection resistance in European sea bass (*Dicentrarchus labrax)* fed mannan oligosaccharides. *Fish & Shellfish Immunology*. (in press, doi: 10.1016/j.fsi.2007.03.007).

Troell, M., Halling, C., Nilsson, A.. Buschmann, A.H., Kautsky, N. and Kautsky, L., 1997. Integrated marine cultivation of *Gracilaria chilensis* (Gracilariales, Rhodophyta) and salmon cages for reduced environmental impact and increased economic output. *Aquaculture,* 156: 45–61.

Troell, M., Halling, C., Neori, A., Chopin, T., Buschmann, A.H., Kautsky N. and Yarish, C., 2003. Integrated aquaculture: asking the right questions. *Aquaculture*, 226: 69-90.

United Nations Environment Programme /Mediterranean Action Plan, 2004. *Marine pollution indicators Fact.* Document UNEP(DEC)MEDWG.264/Inf.14. http://dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id=2213

United Nations Environment Programme/Mediterranean Action Plan, 2005. *Action Plan concerning species introductions and invasive species in the Mediterranean Sea.* Ed. RAC/SPA, Tunis. 30 pp.

Uriarte, A. and Basurco, B. (eds.), 2001. *Environmental impact assessment of Mediterranean aquaculture farms* Zaragoza : CIHEAM-IAMZ, 2001. 416 p. (Cahiers Options Méditerranéennes; v. 55). TECAM Seminar on Environmental Impact Assessment of Mediterranean Aquaculture Farms, 2000/01/17-21, Zaragoza (Spain).

Van Ginneken, V.J.T. and Maes, G.E., 2005. The European eel (*Anguilla anguilla*, Linnaeus), its Lifecycle, Evolution and Reproduction: A Literature Review. *Reviews in Fish Biology and Fisheries* 15(4): 367-398.

Verschuere, L., Rombaut, G., Sorgeloos, P. and Verstraete, W., 2000. Probiotic bacteria as biological control agents in aquaculture. *Microbiology and Molecular Biology Reviews,* 64: 655.

Vezzulli, L., Chelossi, E., Riccardi, G. and Fabiano, M., 2002. Bacterial community structure and activity in fish farm sediment of the Ligurian Sea (Western Mediterranean). *Aquaculture International,* 10 (2): 123– 141.

Viarengo, A., 1989. Heavy metals in marine invertebrates: mechanisms of regulation and toxicity at the cellular level. *Rev. Aquat. Sci.*, 1: 295–317.

Viera, M.P., Gómez Pinchetti, J.L., Courtois de Vicose, G., Bilbao, A., Suárez, S. Haroun R.J. and Izquierdo, M.S., 2006. Suitability of three red macroalgae as a feed for the abalone *Haliotis tuberculata coccinea* Reeve. *Aquaculture*, 248: 75-82.

Wabnitz, C., Taylor, M., Green, E. and Razak, T., 2003. *From Ocean to Aquarium.* UNEP-WCMC, Cambridge, UK.

Waknitz, F.W., Tynan, T.J., Nash, C.E., Iwamoto, R.N. and Rutter, L.G., 2002. *Review of potential impacts of Atlantic salmon culture on Puget Sound Chinook salmon and Hood Canal summer-run chum salmon evolutionarily significant units.* U.S. Dept. Commer., NOAA Tech. Memo. NMFS- NWFSC-53. 83 p.

Weber, M., 2003. *What price farmed fish: A review of the environmental & social costs of farming carnivorous fish.* SeaWeb Aquaculture Clearinghouse. Providence, Rhode Island. 52 pp.

Webster, C.D., Tiu, L.G., Margan, A.M and Gannm, A.M., 1999. Effect of partial replacement of fishmeal on growth and body composition of sunshine bass, Morone chrysops X M. saxatilis, fed practical diets. *Journal of World Aquaculture Society*, 30: 443-453.

Winton, J.R., 2001. Fish health management, In: *Fish Hatchery Management*, Wedemeyer, G. (ed.). 2nd ed. American Fisheries Society, Bethesda, MD, 559–639 pp.

Wolff, W.J. and Reise, K., 2002. Oyster imports as a vector for the introduction of alien species into Northern and Western European coastal waters. In: Leppakoski E., Gollasch S. and Olenin S. (eds), *Invasive Aquatic species of Europe - distribution impacts and management*. Kluwer Academic Publishers, Dordrecht, Boston, London: 193-205 pp.

World Commission on Environment and Development (WCED), 1987. *Our common future*. Oxford UK, Oxford University Press, 383 pp.

World Health Organization (WHO), 2002. *The world health report. Reducing risks, promoting healthy life*. 248 pp.

World Wide Fund for Nature (WWF), 2006. *The plunder of bluefin tuna in the Mediterranean and East Atlantic in 2004 and 2005. Uncovering the real story*. WWF Mediterranean Marine Programme, 101 pp.

Worm, B., Lotze, H.K., Boström, C., Engkvist, R., Labanauskas, V. and Sommer, U., 1999. Marine diversity shift linked to interactions among grazers, nutrients and dormant propagules. *Mar Ecol. Prog. Ser.*, 185: 309-314.

Worm, B. and Lotze, H.K., 2000. Nutrient pollution, low-trophic level harvesting and cumulative impacts on coastal ecosystems. In: *Proceedings of the symposium "Rockweed: management in the face of scientific uncertainty*",(R.W. Rangeley (ed.). Huntsman Marine Science Centre, St. Andrews, New Brunswick, Canada.

Worm, B., Lotze, H.K., and Sommer, U., 2000. Coastal food web structure, carbon storage, and nitrogen retention regulated by consumer pressure and nutrient loading. *Limnol. and Oceanogr.*, 45(2): 339-349.

Youngson, A.F., Dosdat, A., Saroglia, M. and Jordan, W.C., 2001. Genetic interactions between marine finfish species in European aquaculture and wild conspecies. J. *Appl. Ichthyol.,* 17 (4): 153–162.

Yu, Y., 2004. Replacement of fishmeal with poultry byproduct meal and meat and bone meal in shrimp, tilapia and trout diets. *In* L.E. Cruz-Suárez, D. Ricque-Marie, M.G. Nieto-Lopez, D.A. Villarreal-Cavazos, U. Scholz & M.L. Gonzalez-Felix, (eds.) *Proceedings of the VII international symposium on aquaculture nutrition*,. Universidad Autonoma de Nuevo Leon, Hermosillo, Mexico.

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List of Acronyms

APROMAR:	Spanish Marine Aquaculture Producers Association (Asociación Empresarial de Productores de Cultivos Marinos)
BFT:	Atlantic Bluefin Tuna
BIOFAQ:	BIOFiltration and AQuaculture: an evaluation of hard substrate deployment performance within mariculture developments. European Union FP5 (Fifth Framework Programme)
BIOGES:	Biodiversity and Environmental Management Research Centre of the University of Las Palmas de Gran Canaria
BSE:	Bovine Spongiform Encephalopathy
CARE system:	Collection by Artificial Reef-Ecofriendly, developed by Ecocean Inc
CBD:	Convention on Biological Diversity
CIESM:	The Mediterranean Science Commission
CRAB:	Collective Research on Aquaculture Biofouling
ECASA:	An Ecosystem Approach to Sustainable Aquaculture. European Union FP 6 (Sixth Framework Programme)
EEA:	European Environment Agency
EU:	European Union
FAO:	Food and Agriculture Organization of the United Nations
FEAP:	Federation of European Aquaculture Producers
GAFRD:	General Authority for Fish Resources Development

GESAMP:	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GMO:	Genetically modified organism
GFCM:	General Fisheries Commission for the Mediterranean
ICES:	International Council for the Exploration of the Sea
ICCAT:	International Commission for the Conservation of Atlantic Tuna
IFFO:	International Fishmeal and Fish Oil Organisation
IUCN:	The World Conservation Union
MPA:	Marine protected area
MEA:	Algerian Ecologic Movement (Mouvement Ecologique Algérien)
MEDVEG:	Effects of nutrient release from Mediterranean fish farms on benthic vegetation in coastal ecosystems, EU project
MERAMED:	Development of monitoring guidelines and modeling tools for environmental effects from Mediterranean aquaculture, EU project
NMFS / FWS:	National Marine Fisheries Service / Fish and Wildlife Service
MAPA:	Ministry of Agriculture, Fisheries and Food of Spain
MARAQUA:	Monitoring and Regulation of Marine Aquaculture, EU project
NRC:	National Research Council
RAC-SPA:	Regional Activity Centre for Specially protected Areas
UNEP-MAP:	United Nations Environmental Programme – Mediterranean Action Plan
WCED:	World Commission on Environment and Development
WHO:	World Health Organization

Ministry of Agriculture, Fisheries and Food

The Ministry of Agriculture, Fisheries and Food is the department of the General Administration of the Spanish State responsible for proposing and implementing the government's general directions concerning agriculture, fisheries and food policies. The Secretariat General for Maritime Fisheries is in charge of planning and implementing policies related to sea fisheries, basic governance of the fishing sector, aquaculture and commercialization of fish products.

www.mapa.es

Federation of European Aquaculture Producers

The Federation of Aquaculture Producers (FEAP), founded in 1968, currently represents 28 national aquaculture associations in 23 European countries, with a finfish annual production of over 1.3 million tones. FEAP is a Member Organisation of the Advisory Committee on Fisheries and Aquaculture of the Commission of the European Union and carries out numerous European and international activities for the aquaculture sector.

www.feap.info

IUCN – Centre for Mediterranean Cooperation

The Centre was opened in October 2001 and is located in the offices of the Parque Tecnologico de Andalucia near Malaga. IUCN has over 155 members in the Mediterranean region, including 15 governments. Its mission is to influence, encourage and assist Mediterranean societies to conserve and use sustainably the natural resources of the region, work with IUCN members and cooperate with all other agencies that share the objectives of IUCN.

www.uicnmed.org

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