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Integrated Coastal Management & Sustainable Aquaculture Development in the Adriatic Sea, Republic of Croatia

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Executive Summary

The health and sustainable use of coastal and ocean resources are of critical importance given their role in food production, economic activity, genetic biodiversity and recreation. In addressing costal management and aquaculture it is essential to strike a balance between the need for economic development and the need for natural resources conservation within the same management plan. Therefore, Integrated coastal management and sustainable aquaculture development in the Adriatic, includes careful consideration of a multiplicity of parameters and their interactions. Adequate policy addresses the resolution of potential conflicts, which is often hindered by lack of information or appropriate methodologies. Planning for sustainable uses is a process that comprehensibly and holistically analyses islands and coastal systems: natural resources conditions, human uses and socio-economic aspects.

Around the world, examples of sustainable aquaculture have proved to be a revitalizing economic force in a number of rural and coastal. In such communities, however, the introduction of aquaculture into areas traditionally used largely for commercial fisheries and a variety of recreational activities have sometimes coincided with impassioned user group conflict. To overcome this issue a planned, balanced and inclusive community approach to rural economic and social development is required. Through effective research, development, monitoring and incentive programs that maintain ecosystem integrity and balance human values, economic development can be attained in an environmentally and socially sustainable manner. Therefore, inevitable process of globalization might become more sustainable if the local level development becomes more self-sustainable, within the capacities of its natural and cultural resources.

Practitioners have discovered that sustainable aquaculture must not only maximize benefits, but also minimize accumulation of detriments, as well as other types of negative impacts on natural and social environment. Aquaculture can be developed in ways that do not degrade coastal and marine biodiversity. One possible solution is integrated, multi-species aquaculture or 'polyculture'. It is based on the harmonious stocking of different varieties of fish species at different levels of population, using an understanding of the production cycle and energy flow through the selected natural habitat.

The proposed vision for aquaculture development in the Adriatic is based on the approach that *'the environment sets the limits for sustainable development'*, which should be used for any other coastal, marine or island activity and resource use. Aquaculture development has to be advanced in a manner that is environmentally responsible and sustainable, protecting the quality of the environment for other users, while it is equally important for society to protect the quality of the environment for aquaculture. Adherence to both aspects requires effective and transparent research, adaptive management, monitoring, enforcement and incentive. The Government-approved and industry/stakeholders-led 'Environmental Codes of Practice' and National Aquaculture Plan will support this approach through the Integrated Coastal Zone Management implementation.

Finding suitable sites for aquaculture in the marine and coastal environment is one of the most critical challenges facing this industry. The most important step is to identify the environmental conditions necessary for aquaculture activities to succeed. Determination of suitability for aquaculture involves an evaluation of natural and anthropogenic limitations of a certain area in order to decide if the locality can support the activity. Developed protocols for aquaculture (as well as any other coastal activity) can be used as environmental quality standards that will help guide and control activities within certain environmental limits. If aquaculture requires an excellent water quality and certain type of environmental conditions, than this activity should also maintain this environmental quality within established environmental quality standards. Ultimately, through guidance of monitoring programs (environmental and socio-economic), better information can be incorporated into the analytical protocols. This will improve evaluations, and complete the feedback loop for the planning of ICZM and sustainable aquaculture development.

The main outputs and results of integrated GIS (Geographic Information System) site suitability analysis for aquaculture are: established aquaculture site suitability criteria with map portfolio of suitable sites for aquaculture, and coastal management action plan with identified issues, possible options and recommended scenarios.

Management choices will be required when certain activities can appear in the same locations based on suitability analysis of the area (e.g aquaculture vs tourist beach area, vs marina). In these instances, choice has to be based on environmental requirements for the activity and the activity's interaction with the environmental resources (impact assessment, EIA). First priority should be given to the activity with the highest environmental suitability level and the lowest adverse impact on the respective land/water ecosystem. Implementation and final decision-making must incorporate socio-economic suitability, and cultural factors. Involving the community in the planning and decision-making process is an important step toward acceptability and success of the coastal management project. The use suitability and use conflict analyses support the interdisciplinary aspects of ICZM planning, and decision-making processes addressing where, how and why aquaculture or any other activity will mostly succeed in sustainable manner.

Introduction

This report discusses development of responsible aquaculture in the Republic of Croatia as part of the integrated coastal zone management and sustainable development of marine, coastal and islands natural and human resources. Based on literature review examples of aquaculture development and its constraints are presented, as well as possible solutions and recommendations. In addition, one attachment document provides brief summary information regarding Mediterranean lessons in aquaculture practices, while second document provides draft guidelines for sustainable aquaculture development in Croatia. Report is a contribution to the project *'The Integrated Coastal Zone Management for Croatia with special focus on aquaculture'*, administered by the Ministry for Agriculture, Forestry and Fisheries, the Government of Croatia.

Vision statement

Aquaculture development has to be advanced in a manner that is environmentally responsible and sustainable, protecting the quality of the environment for other users, while it is equally important for society to protect the quality of the environment for aquaculture. Adherence to both aspects requires effective and transparent research, adaptive management, monitoring, enforcement and incentive. The Government-approved and industry/stakeholders-led 'Environmental Codes of Practice' and National Aquaculture Plan will support this approach through the Integrated Coastal Zone Management implementation.

Background - Aquaculture Industry

Landings from worldwide aquaculture have been increasing rapidly in the last decade, approximately 10 to 15 percent per year depending on the reference sources. According to FAO 2002, total aquaculture in 1996 was 26.7 million tons, and in 2001 increased to 37.5 million tons. The rapid growth was due to the combined effects of an increasing world population, decreasing catches from traditional fisheries (Caddy and Griffiths, 1995; Pauly et al, 2002; Mayers, 2003), and changing consumer preferences in developed countries (Tacon, 1997; Lem and Shehadeh, 1997).

Landings from the marine environment in 1996 accounted for 51% of total world aquaculture output. Although the proportion of total aquaculture production by weight and value originating from marine waters in 1996 is high (17.5 million metric tones), over 90% of mariculture production is still centered on primary users of nutrients (e.g. aquatic plants and filter feeding invertebrates) and only 7% for mainly carnivorous finfish species (FAO, 1998). Moreover, when aquatic plants are excluded from the marine environment total, about 86% of the contribution of total finfish and shellfish production originates from filter-feeders such as mussels, oysters, scallops and cockles. Predominant use of plants and filter feeders in mariculture may also contribute to minimizing the levels of nutrient enrichment of coastal waters resulting from other human activities and resource uses (FAO, 1998; Stickney et al, 2002).

Despite rapid growth trends, aquaculture development continues to be hindered by a number of constraints. These include limited suitable sites, concerns regarding negative environmental impacts, and multi-use conflicts (Goldburg and Triplett, 1997). One problem is an intensive use of the natural coastal habitats and ecosystems for monoculture technology, which when exceeds the ‘carrying capacity’ of the area, might cause environmental degradation, disease outbreaks, and reduced growth (e.g. coastal mangroves devastation by pond aquaculture of tiger prawns; Binh et al, 1997; Treece, 2002; Davenport et al, 2003).

Another major problem is aquaculture’s contribution to the global issue of farming up the food chain by using industrial fishing products to increase production (Pauly et al, 2001; Pauly et al, 2002). According to the long-term study by Meyers and Worm (2003), 90 percent of all large fish in the world's oceans are gone, and just 10 percent remain after commercial fishing vessels have taken their toll over the past 50 years. The scientists say there is an urgent need to attempt fisheries restoration on a global scale. Fish stock depletion not only threatens the future of the fish biodiversity and the fishers that depend on them, it could also bring about a complete reorganization of ocean ecosystems, with unknown global consequences. The fishing nations must reduce quotas, reduce overall fishing effort, cut subsidies, reduce by-catch, and create networks of marine reserves. Marine protected areas (MPAs) with no take reserves at their core, combined with a limited efforts in the remaining fishable areas, have been showing positive effects in helping to rebuild depleted stocks (Roberts et al, 2001; Mosquera et al, 2000). On the other side, sustainable aquaculture development should be able to support global food need without depleting natural fish stocks and biodiversity.

Carnivorous fish farming, like salmon trout, marine fish, shrimp and tilapia, consume more fish meat than they produce. Producers of finfish feeds are improving the chemical, nutrient, and physical shape and structure of food for finfish. Field observations report significant reductions in accumulations of unused food stuffs; indicating that culture enclosures can be towed to other grow out areas, allowing improvement in the original benthic habitats, by reducing organic buildup, eutrophication, and hypoxia (Stickney et all, 2002). Japan developed a new type of feed using substitute protein such as soy been cake, corn gluten instead of fish-meal, and achieved feeding efficiency approximately 10-15% less than original feed (Morikawa, 1999). However, the appearance of the finfish color, taste and quality fresh meat was better than the fish reared on fresh fish feeds. Reducing the quantity of omega 3 oils in feed production and substituting some of the current fish oil content with vegetable oils (rape seed, linseed, palm oil) would make fish farming more sustainable. In that way the production of omega 3 in the sea by not over fishing current stocks of industrial fish will be secured (Sargent, 2003). This applies in fish farming of salmon, trout and freshwater fish. In addition, N losses can be reduced by more than 50% in sea bass through adjustment of feed delivery according to the fish needs (Bonjard, 2003). This approach contributes to avoiding sea pollution as well as to more efficient and sustainable utilization of marine living resources. One of the tasks still remaining in the aquaculture industry is to determine how to prevent pollution of rearing waters by artificial feed!

One possible solution to avoid and lessen aquaculture impacts on the environment, is extensive and balanced *'polyculture'* - an integrated fish farming practice adopted over 4000 years ago in China, and over 1500 years ago in Hawaii (Chang, 1987; Costa-Pierce, 1987; FAO, 2000). Polyculture techniques mix fed species (e.g. finfish, shrimp), herbivorous species and extractive species (filter feeders, such as shellfish, and seaweeds) in a more balanced ecosystem-approach aquaculture (Naylor et al, 2000; McVey et al, 2002; UNEP, 2002; Davenport et al, 2003). While polyculture has not been implemented to any great extent, it may offer opportunities for reducing or transferring nutrient loads. Ecosystems are inherent recyclers of energy, and can provide the resources humans need as long as critical processes are left undisturbed. Ecosystems, although frequently described as "fragile", have remarkable powers of resiliency. As long as basic processes are not irretrievably upset, ecosystems will continue to recycle and distribute energy. A healthy functioning ecosystem not only sustains itself, it also sustains local communities, regional economies and resource based industries, in this case aquaculture. This suggests that strategies and guidelines for sustainable management should focus on maintaining resilience and healthy functioning of coastal and marine ecosystems (Scheffer et al, 2001).

Without proper management of all components within the ecosystem, the viability of the ecosystem is threatened. However, since there is no consensus regarding the concept of sustainable development, no base exists for establishing criteria for attainment. Frequently, a single-issue approach to ocean and coastal management creates overlapping and uncoordinated laws and jurisdictions that result in conflict and increasing ineffectiveness with increasing coastal activities. Therefore, sustainable development of aquaculture requires adequate consideration of interactions among environmental, social, and economic

factors that accompany any development (NACA/FAO, 2000; WB, 1998; Chua, 1992). Around the world, examples of sustainable aquaculture have proved to be a revitalizing economic force in a number of rural and coastal communities – areas where sustainable economic development is often difficult (FAO, 2000; Stickney et al, 2002; Davenport et al, 2003). In such communities, however, the introduction of aquaculture into areas traditionally used largely for commercial fisheries and a variety of recreational activities have sometimes coincided with impassioned user group conflict. To overcome this issue a planned, balanced and inclusive community approach to rural economic and social development is required. Through effective research, development, monitoring and incentive programs that maintain ecosystem integrity and balance human values, economic development can be attained in an environmentally and socially sustainable manner.

Background - Integrated Coastal Zone Management (ICZM)

Sustainable development of coastal areas can be achieved through ICZM implementation processes. ICZM is a strategy or framework to be implemented at the community level and at national level (COM, 2000). However, after thirty years of costal management planning we have not identified simple, effective, and widely applicable models. The most appropriate approach will depend upon a wide range of local factors, including available skills and resources, the urgency of the problems or opportunities, and the nature of existing planning and development frameworks.

Croatia needs an ICZM plan that will help combine all aspects of human (socio-economic), physical and biological factors within a single coastal management framework. One of the main aspects and goals of this project is to emphasize holistic and interdisciplinary approach in careful planning and management of all sectoral activities. This approach should simultaneously result in greater overall benefits than just pursuing sectoral development plans independently of one another (e.g. agriculture, tourism, aquaculture, fisheries, education). Islands and coastal ecosystems sustainable development strives to maintain or restore a balance between natural and human environments. Therefore, sustainable development will involve management in time and space of the constant interactions between ecological and economic, and social and natural variability, supporting co-existence of ecosystems and lifestyles side by side. Natural and cultural components of the coastal and islands heritage are inseparable and could not be addressed independently of each other, neither in development planning or conservation efforts.

ICZM plan for sustainable development includes careful consideration of a multiplicity of parameters and their interactions. Adequate policy addresses the resolution of potential conflicts, which is often hindered by lack of information or appropriate methodologies. Planning for sustainable uses is a process that comprehensibly and holistically analyses islands and coastal systems: natural resources conditions, human uses and socio-economic aspects. Socio-economic sector conflicts can be managed simply by controlling where certain activities are undertaken (e.g. different types of agriculture, tourism, aquaculture, fisheries, etc), but sustainability can only be attained when environmental conditions are appropriate. This means that choices should be based on environmental requirements and suitability for the activity and the activity's interactions with the environmental resources.

Site suitability assessment and implementation also must incorporate socio-economic, and cultural factors. Although, the Croatian Government has the responsibility to determine the appropriate balance of resource preservation and utilization of coastal, marine and islands ecosystems, decisions should be based on interests and participation of the local communities. Therefore, important parts of the ICZM process are actions at the local level. All stakeholders must be able to participate in the planning process to ensure that it is as equitable as possible, and that they understand the connections between different elements of the process and understand how their actions can contribute to the achievement of the common good or vice versa (Frankic, 1998).

Although the ICZM plan does not yet exist for the Croatian coast and islands, one successful attempt was done in 1996, when METAP funded the Environment Management Plan for Cres-Losinj archipelago. However, it was never implemented. Recently, the Croatian Government, the Ministry for Environmental Protection and Physical Planning (MEPP) and Ministry for Agriculture, Forestry and Fisheries (MAF) initiated development of the Master plan for ICZM, which will be based on the EU strategy for ICZM, adopted on September 27 2000 (COM/2000/547). The EU Strategy addressed coastal zones' serious problems of habitat destruction, water contamination, coastal erosion and resource depletion. This depletion of the limited resources of the coastal zone (including the limited physical space) is leading to increasingly frequent conflicts between uses, such as between aquaculture and tourism. Coastal zones also suffer from serious socio-economic and cultural problems, such as weakening of the social fabric, marginalization, unemployment and destruction of property by erosion. Given a value and diversity of physical, economic, cultural and institutional conditions, the EU ICZM Strategy is calling for response that must be a flexible strategy focused on addressing the real problems on the ground. An integrated, participative territorial approach is required to ensure that the management of coastal zones is environmentally and economically sustainable, as well as socially equitable and cohesive. Therefore, the Commission has been vigorously promoting ICZM, ensuring that policies and legislations are compatible with ICZM, promoting dialogue between stakeholders and developing best practices and disseminating information to public (COM, 2000). The goal is to build on existing instruments and programmes, many of which were not conceived exclusively for the coastal zones. These will be complemented by certain new activities, particularly with regard to the development of best practices, multidisciplinary efforts and information diffusion.

Review and survey in 2000 stated that the problems in some Croatian coastal areas are: demining, unemployment, negative birth rate, non-existence of economic subjects, unorganized agricultural production, reconstruction and return of population (source: Ministry of Public works, reconstruction and construction). Regarding islands, several other problems can be added: insufficient water supply, insufficient traffic connection with the mainland and between the islands, non-existence of solid-waste depots and sewage-systems, deficient education, and insufficient health services (source: National Program for Island Development, and the Law on Islands, April 1999, Ministry of PWRC). In order to address these complex issues, planning for sustainable uses must be a process that comprehensibly and holistically analyzes islands and coastal systems: natural resources conditions, human uses and socio-economic aspects.

A consensus set of integrated coastal management guidelines

(*Source: Cicin-Sain & Knecht, 1999*)

- The aim of ICM is to guide coastal area development in an ecologically sustainable fashion.
- ICM is guided by the Rio Principles with special emphasis on the principle of intergenerational equity, the precautionary principle and the polluter pays principle. ICM is holistic and interdisciplinary in nature, especially with regard to science and policy.
- ICM strengthens and harmonizes sectoral management in the coastal zone. It preserves and protects the productivity and biological diversity of coastal ecosystems and maintains amenity values. ICM promotes the rational economic development and sustainable utilization of coastal and ocean resources and facilitates conflict resolution in the coastal zone.
- ICM programme embraces all of the coastal and upland areas, the uses of which can affect the coastal waters and the resources therein, and extends seaward to include that part of the coastal ocean, which can affect the land of the coastal zone. The ICM programme may also include the entire ocean area under national jurisdiction (Exclusive Economic Zone), over which national governments have stewardship responsibilities both under the Law of the Sea Convention and UNCED.
- Overcoming the sectoral and intergovernmental fragmentation that exists in today's coastal management efforts is a prime goal of ICM. Institutional mechanisms for effective co-ordination among various sectors active in the coastal zone and between the various levels of government operating in the coastal zone are fundamental to the strengthening and rationalization of the coastal management process. From the variety of available options, the co-ordination and harmonization mechanism must be tailored to fit the unique aspects of each particular national government setting.
- Given the complexities and uncertainties that exist in the coastal zone, ICM must be built upon the best science (natural and social) available. Techniques such as risk assessment, economic valuation, vulnerability assessments, resource accounting, benefit-cost analysis and outcome-based monitoring should all be built into the ICM process, as appropriate.

What does ICZM mean for aquaculture? It means that the only way toward sustainability and longevity of aquaculture development is if it will have a positive impact on the coastal zone and adjacent sectors. For example, aquaculture has to have a positive impact on tourism development, supplying fresh and healthy seafood; securing jobs and sea food for local communities; and at the same time providing stock enhancement of depleted fish species. It also means that the precautionary principle and policy initiatives such as the **Strategic Environmental Assessment Directive** will guide future decision-making processes. Efforts to integrate aquaculture into coastal management can contribute to improvements in selection, protection and allocation of sites and other resources for existing and future aquaculture developments (FAO/CCRF, 1999).

Sustainable Aquaculture Development & ICZM

"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 agriculture, forestry, fisheries sectors) conserves land, water, plant, and animal resources, is environmentally non-degrading, technically appropriate, economically viable, and socially acceptable." (Code of Conduct for Responsible Fisheries - CCRF, FAO, 1995).

Sustainability refers to the ability of a society, ecosystem, or any such on-going system to continue functioning into the indefinite future without being forced into decline through exhaustion or overloading of key resources on which that system depends. In general, the concept of sustainable development is simple and important, but translating it into specific standards or criteria is difficult, often subjective and misused. Although many specific sustainability criteria have been proposed there is no single universally agreed criteria set.

In assessing the sustainability of any industry, enterprise or technology, consideration should be given to at least the following:

- the sustainability (or continuity) of supply, and quality of inputs
- the social, environmental and economic costs of providing the inputs (e.g. depletion of resources elsewhere)
- the long term continuity (or sustainability) of production
- financial viability
- social impact and equity
- environmental impact, and
- efficiency of conversion of resources into useful product (Penmen and Bell, 1994; Scialabba, 1998).

When defining sustainability we must be clear what the objective of the definition is, and come to a conclusion of what it means to a particular concept, in this case different types of aquaculture practices. Sustainability can only be attained when environmental conditions are appropriate and maintained, and this includes ecological, socio-cultural and economic aspects of environment. Therefore, any activity, use or practice, in this case aquaculture development, should comprehend and include the following six general steps of sustainable resource management (Frankic and Hershner, 2001):

1. Environmental Resource Assessment – Inventories of marine, coastal and islands natural and human resources are a necessary first step for successful management programs. To enhance resource development capabilities, a country/local community should acquire and maintain a comprehensive inventory of the physical and biological resources of the coastal area as well as their uses and users. The inventory will provide a database for making decisions about long-term goals, such as ecosystem preservation, that might conflict with immediate development of aquaculture. This first step is necessary for assessing the coastal zone vulnerability to various activity impacts, and it provides one of the basic requirements for development of an integrated coastal resource management program. Environmental resource assessment has to include a long term and in depth research studies of organisms that are being cultured or are intended for culture, as well as understanding of utilized ecosystems biocomplexity and healthy functioning.

2. Environmental Impact Assessment – Information about the impact aquaculture (or any other activity) will have on the environment must be provided in a clear form to decision-makers and stakeholders. Impact assessments should be incorporated in each phase of aquaculture development projects. It also has to present clear options for the mitigation of impacts and for environmentally sound management. Impact assessment should be based on the best available knowledge and provide timely technical information to environmental

decision makers while acknowledging uncertainties. The most important development in the environmental decision process in the last decade has been the inclusion of environmental impact assessments by regulatory managers (Power and Adams, 1997).

3. Policy Framework and regulatory measures –This is a basic tool for training and educating, as well as for local community participation in decision-making processes. The policy statement should declare the intention of a state/nation to review and regulate, in this case aquaculture activities affecting the sustainable use of the coastal renewable natural resources (PAP, 1996). Formulation of a policy framework for coastal and marine management must address cross-sectoral issues that infringe on coastal resource management and national development planning. The basic approach is to review and analyze existing institutional and legal mechanisms (including regulations and enforcement) for integrated coastal and marine management and aquaculture development potential. Based on this review, the country should propose a generic institutional and legislative framework to address coastal issues and encourage integrating aquaculture in the coastal zone management plan. Through a series of application scenarios, the policy framework will become a basic tool for training and educating decision-makers, resource managers, scientists, stakeholders, and the public in general. In addition, comprehensive policies and institutional legal frameworks should recognize the potential benefit of traditional tenure and management systems, and ensure that they are incorporated into the rules and regulations for conservation and sustainable use, where relevant (WWI, 1995).

4. Socio-cultural and Economic assessment - important component of a systematic, integrated assessment of coastal resources for any type of uses. It has to provide a social and economic framework from which differing adaptation strategies (solutions) can be studied (WB/GEF, 1996). In a process of use conflict analysis and assessments of alternatives, decision-makers should be provided with information on how each option compares in respect to the relative costs and benefits for each e.g. aquaculture type impact (Sorensen and West, 1992). Identification of the full range of reasonable alternatives to resolve a conflict among competing interests means that no feasible options for maximizing benefits and minimizing costs have been missed (Edwards, 1999). Therefore, successful selection of suitable locations for aquaculture and the long-term maintenance of site suitability require accurate assessment of both existing conditions and probable trends in environmental, social, and economic factors.

5. Implementation - The success of a coastal resource management program is based on the country's ability to understand how an effectively established program manages natural and human coastal resources. It is necessary to establish monitoring and evaluation of land use decisions and changes in coastal resources as well as in their integral uses. The basic question of an implementation strategy is how to apply science, and develop and implement best management practices (BMPs) for aquaculture or any other activity? Comprehensive BMPs should be a like a 'living document', open to revisions and expansion (Frankic, 1998). Established BMPs provide consistent national standards and practices for implementation of different types of aquaculture in the coastal areas. They provide a base for successful monitoring and control, strengthening environmental protection and sustainable aquaculture development in the coastal areas. Aquaculture and

other coastal industries, agencies, and environmental organizations have recognized the need for BMPs. BMPs for site planning and for ICZM provide opportunities for early intervention and collaborative review of new activities. By publishing standards and goals in advance of the submission of plans by a private developer, for example, will provide guidance before major investments are made in site development (e.g. for marinas, mariculture, hotels, ports, protected areas, etc). Standards (environmental, social, economic) provide objective measures (indicators and criteria) that can also be used by communities and environmental NGOs to question specific elements of aquaculture development proposals, as well as to award if it is environmentally sound and sustainable.

6. Monitoring and evaluation– Monitoring means acquisition, management, synthesis, interpretation, and analysis of data with an emphasis on temporal and spatial scales. It should be coupled with research programs designed to improve the appropriateness of routine measurements and allow interpretations of the implications of monitoring results (NAS, 1990). A useful monitoring program provides mechanisms to ensure that knowledge is used to convert data collected into useful information. In addition, the purpose for monitoring implementation of aquaculture practices is to assure that the major policies (goals, comprehensive plans, and agency authorities) are properly implemented. Monitoring will assess the cumulative effects of changes and assure that management program elements for aquaculture are updated to reflect changing needs and circumstances, consistent with its basic requirements. It will provide multidisciplinary data for a "feedback loop" evaluation of our activities and their impacts on natural and human resources. This approach is a must for a general evaluation of the aquaculture success or failure in achieving its overall objectives of balanced development and resource preservation (Center, 1993; Oregon CMP, 1997).

Practitioners have discovered that sustainable aquaculture must not only maximize benefits, but also minimize accumulation of detriments, as well as other types of negative impacts on natural and social environment. One of the early lessons learned has been that increasing the density of organisms in a culture operation results in significant waste disposal problems, specifically intensive culture of carnivorous fish and prawns risks organic pollution from uneaten food or faeces (Brooks et all, 2002; Davenport et all, 2002). This results in a potential degradation of the environment and a loss of suitability for the culture practice. Determination of suitability for aquaculture involves an evaluation of natural and anthropogenic limitations of a certain area in order to decide if the locality can support the activity. The carrying capacity for aquaculture is defined as the maximum number of marine species that can be supported by a natural or man-made resource without producing negative environmental consequences to their future activity, productivity and quality (PAP/RAC, 1996). It is also referred as 'environmental capacity' (absorptive capacity or assimilative capacity), which in practice represents the rate at which nutrients are added without triggering eutrophication; or the rate of organic flux to the benthos without major disruption to natural benthic processes (GESAMP, 2001).

General management controls for the aquaculture farming areas are based on GESAMP (2001) (see Attachment 3 for details), and inlcude:

- environmental controls relating to carrying capacity;
- environmental controls relating to monitoring (water quality, benthos, shellfish growth);
- control of chemicals (must comply with legal requirements);
- control of waste disposal;
- disease controls;
- visual controls to reduce visual impacts (esthetics);
- access controls;
- other controls, e g. related to other legal requirements (such as predator control, and other environmental management legislation).

Regarding socio-economic, human considerations: **"States should promote responsible aquaculture practices in support of rural communities, producer organizations and fish farmers."** ***(CCRF Article 9.4.1)*** Responsibilities for sustainable aquaculture development needs to be shared among government authorities, aquafarmers, manufacturers and suppliers of aquaculture inputs, processors and traders of aquaculture products, financing institutions, researchers, special interest groups, professional associations, non-governmental organizations, and others (FAO, 1997). A major task is to generate commitment for constructive dialogues and effective collaboration, among partners in aquaculture development, at local, national, and international levels when considering Adriatic region.

Socio-cultural considerations should address: concept of advantage and incentive (e.g. informal cost-benefit analysis); information input and education of targeted local communities regarding aquaculture practices; introduction of aquaculture technologies that meet the traditional work patterns of targeted population (explaining step by step process of aquaculture operational development including market demand); direct involvement of local community in trial operations, presenting them with tangible evidence that they can successfully operate aquaculture projects (Pollnock, 1991).

Adriatic Aquaculture

Adriatic region has about 1,200 islands, 48 islands are permanently inhabited, and 100 are occasionally inhabited, with average island settlement of 417 inhabitants (see Attachment 1). Islands have experienced profound demographic and environmental changes over the past decades, due to the war and post-war circumstances, decline of socio-economic opportunities (education, employment, health care) and higher level of poverty. The natural and cultural heritage has been increasingly neglected, disintegrated and forgotten, causing imbalance and threat in once maintained harmony between natural and traditional life and customs. Underutilization on one side and unsustainable use of resources on the other, proverbial lack of labor force, and islands isolation, caused deterioration of economic development which should be based on traditional agriculture, fisheries, aquaculture.

However, aquaculture if developed in responsible and sustainable way, has enormous potential benefit for both socio-economic and natural resources in the Adriatic area, particularly the islands. The basic initiative should include development and implementation of the National Codes of Practice for responsible aquaculture and fisheries plan (FAO, 1999).

In the Adriatic Sea, the majority of cultured marine fish species are grown in cages. These are square, floating frames of surface area 8 - 50 m^2 with nets suspended into the water column to contain the fish (PAP, 1996). According to present trends and experiences in the Adriatic and north Mediterranean, shellfish mariculture include oysters (*Ostrea edulis*), and Mediterranean mussel (*Mytilus galloprovincialis*) (Heral and Prou, 1994; Hrs-Brenko and Filic, 1973). Current production of shellfish is only about 4.500 MT/year, while for example Ireland production of mussels and oysters (*Crasostrea gigas*) is 23.210 MT/year! Fish farming in floating cages include mainly sea bass (*Dicentrarchus labrax*), and sea bream (*Sparus aurata*), producing only about 2.700 MT/year based on fry stock (Benovic, 1997; Franicevic and Katavic, 2001; Katavic and Vodopija, 2001).

Water quality is the most important factor for aquaculture development (as well as other coastal activities). Globally, nitrogen pollution is widespread in coastal waters and estuaries. Excess nitrogen in the environment degrades air quality, disrupts forest growth, acidifies lakes and streams and starves coastal waters of oxygen (Bioscience, April, 2003). Adriatic sea is in general a low productive, oligotrophic sea, but it is more productive along the coast and in the area of channels than in the open sea. The low level of organic production in the Adriatic Sea is a result of a low content of nutritious salts in water, of phosphorus and nitrogen in particular (see Attachment 1). As a consequence, shellfish farming is likely to be restricted to areas where nutrient levels are increased due to run-off carried from the land by rivers (e.g. Mali stone bay and Limski channel). However, due to various specific influences Northern Adriatic is considered a highly productive region, one of the most productive in the Mediterranean Sea, causing algal blooms and eutrophication that in recent years appeared even along south Dalmatian coast.

Shellfish aquaculture development has a huge potential in the Adriatic region, both ecologically and economically (see Attachment 2 for Mediterranean examples). Mussel filtration enhances the grazing pressure on the phytoplankton community and harvesting of the mussels represents an export of both carbon and nutrients. However, relatively little is known of the effects of longline mussel farming on benthic ecology, microbial mineralization and nutrient dynamics (Christensen et al, 2003). The mussel production has a significant local impact on benthic microphyte and infauna composition as well as on oxygen and nitrogen cycling. Conditions of localized enrichment can arise through excretion of dissolved inorganic nutrients into the water column and increased sedimentation of organic material below the farms in the form of faecal and pseudofaecal materials, dead mussels and associated epibiota. Sedimentation rates have been reported to be two to three times higher underneath the mussel farms compared to ambient rates outside the farms (Dahlback and Gunnarson, 1981; Grant et al., 1995). Natural aquatic systems have a built in capacity for handling nutrients, for example, denitrification processes in Norwegian fjord can generally remove 50% of the nitrogen loading from the

land (Christensen et al, 2000). Therefore, the most important is to identify suitable sites for shellfish farms or any other types of aquaculture practices, and provide a detail assessment for their capacity and quality (Spencer, 2002).

Aquaculture can be developed in ways that do not degrade coastal and marine biodiversity. The loss or alteration of habitat becomes a biodiversity effect when it changes living conditions for other species. Integrated, and extensive systems will be more sustainable than intensive monocultures. Integrated, multi-species aquaculture or **'polyculture'** is based on the harmonious stocking of different varieties of fish species at different levels of population, using an understanding of the production cycle and energy flow through the selected natural habitat. The result is that energy flow and transformation are extremely efficient, and at the same time the negative effects on biodiversity can be mitigated or eliminated. Good example is autochthonous organic-based or natural trophic system mariculture of sea weed (kelp) and raft culture of mussels or oysters. Such cultures derive their energy from solar radiation or nutrient sources already available in natural ecosystems, having fewer negative effects on biodiversity.

Example of polyculture in Adriatic archipelago could be a combination of shellfish (e.g. *Mytilus galoprovincialis, Ostrea edulis*), seaweeds (eg. *Fucus virsoides*, *Laminaria* sp.), sea urchin, sea cucumber, and finfish (e.g. sea bass, *Dicentrarchus labrax*), if we add a suitable species of crabs we have almost the whole food web represented. This approach uses sustainable aquaculture for conservation *in situ*, and suggested guidelines are presented in the Attachment 3. Some other marine examples include grouper and mudcrab in ponds; milkfish and siganids in marine net cage; sea scallops suspended from salmon net pens; shrimp and scallops; or ezo scallop, Japanese kelp and sea cucumber cultured in combination with open water mariculture (finfish in net cages) (UNEP, 2002); or mussels, sea urchins and Atlantic salmon (Kelly et al, 1998; Stirling, 1995). In Alaska they are stocking sea cucumbers in salmon net pens to graze on fish faeces, excess feed and fouling organisms (Ahlgren, 1998).

Aquaculture Sustainable Development – Case Study Procedures:

1. **Develop qualitative and quantitative criteria for general aquaculture suitability protocol, and develop comprehensive zoning plan that will help identify suitable aquaculture sites for the Adriatic coast and islands based on the international and national environmental standards, policies and laws;**
2. Develop specific aquaculture suitability protocols for each type of existing aquaculture as well as for future potential species (finfish, shellfish, algae, crabs); specifically for selected project pilot areas (Velebit Channel and Maloston Bay); Prepare EIA for each type of aquaculture (done for Velebit Ch.)
3. Identify and map sites for potential aquaculture based on: developed suitability protocols; counties spatial/physical plans; land use/land cover data; existing environmental inventories, mapping and monitoring data; satellite images and aerial photography; prepare GIS coverages/layers and use IGIS for site suitability analysis and zoning; output maps will show suitable aquaculture sites based on environmental suitability criteria;
4. Perform use conflict analysis, which includes identification of current and potential uses and IGIS modeling; e.g. tourism and recreational activities, nautical tourism, marinas and ports and other infrastructure, settlements, waste water, agriculture, fisheries, protected areas, species, habitats (natural and cultural), hunting areas, industries (e.g. mining, aquaculture); output map will show suitable aquaculture sites based on use conflict analysis;
5. Identify all existing and potential management issues; develop action plans and management plans for each suggested scenarios for potential aquaculture development; this will be implemented through the Integrated Coastal Zone Management Plan;
6. Identify all the gaps in existing data that would help guide future scientific research and decision-making process for the long-term sustainable coastal zone management;
7. Develop National Code of Practice for aquaculture and fisheries.

Aquaculture Site Suitability Analysis

Phase One

Finding suitable sites for aquaculture in the marine and coastal environment is one of the most critical challenges facing this industry. **The most important step is to identify the environmental conditions necessary for aquaculture activities to succeed. Based on extensive literature review and present knowledge, the environmental site suitability indicators (parameters or criteria) for sustainable aquaculture development can be identified and derived. Examples of aquaculture protocols for finfish and shellfish are presented in Tables 1 and 2.**

Indicators are key variables that signal change, and can be physical, biological, chemical, social, and economic. They may be directly measurable or calculated from measurements of a number of data sets, or derived from other information (derived indicators) (NRC, 2000). In addition, indicators can and should guide policy and help direct scientific research (Frankic and Hershner, 2001). International, regional and national regulations related to environmental quality standards and indicators are well developed for the control

of water quality and chemicals, although further development is required for sediment and ecosystem quality (e.g. FAO Code of Conduct, ICES – International Council for the Exploration of the Sea). Environmental monitoring surveys are determined by country's environmental quality objectives (EQO) and environmental quality standards (EQS). Application of environmental indicators have reduced point source of pollution, and provided public access to beaches, while just recently more attention is devoted to indicators for ICZM performance and sustainability in coastal planning (UNESCO, 2003). Environmental surveys should use the best available practices and technologies for the environmental monitoring of impacts and modeling of carrying capacity at farm sites (Frankic, 1998). However, multiple criteria analysis must be considered when determining the suitability of a site for different types of aquaculture. Hence, examples of socio – economic indicators in coastal management and aquaculture development are rare (UNESCO, 2003). In general, the larger the number of indicators evaluated, the more comprehensive the assessment of potential aquaculture development will be (Rodgers, 1997; PAP/RAC, 1996; Ross et al, 1993; Kapetsky et al, 1990; Ibrekk et al, 1991).

Phase Two

The main objective is to develop GIS **maps of environmental indicators required for potential aquaculture sites.** Aquaculture sites have requirements for space on water and land. Determination of suitability involves an evaluation of natural and anthropogenic limitations of a certain area in order to decide if the locality can support the activity (Hershner et al.1999). The initial phase of a suitability evaluation includes classification of current environmental conditions, identification of existing and possible future constraints, and assessment of compatibilities and incompatibilities between resources and human activities (PAP, 1996).

Developed aquaculture protocol (from Phase one) will help the process of selecting environmentally suitable aquaculture areas using integrated GIS analysis and modeling (Ross et al, 1993). GIS provides managers with a tool for recording and viewing environmental data over space and time. This includes spatial analysis (aerial photos and satellite images) that is useful in overlaying possible zoning schemes onto current land use and land cover. Ideal data sets have parameters for physio-chemical, biological, political or administrative, and socio-economic data. The data should have, as a minimum, accompanying information on the time the data were collected, who collected the data, the method that was used, the units of measurement and a geographical reference point.

This approach will allow integration of GIS coverages (data layers) for e.g. temperature, salinity, bathymetry, exposure (also considering wind effects in bays), water quality data, circulation pattern, slope, substrate types, SAV, protected areas, accessibility, etc. (Table 1 and 2; Frankic, 1998). Riparian lands should also be analyzed using digital elevation models to select areas with lower slope, reduced erosion potential and easier access. Presence or absence of submarine springs could be used together with salinity data. Submarine springs decrease salinity, often favoring aquaculture activity (Frankic, 1998). Submerged aquatic vegetation (SAV) areas are unsuitable sites for aquaculture activities,

because of the high natural resource value of SAV beds (e.g. SAV areas could be used with 200m buffer zone).

There is often a case that ideally developed aquaculture protocols can not be applied in the real life, manly due to the lack of data, or even when data are present they are not geographically explicit and could not be used in the GIS analysis and modeling. Based on available environmental suitability indicators, identified suitable aquaculture areas can be ranked as desirable, desirable with limitations and undesirable; or just as excellent, good and poor. Examples of GIS maps of assessed existing environmental data are presented in Figs. 3-6.

Overview list of **Environmental indicators** that should be considered but are not limited for aquaculture planning, zoning and site suitability selection (based on Frankic, 1998; PAP/RAC, 1996):

- Species types (autochthonous finfish, shellfish, algae, crabs, etc)
- Salinity
- Exposure
- Depth (bathymetry)
- Currents (velocity, direction, surface, tides and water column movements)
- Wind (fetch, speed and direction)
- Coastal topography (slope, geology, pedology)
- Substrate (benthic type and quality)
- Suspended matter
- Trophic status (oligotrophic)
- Water quality (% oxygen, temp, ppt, coliforms, heavy metals, nitrate, phosphate, chlorophyll, etc.)
- Land use/land cover
- Fouling
- Predators (e.g. birds, other marine species, etc)
- Threatened and endangered species, habitats (e.g. SAV), migratory pathways
- Protected areas
- Buffer zone for aquaculture sites (related to pollution, protected species, use conflicts, etc)
- Accessibility (related to transportation, roads, etc)
- Site carrying capacity or environmental capacity
- Finfish feed quality and quantity (e.g. strict regulation of GMOs)

Phase Three

After selecting suitable aquaculture areas based on environmental indicators, **the next step is to perform a use conflict analysis**. In this process all the existing and potential uses have to be identified and mapped. The purpose of this analysis is to identify areas that, although suitable for aquaculture on the basis of environmental conditions, may be less desirable due to incompatible uses (tourism, recreation, fishing, boating, etc.) that are present or planned. GIS algorithms have to be developed in order to analyze and model criteria and create indices of suitability related to aquaculture siting.

The output map will show suitable aquaculture sites based on environmental and use conflict analysis.

Examples of identified existing uses are presented in Figs. 7-8. Example of the site suitability analysis is presented in Fig. 9. Examples of IGIS use conflict analysis and modeling, resulting in identified suitable sites for aquaculture is presented in Figs. 10-11.

In addition, examples of identified land uses for aquaculture site suitability analysis in Chesapeake Bay, Virginia, are presented with Figs. 14-15. Examples of site suitability analysis for existing aquaculture activities for hard clams and oyster in Ch. Bay, Virginia are presented in Figs. 13, 16-17. Finally, Fig 18 shows all the aquaculture sites in Virginia, while Fig 19 will hopefully present as one of the results of this project, the suitable aquaculture sites in Croatia!

Phase Four

Now, when we have identified where we could really place aquaculture activities (based on both environmental suitability indicators and use conflict analysis), we have to identify all possible management issues that could be caused by aquaculture development in certain area. This means, in our analysis we have to incorporate and add socio-economic considerations, which sometimes could be presented as a parameter but often have to be descriptive. In addition, each identified management issue has to be analyzed and presented with adequate management options and recommended scenarios. Example of this phase is presented in the Table 3.

Phase Five

Based on all these findings we can prepare action plans for specific aquaculture activities at identified most suitable sites. Developed action plans will be part of the Integrated Coastal Zone Management Plan, and implementation phase will be performed through the integrated process of CZM. The action plans will include monitoring and evaluation based on environmental quality standards selected from developed aquaculture protocols (see Tables 1 and 2).

Summary of Aquaculture Site Suitability Analysis

I) Optimal aquaculture sites are selected based on environmental suitability analysis and GIS model. Based on literature review and present scientific knowledge, environmental suitability criteria required for potential aquaculture sites were identified and generic aquaculture protocols for target shellfish (Table 1) and finfish (Table 2) species are developed. However, often a modified version of the aquaculture protocols have to be created and applied based on available and spatially explicit data.

II) Identification of coastal, marine and land uses and performing the use conflict analysis. This analysis may include marina areas; residential; commercial/industrial sites; protected areas and sanctuaries; tourism and recreational sites. This analysis includes identification of offshore land uses, where selected o**ptimal** sites are adjacent to wetlands, forests, or grasslands; **suitable** sites are adjacent to low residential areas and low agricultural lands; **unsuitable** sites are adjacent to high residential areas, and commercial/industrial areas (Example from Chesapeake Bay is presented in Figs.13-15).

III) Identification of management issues (Table 3) - socio-economic issues are part of management issues and include aesthetics, cost benefit analysis, etc.;

IV) Management options (Table 3) - include identification of socio-economic advantages and disadvantages of established management options (e.g. zones and buffers);

V) Outcome scenarios and recommendations (Table 3) - Final maps that will show both ecological issues and management issues. Questions to answer: Where should aquaculture be a priority and why? What other uses are allowed around primary aquaculture sites? What aquaculture types and capacity is compatible with other uses in identified suitable sites?

In the end, our outputs and results are: established aquaculture site suitability criteria with map portfolio of suitable sites for aquaculture, and coastal management action plan with identified issues, possible options and recommended scenarios. Approach: *'the environment sets the limits for sustainable development'*, is in this case applied for aquaculture development, but it can be used for any other coastal, marine or island activity and resource use.

Two additional examples of protocols are provided: one can be used for marina or small port development (Table 4), and another for tourism development (Table 5). For each use the five step process should be applied and integrated in the IGIS use conflict analysis and modeling.

Discussion

Integrated coastal zone management for sustainable development of a given area, requires careful consideration of a multiplicity of parameters and their interactions. Adequate policy must address the resolution of conflicts, but this is often hindered by lack of information and/or appropriate methodologies. The technique of multiple criteria analysis helps to overcome methodological problems and permits manipulation of heterogeneous information (Niu et al. 1993). Planning for sustainable aquaculture as well as other uses and activities must be a process that comprehensively analyzes coastal systems (natural resource conditions and uses) in order to produce a framework to guide decision-makers in allocation of scarce resources among competing interests (Ackefors and White, 2002).

Resource use and development has explicit spatial dimensions. To make development sustainable, it is necessary to develop an analytical framework that can incorporate spatial (and temporal) dimensions of parameters that affect sustainability. Scale is a very important factor in developing such a framework. A broad scale analysis may give an appropriate description of a region, but may not be useful for specific *in situ* problems and circumstances that each coastal bay area or Adriatic island have. The scale at which necessary data has been collected controls resolution of the analytical framework. For this reason, scale must be addressed in development of environmental assessments and monitoring programs. Decisions about the structure of inventory and monitoring programs can be facilitated by first determining what information is essential to define suitable conditions for various uses. In this and other similar projects available data is often the principle limitation to development of sophisticated analyses and models.

Remote sensing information, assimilated into GIS and integrated with other databases, can elucidate interactions between human activities and environmental resources. Remote sensing and GIS can be technically linked in models that incorporate spatial and process analysis capabilities, creating Integrated GIS (IGIS). By linking these technologies, the information system becomes richer, more sophisticated, and useful in substantial applications (Davis and Simonett, 1991). The relative efficiency of remote sensing in creation of spatially extensive databases, recommends its incorporation in development of use suitability and use conflict analyses.

Spatial use conflicts refer to the existing or potential use of a land/water unit by incompatible activities (Hershner at al. 1999). The framework developed here as an example provides a basis for assessing both the location and quality of the conflicts. The underlying assumption in this project is that environmental conditions are the primary determinants of sustainability. Use conflict can be managed simply by controlling where certain activities are undertaken. But sustainability can only be attained when environmental conditions are appropriate.

Management choices will be required when certain activities can appear in the same locations based on suitability analysis of the area (e.g aquaculture vs tourist beach area, vs marina). In these instances, choice has to be based on environmental requirements for the activity and the activity's interaction with the environmental resources (impact assessment, EIA). First priority should be given to the activity with the highest environmental

suitability level and the lowest adverse impact on the respective land/water system. Implementation and final decision-making must incorporate socio-economic suitability, and cultural factors. The Government has the responsibility to determine the appropriate balance of resource preservation and utilization in any given area. This decision should be based on interests of the local communities! Involving the community in the planning and decision-making process is an important step toward acceptability and success of the coastal management project. The use suitability and use conflict analyses support the interdisciplinary aspects of ICZM planning and decision making processes. It also enables people with less knowledge about specific physical, chemical, biological processes in coastal ecosystems, to include consideration of all of them in decision making at a variety of scales.

This approach's strength is that it evaluates options based on the best available information but clearly indicates where better information is desirable. It establishes guidelines for best available environmental assessment, and for development of rational and integrated long-term social and economic policies for the continuing use of the coastal, marine and islands resources. The approach is useful for discriminating environmental potential among sites, as well as use conflict resolutions. For better prediction of long-term sustainability, socio-economic considerations must always be incorporated in the site suitability assessment.

Developed protocols for aquaculture (as well as any other coastal activity) are a good base for monitoring programs. Protocols can be used as environmental quality standards that will help guide and control activities within certain environmental limits. If aquaculture requires an excellent water quality and certain type of environmental conditions, than this activity should also maintain this environmental quality within established environmental quality standards (this could be supported by new or updated laws and regulations, and policies). Ultimately, through guidance of monitoring programs (environmental and socio-economic), better information can be incorporated into the analytical protocols. This will improve evaluations, and complete the feedback loop for the planning of ICZM and sustainable aquaculture development.

Conclusion

The health and sustainable use of coastal and ocean resources are of critical importance given their role in food production, economic activity, genetic biodiversity and recreation. In creating a "sustainable aquaculture" and costal zone management plan, it is essential to strike a balance between the need for aquaculture development and the need for natural resources conservation within the same management plan. In this context it is necessary to recognize and deal with the increasing competition for resources (use conflicts). The diminishing role of the public sector as a promoter of development and the globalization of markets must also be taken into consideration. However, free trade and globalization ignores that we cannot trade ecosystems and community services (Hawken at all, 2000). Therefore, inevitable process of globalization might become more sustainable if the local level development becomes more self-sustainable, considering the capacities of natural and cultural resources that are necessary for a long-term responsible environmental, social and economic development. We have many choices of how to do it, but we have even more

examples all over the world of how not to use our resources. One recent example comes from the US where the CZM Act and Plan were first established more than thirty years ago. The Independent Ocean Commission just published the first ever-comprehensive report- *America's Living Oceans: Charting a Course for Sea Change*,[*] as the result of a three-year, nationwide study of the oceans and coasts. Their findings are alarming, identifying that "…root cause of this crisis is a failure of both perspective and governance. We have failed to conceive of the oceans and coasts as our largest public domain, to be managed holistically for the greater public good in perpetuity. We have only begun to recognize how vital our oceans and coasts are to our economy as well as to the cultural heritage of our nation. Finally, we have come too slowly to recognize the interdependence of land and sea and how easily activities far inland can disrupt the many benefits provided by coastal ecosystems."

Croatia has a certain advantage for still having undeveloped and pristine islands, as well as some parts of the coast and the sea. However, we were not responsible for being 'awarded' with such a beautiful treasure, but we are certainly responsible and obligated to do everything in our power to preserve the natural and cultural values for generations to come.

[*] http://www.pewoceans.org./oceans/oceans_overview.asp

Attachment 1

Brief description of the Croatian coast and islands

Croatia has 1,246 islands and they are divided into 79 islands, 526 islets, and 641 reefs and rocks. All together they represent just 5.8% (or 3,300 km²) of the Croatian land, but 70% of total Croatian coastline (4,057 km of 5,835 km), while 20 islands exceed 20 km² (Leder, et all, 2000). Only 48 islands are permanently inhabited, and 100 are considered occasionally inhabited. Average island settlement has 417 inhabitants, although the largest town Mali Losinj (North Adriatic area) has 6,566 (1991 census). Islands experience Mediterranean climate, with mean annual temperature of 15ºC and approximately 2,500 hours of sunshine a year, and average annual precipitation between 889-977 mm. Croatian islands (except Brusnik and Jabuka) are all part of the karst relief, built of Cretaceous sediments deposited in a form of carbonate platform (BSAP, 1999). Specific geological processes formed so called **Dalmatian type of coast,** with parallel spreading of coastline, hinterland mountain ranges, and island chains. By the end the last glaciations (10,000 years ago), the sea level rise of 100 meters and tectonic motions separated islands from the mainland. Today's lines of the islands are tops of former mountain ranges, and the general trend of geological structure is 'Dinaric direction'. The product of limestone weathering is '*terra rosa'*, red soil colored from the conversion of hydrated ferric oxides to hematite. Such a soil and luck of water on the islands allow just a poor agriculture: small vineyards, olive grove, sheep and goat pasture. But coastal, and submarine karst environment is ideal for fishery, recreation, diving, and nautical tourism.

Biogeographical position of Croatian coast and islands, the dominating geological base (limestone), a distinctly karst relief, the indentation of the coast and islands, and the fact that this area was a sanctuary for plants and animals during the Ice Age, resulted in outstanding coastal biodiversity and uniqueness of flora and fauna. Peculiarities include predominantly stony limestone coast (karst relief) with gravelly and rare sandy beaches, endemic flora of coastal rocks, endemic flora and fauna of the islands, endemic underground fauna, rivers of the Adriatic catchments area with endemic fauna (fresh-water fishes), Mediterranean marshes and natural lakes (BSAP, 1999). Due to their karst hydrogeology, and geomorphology, Croatian islands and marine ecosystems are extremely rich in fauna of diverse habitats, including the interstitial fauna, fresh-water and terrestrial species inhabiting numerous caves and pits, as well as deepwater coral reefs habitats. The most numerous *endemic plant species* can be found on small off-shore islands, and cliffs of Dalmatia's islands facing south and south-west. Ecosystems of the Croatian islands and surrounding sea have also been recognized internationally as extremely valuable and rich in biodiversity, as well as in their cultural heritage.

The Adriatic Sea

The Adriatic Sea is a gulf of the Mediterranean Sea lying in the southeast-northwestern direction in the length of 783 km, with the surface area of 138,595 sq km at the mean sea-level. The Adriatic is a shallow sea, with the greatest depth not exceeding 1,330 m and the

mean 173 m. The depths of up to 200 m (continental shelf) occupy as much as 73.9 p.c. of the Adriatic sea bottom. Depths exceeding 200 m may be found in the depression of the island of Jabuka and of the south Adriatic. In general, it is a low productive, oligotrophic sea, but it is more productive along the coast and in the area of channels than in the open sea. However, due to various specific influences Northern Adriatic is considered a highly productive region, one of the most productive in the Mediterranean Sea. The low level of organic production in the Adriatic Sea is a result of a low content of nutritious salts in water, of phosphorus and nitrogen in particular.

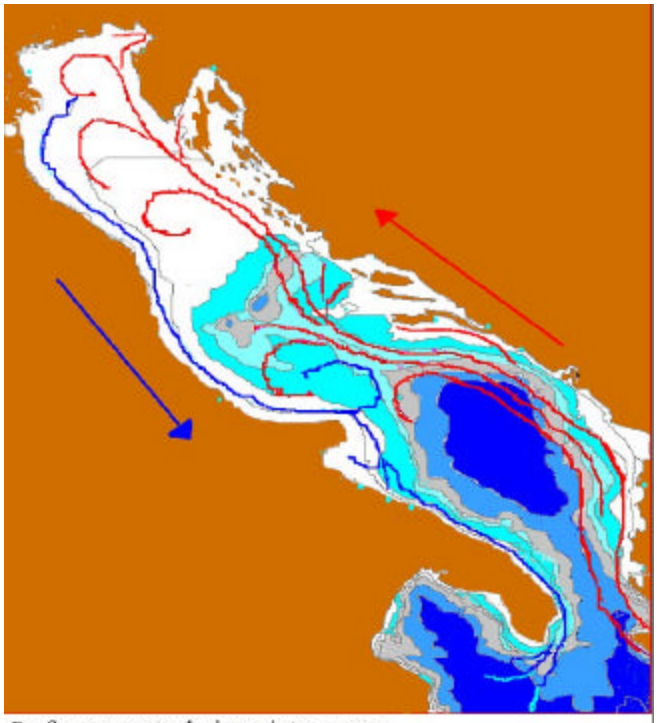
The Adriatic Sea is a very sensitive system, both as a physical and as a bio-geo-chemical environment. The physical component of the Adriatic Sea system depends on one hand on the buoyancy accumulated in the water column, and on the other hand it is conditioned by the air-sea buoyancy exchange and by the buoyancy input via riverine freshwater discharge. The Adriatic Sea has a peculiar property that is characterized both by the estuarine circulation type and by an anti-estuarine circulation pattern in the Strait of Otranto. These properties are mirrored by biological species that are present along the coasts and in the pelagic systems of north, middle and south Adriatic.

The South Adriatic Pit is a portion of the Adriatic Sea where dense water formation takes place via an open-ocean convection. This is an oligotrophic area and a spring phytoplankton bloom is triggered by nutrient injections into the euphotic zone by the winter convection. Therefore, to some extent, the spring primary production maximum should be associated to the intensity of the deep-water formation processes. The winter heat losses strongly change on interannual time-scale resulting in a variable convection depth, which then determines the nutrient input into the euphotic zone and thus the new and export production. The vertical carbon flux data interpreted with remotely sensed algal biomass and *in situ* nutrient data suggest that the interannual variations of the Southern Adriatic open-sea spring bloom are indeed associated mainly to local winter climatic conditions.

Correspondence of the high-chlorophyll content patch and the center of the cyclonic gyre confirms that the intermediate high-nutrient content water advected from the Eastern Mediterranean, is vertically mixed in the center of the Southern Adriatic by winter convection and dense water formation processes. Sometimes, mild winter results in a complete absence of the vertical convection and, in these conditions the spring phytoplankton bloom in the open-sea area should be determined by other mechanisms such as the exchange with the nutrient-rich coastal waters and the large-scale vertical mixing. The new production estimated from the amount of nutrients made available to the phytoplankton by mixing over the convection depth is in a good agreement with the sediment trap data, confirming the predominant role of local winter climatic conditions in the Southern Adriatic biological pump. It was also evidenced that the spring bloom undergoes high-frequency weekly time-scale variability as determined by strong heat loss events on the synoptic time-scale. In fact, the spring algal bloom maximum consists of a series of short-term high-production episodes associated with the calm weather periods, which typically take place after the violent mixing events and transient nutrient injections into the euphotic zone. The total spring primary production, which is to a large extent a new production, represents then the sum of these single bloom events.

This high-frequency pulsating mode of the spring phytoplankton bloom in the Southern Adriatic requires the high-resolution biological sampling in order to resolve short time-scales associated with the open-sea convection and events in the local meteorological forcing function. Interannual variations of the intensity of the vertical convection cause changes in the dense water volume formed. Dense water outflow measurements in the Strait of Otranto revealed interannual variations of the flow rate ranging from 0.1 to 0.4 Sv, which agreed perfectly with the winter climatic conditions: mild winters result in a weak outflow, while severe winters generate strong bottom water outflow in the Strait of Otranto. These characteristics make the South Adriatic Pit and the Strait of Otranto key areas for the long-term monitoring of the variations of the sea response to interannual climatic variability. This monitoring should be interdisciplinary and should include some key biological and chemical parameters in addition to physical oceanography components.

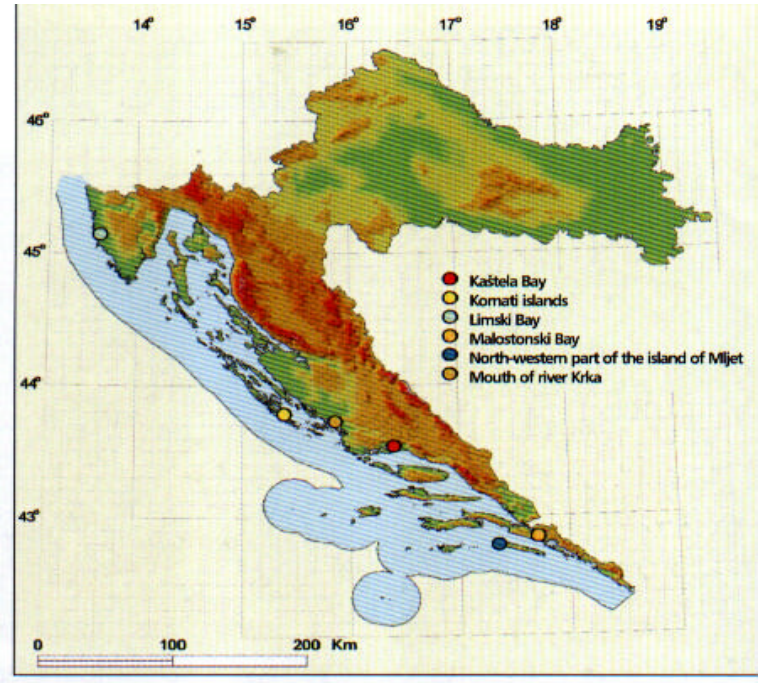
Because of water mixing and sea currents that shift major portions of water masses from the south toward north Adriatic areas, bio-geo-chemical properties of the South Adriatic have major role in the behavior of other Adriatic zones. On the contrary, the South Adriatic area is less researched than other zones, and consequently has poor database of biodiversity and other components necessary for the biocomplexity project. The South Adriatic Region and the biocomplexity project will include area between Bay of Kotor and the island of Lastovo. In this area there are island of Elaphits, the National Park “Mljet”, sea-reserve Bay of Mali Ston and the Neretva rivermouth.



Surface currents during winter season

The south Adriatic area has been identified by the Conservation International as one of the 25 hotspots to be preserved globally (CI, 2001). In addition, recently completed WWF Mediterranean Gap Analysis identified Dalmatia as one of 13 key priorities in the Mediterranean to be conserved and protected. The Government of Croatia identified six most ecologically valuable and threatened sites in Croatia that are all within coastal, marine and islands areas (Fig 1). Adriatic Sea does not only have enormous natural value, but also economical. Estuarine and marine coastal ecosystems have been evaluated as the world's highest economical assets among 16 biomes that define the globe (Costanza et al,1997).

Fig. 1. Ecologically vulnerable and threatened areas of the Adriatic area



Socio-economic aspects

This whole area has experienced profound demographic changes over the past decades, due to the war and post-war circumstances, decline of socio-economic opportunities (education, employment, etc.) and increased level of poverty. Population density is extremely low, and it remains very old (average 64). Other problems include isolation and dispersion of the islands area, singularity of most islands, poor natural resources regarding soil types, lack of water, dry summers, inadequate government policy, socio-geographical and economic decrease due to collapse of sailing, fisheries, handcrafts, schools, etc.

Over the past 2-3 decades the natural and cultural heritage has been increasingly neglected, disintegrated and forgotten, causing off balance and threat in once maintained harmony between natural and traditional life and customs. In planning and developing a

biocomplexity project we should specifically emphasize and address social and economic elements and needs for integrated resources management and sustainable development plan (or ICZM).

Underutilization of resources and the proverbial lack of a labor force causes agriculture, the oldest and until recently the most important economic activity of this part of the Croatian islands, to rank very low in terms of economic priorities. Viticulture, for centuries the most important agricultural branch, does not produce any surplus and hardly meets the needs of the local population. The tradition of growing and gathering medicinal herbs has also died out. Growing olives, for which there are very good natural conditions, is gaining in importance as an economic activity. Sheep breeding, which is complementary to olive growing, is also increasing. However, while islanders are good producers, there is a lack of products processing and marketing. In spite of truly ideal resources for numerous Mediterranean crops including mariculture, which if grown sustainable and responsible could complement upscale tourism. There is a need for establishment of farming cooperatives in agriculture and mariculture that would create incentives for gathering the remaining farmers together, recruiting new ones and provide conditions for a modern, organized farming activity on land and in the sea. Based on its natural and cultural heritage Adriatic archipelago has numerous potentials for prosperous and sustainable socio-economic development.

Attachment 2

Mediterranean lessons

The production of Mediterranean fish farming, primarily concerning sea bream and sea bass, increased from 374 tons in 1985 to 110,000 tons in 2000 (FEAP,2001). Almost 90% of this production comes from four Mediterranean countries: Greece (50%), Italy (14%), Spain (13%) and Turkey (12%). This represents the fastest growing fish farming activity within the European aquaculture sector (Table 1). However, prices have changed significantly during the last 10 years, from an avarage value of US$15/kg to US$5-6/kg in 2000 (FEAP, 2001). In recent years other sparids (*Diplodus sargus, Puntazzo puntazzo*) and, more recently still, the imported *Sciaenops ocellatus* (Israel) are contributing to the diversification of production (FAO, 1999).

Mediterranean marine fish farming production systems can be divided into:

1) Extensive systems: coastal lagoons, vallicultura (Italian, most ancient form of aquaculture in the region) (CIHEAM/FAO/INRH, 1999);
2) Semi-intensive systems: pond culture (mullet in Egypt, and prawn in Portugal, and south of Spain);
3) Intensive systems: land based systems and cage farming;

Cage farming is the primary basis for the rapid growth of the Mediterranean marine fish farming sector. Although in many parts of the Mediterranean there is a strong competition with tourism for coastal resources, cage farms are pursuing an increase of production capacities by installing more cages and increasing their size (from 16 m to 25 m diameter), and by increasing automation processes (Ferlin and Lacroix, 2001). However, marine aquaculture is facing common problems in all the countries, such as a progressive saturation of available sites (both for extensive and intensive aquaculture), high competition in coastal areas use (especially with tourism development), and market restrictions (particularly due to the recent European Union (EU) import regulations). Rapidity of this production growth is not the only reason that weakened the staibilty of the markets. All food production and consumption has been affected by a crisis in consumer confidence for livestock farming (dioxins, pesticides, use of animal meals, etc). Slow but continuous expansion of me aquaculture sector is generally anticipated, while off-shore fish culture is the activity which is actually attracting potential investors.

In order to secure sustainable aquaculture development in the Mediterranean it is important that the industry and environmental authorities have access to suitable management and regulation tools (EC, 2002; Davenport et al, 2003). The European Union sponsored the MERAMED programme that studies environmental interactions near fish farms in the Mediterranean and developes models, methods and standards that can be used for production optimisation as well as environmental assessment and monitoring. The project was designed by the Norwegian company Akvaplan-niva, and the work was carried out in cooperation with researchers from the Institute for Marine Biology Crete (Greece), Institut

für Meereskunde in Kiel (Germany) and Dunstaffnage Marine Laboratory (Scotland) (MERAMED, 2000).
Another similar project has been funded under the European Union FAIR[1] program entitled "Monitoring and Regulation of Marine Aquaculture" (MARAQUA). This project, which started in January 1999, is a "Concerted Action", which means it does not involve new research but instead concentrates on a review of existing information and establishment of agreed guidelines for monitoring and regulating marine aquaculture. The project facilitates establishment of a European Network to bring together scientists, producers, regulators and volunteer organizations, in an effort to co-ordinate and provide means for the efficient exchange and review of information (MARAQOA, 1999). The overall aim of MARAQUA is to define scientific guidelines for Best Environmental Practices (BEP) for the monitoring and regulation of marine aquaculture in Europe.

However, environmental problems related to aquaculture industry worldwide have been exacerbated. Decade of poorly regulated expansion in fish farming in e.g. Scotland, Canada, the US, Norway, Ireland, Iceland, and the Faroe Islands has jeopardized the future of wild salmon stocks. Decline of wild stocks is increasingly linked with sea-lice infestations from fish farms and the mixing of escaped farmed salmon with wild populations (Wolrd Farming, 2003). While populations of wild Atlantic salmon have declined 45 % between 1983-2001, farmed salmon production in the north Atlantic has been allowed to grow to over 700,000 tones in 2002, a 55 % increase in 20 years.

To combat this and similar issues, the goal of sustainable development, which is now integrated into the EU objectives, calls for use of a wider range of tools for environmental policy. It is essential that fish farmers demonstrate a responsible approach to managing environmental impacts of the industry and provide external assurance of environmental management performance. One of the tools is the voluntary Eco-Management and Audit Scheme (EMAS). The application of EMAS to the aquaculture sector should help the industry improve the transparency of the productive process, while improving resource management and environmentally sound practices (MARAQUA, 2001).

Important are TECAM (Technology of Aquaculture in the Mediterranean) Network, which is, together with the SELAM (Socio-Economic and Legal Aspects of Aquaculture in the Mediterranean) Network, coordinated by the International Centre for Advanced Mediterranean Agronomic Studies through the Mediterranean Agronomic Institute of Zaragoza (CIHEAM-IAMZ). The SELAM and TECAM Networks, together with the SIPAM Network, lie within the framework of the Aquaculture Committee of the General Fisheries Commission for the Mediterranean (GFCM).

Global demand for organic food, and environemtnally friendly wild-cought and cultured speacies is increasing (MSC, 2000). Therefore, another tool that can provide assurance of environmentally sound aquaculture practices is through eco-certification programs that empower consumers to chose aquaculture products grown in environmentally friendly sound manner and provide incentives to produce products which can bring higher prices.

[1] http://www.nf-2000.org/secure/Fair/F32.htm

(Goldberg & Triplet, 1997). Marine Stewardship Council (MSC) was formed in the late '90s through partnership between Wolrdwide Fund for Nature and Unilever. The MSC is based on the principles of the FAO Code of Conduct for Responsible Fishing (CCRF) but also developing its own procedures and criteria to define and eco-label products (Muir & Young, 1998). Recently, the world's biggest multi-national aquaculture company developed a new integrated food quality management system – NuTrace for food safety that is 'tracing and tracing' produced, marketed seafood. For example, NuTrace Salmon provides the ability to trace back from the final product to original breeding and feed ingredients, and to track the distribution of all related products (NUTRECO, 2003).

There have been an increasing number of similar initiatives, like the international environmental management system - ISO14001, Naturland 2000, Agro-Eco Consultancy 1999, MSC 2000. Potential benefits of ISO 14001 to the aquaculture industry could include:

- Regulatory compliance - avoiding costs of prosecution and fines;
- Brand enhancement and protection - avoid damage to brand value and market position by avoiding incidents and prosecution, enhance brand value through ISO14001 label;
- Loss of control and process efficiency - reduce costs, particularly energy, effluent discharge and waste management;
- Meet customer requirements - ISO14001 provides external third party assurance - link to quality and food safety issues;
- Improve performance - drives systematic management of environmental impacts, often leading to other business improvements;
- Responds to stakeholder concern - provides assurance of good environmental performance to NGOs, local communities and to other external interested parties (Westwood, MARAQUA, 2001).

National aquaculture plans exist in Cyprus, Egypt, Israel, Greece, Italy, Malta, Spain and Tunisia. The precautionary approach for the environmental impacts of aquaculture is practiced in Cyprus, Egypt, Malta and Israel (FAO, 1999). Most of the EU countries are developing national CCRF, although in most Mediterranean countries a specific aquaculture policy document does not exist. In Greece, the aquaculture plan promotes awareness for responsible aquaculture. The beneficiaries are usually the commercial sector, artisan fishermen, rural areas, research and consumers. All strategies are funded by national government, although in Turkey and Israel Foundations/Associations also play a significant role. Although the role of Producer Associations (PA) is widely accepted, fragmentation and large numbers of local associations complicate rather than resolve critical administration or policy issues. International federations such as the Federation of European Aquaculture Producers (FEAP) can therefore play a vital role.

In 2000, Ireland developed and started CLAMS (Coordinated Local Aquaculture Management Systems) project. This initiative is mapping development of fish farming in bays and inshore waters throughout Ireland on a local level. CLAMS, in line with county development plans and EU policies, provides a framework for addressing issues that affect or are affected by aquaculture activities and streamline the resolution of these issues. It will

also form a sound basis for further expansion into the areas of integrated inshore fisheries management and ultimately Coastal Zone Management plan (CLAMS, 2000).

The marine aquaculture of bass, bream, sparids and mollusks is relatively well developed in all Mediterranean countries whereas shrimp culture is a relatively minor industry. Land based coastal aquaculture, with hatcheries producing bream, bass and shrimp, exists in most EU Mediterranean countries, Turkey, Cyprus, Israel and Tunisia. The extensive aquaculture of bream, bass, mullet and Manila clams in coastal lagoons is developed in Italy, Greece, Bulgaria and Egypt. Inshore aquaculture, with cage culture of bass and bream, is well established in EU Mediterranean countries, Turkey, Croatia, Morocco, Bulgaria, Israel and Cyprus whereas mollusk culture (mussels, oysters) is less developed. Besides seabass and seabream, turbot (*Scophthalmus maximus*) is mainly produced in Spain and France, but only in land based installations, and eels in highly intensive recirculation systems (CIHEAM/FAO/INRH, 1999).

Mollusk culture is more commonly a corporate activity**,** bringing direct positive social benefits, while fish culture is mostly dominated by private enterprises (FAO, 1999). In 1996 the worldwide **mussel production** reached 1.2 million tones with the largest producers during the 1990's being China and Spain. There are two mussel-farming systems: off-bottom longline and raft culture. The most common way to grow mussels is just to let the mussel hang on to the collectors (longline) until they reach the market size. As this is not a very productive way, growers are looking into using re-tubing systems (stockings) for more effective way to farm mussels. There is a market for blue/black mussel, and it is in Europe. Statistics show that Europeans eat three times as much blue mussels as they eat Norwegian salmon, about 800,000 tons of mussels are consumed in a year. However, European producers provide 600,000 tons: Spain 34%, Denmark 16%, the Netherlands 12%, Germany 9%, France 6%, Ireland 5%, others 9% (Havbrouk, 2000).

There is a great potential for mussel farming (*Mytilus galloprovincialis*) within the Adriatic sea archipelago, as a sustainable food production and at the same time combating the negative effects of eutrophication. Most of the nutrient supplies from anthropogenic sources reaching coastal waters are presently out of control, and it has been difficult to reduce the nutrient levels there drastically. The elevated nutrient concentrations in the sea enhance phytoplankton production, which can feed cultured mussels. The supply of nitrogen and phosphorus has, however, changed the relationship between these nutrients and also those to silica in the sea, which might have favored growth of toxic dinoflagellates, okadaic acid-producing Dinophysis spp. causing diarrheic shellfish poisoning.

The common blue mussel (*Mytilus edulis*) can efficiently filter out organic particles in the seawater, thus reducing phytoplankton biomass and increasing water clarity (e.g. adult oyster may pump up to 10 liters per hour of sea water, Spancer 2002). The mussels structuring grazing effect on the phytoplankton community, which most likely reduces the sedimentation of organic material to the bottom, has also been demonstrated. Mussels grown on the west coast of Sweden are of high quality, have a good reputation among

consumers, and do not have an occurrence of toxic dinoflagellates (Haamer, 1995). Swedish mussel farming is efficient and cost effective through the long-line technique.

Mussel farming in Shetland, Scotland, is a success story. Steady growth since 1995 when rope growing of mussels started around Shetland means that today the industry is expected to produce 1,200 tones of high quality this year, which is easily absorbed by the European market. Spain produces approximately 250,000 tones, 60,000 tones in Holland, 80,000 in France. Denmark produces about 100,000t per year, which is a wild fishery, and most of the harvest is processed into a low-cost canned product. Germany and the Netherlands together produce about 110,000t per year. The mussels are grown in bottom culture in the extensive intertidal areas along the North Sea coast.

A substantial portion of the European production is grown on suspended ropes, a technique which can be extended further offshore and which, although quite sensitive to plankton blooms, is the only one which could further increase production, since both the 'bouchot' and the bottom culture techniques are faced with growing coastal pollution, bird predation and land use constraints (Aqua-media.com). In addition, bivalve culture may cause accumulation of organic materials (faeces and pseudofaeces) underneath dense bivalve aggregations. This is particularly true of mussel culture operations, as mussels produce large quantities of pseudofaeces, suspended material that may impact benthic substrates.

Presently, the industry is focusing on the following targets: Identifying strategic sites where mussel farming is profitable and counter-acts the negative effects of eutrophication (identifying suitable sites carrying capacity); Developing temporal and spatial models on potential occurrence of toxic algae, pathogenic microbes and DST; Improving methods for monitoring toxins and the hygienic quality of water and products and improve methods for depurating mussels from DST-toxin; and evaluating the economical value of mussel industry on improving coastal water quality.

Although practiced by the ancient Romans, **oyster culture** was rediscovered in France during the 17th century and modern techniques were developed in the 19th century. In France, a special treatment (depurification) may be applied for the supply of top quality oysters: prior to selling these are placed in former salt marshes, which have been converted into ponds. During their second year oysters are spread in the intertidal range directly on the ground (bottom culture), in bags on trestles, or suspended from long-line floats (in the Mediterranean). Normally, harvesting takes place during the third year.

Manila clam (Japanese carpet shell, introduced 20 years ago) culture has also lead to additional activity, in that the natural reproduction of animals released for farming has created wild populations in areas that were previously non-producing; these are currently exploited using traditional fishing methods. This is an example of 'culture-based fisheries'. This situation led to some concern over competition with the European species and the risk of diseases being spread. To date, however, there is no clear evidence that Manila clam plays a role in the observed reduction of the European clam yield. This reduction is probably due to fisheries over-exploitation.

The Mediterranean coast, which is about 46,000 km long and is highly populated, and supports many functions, such as tourism, residential development, and conservation, which competes with aquaculture for resources. Many coastal areas are also physically exposed and therefore unsuitable for traditional inshore-based farming.

Offshore farming is seen as a means to overcome such difficulties, and as a way to increase production in areas where it would otherwise not be possible. Indeed, a number of offshore farms have already been established and have operated with varying degrees of success for a number of years. Offshore aquaculture of sea bass and bream is well developed in Malta, Cyprus, Spain and Italy, while mussel offshore aquaculture is developed in France (CIHEAM/FAO/INRH, 1999; CIHEAM, 2000). Offshore farming is particularly well developed in Cyprus (840 t/yr; 87% of the total national aquaculture production) and Malta (about 2,000 t/yr; which is almost the total aquaculture production of the country), where no sheltered areas exist. It is also becoming more of an aquaculture option for Italy, Spain, and France where conflicts with the tourism industry or scarcity of appropriate sites are already forcing the producers to move far from the coast. In addition, the Black Sea countries reported interest in developing offshore aquaculture, and some activities are already carried out by Turkey involving the farming of salmon and large-size trout (FAO, 1999). However, the offshore environment continues to present many challenges, not only to systems design and installation, but also to stock management (Muir, 1997; FAO, 1999). Also, if marine offshore aquaculture moves offshore there will be more business opportunities for fishermen! (Barnaby and Admas, 2002).

Another emerging aquaculture is fattening of **bluefin tuna** (*Thunnus thynnus*). During the last 5 years there has been a very important development of tuna farms in Mediterranean, with approximately 20 farms (most of them in Croatia 9 and Spain 7). It is estimated that more than 70% of the Mediterranean recommended catch quota is already being used for this production, which is mainly exported to the Japanese market (one bluefin tuna can reach price of 30,000 US$). This year, the researchers from seven countries (Spain, Israel, France, Germany, Italy, Greece, and Malta) started a three year project REPRO-DORR, "Reproduction of the Bluefin Tuna in captivity: Domestification of *Thunnus Thynnus* (Fish Farming International, 2003). Japanese researchers have closed the bluefin tuna life cycle, and the current goal is to improve incubation, hatching and larval rearing of tuna and to release juveniles into oceans to replenish natural stocks (bluefin tuna is on the list of endangered species).

Although there have been on-going trials to produce new marine finfish species, no real replacement has been found for seabream and seabass. With the beginning of 21 century, new major species production includes sharp-snout seabream (*Puntazzo puntazzo*) in Greece, and white seabream (*Diplodus sargus*) in Italy (FEAP source). Additional new candidates may increase the number of farmed species in future: *Pagrus pagrus*, *Dentex dentex*, groupers, and seriola (Ferlin and Lacroix, 2001). Options for Mediterranean marine aquauclture development (specifically important for Croatia) have to target three areas: marketing, production and entrepreneurship. Regarding **marketing**, there is a need for better development of local markets, improvement of product quality, diversification in products (fillets, caned fish and shellfish, precooked, etc). Regarding **production** there

needs to be a significant reduction of production costs (better management, automation, nutrition and feeding, health management, etc); also diversification of production systems (offshore, recycle systems, etc); species diversification, polyculture. Regarding **entrepreneurship** there is a need for association of producers through a common market, as well as integration of production units (e.g. hatcheries, on-growing farms, feed manufacturing, and marketing) (FAO, 2002; Ferlin and Lacroix, 2001).

Table 1. Seabream and Seabass fry production in Mediterranean countries in 1999 (FEAP source)

Country	Hatchery (#)	Seabream fry (millions)	Seabass fry (millions)	Total (millions)
Greece	33	90	75	165
Italy	15	46	62	108
Spain	9	35	8	43
France	9	19	21	40
Turkey	16	3	24	27
Portugal	5	13	6	19
Cyprus	4	15	3	18
Morocco	1	3	6	9
Tunisia	2	2	6	8
Israel	2	5	0	5
Croatia	4	1	3	4
Malta	1	1	0	1
TOTAL	101	233	214	447

Major provisions in national aquaculture plans (FAO, 1999):

NATIONAL PLAN	MAJOR PROVISIONS
Cyprus	• sustainable development; • EIAs; • environmental monitoring; • caution over future expansion;• limits on the expansion of existing farms; • limits on the establishment of new farms;• minimum water depths and cage separation; • GESAMP monitoring procedures, with costs to be borne by the industry; • targets for (species) diversification, the development of cage technology; • criteria for new entrants to the production sector (with priority for local people, especially fishermen); • the inclusion of marine aquaculture in all coastal management plans; and • the urgent implementation of the legal framework set up by the aquaculture legislation. Importantly, the aquaculture plan of Cyprus sets a relatively short time span for its revision (three years).
Egypt	Expanding the development of aquaculture through encouraging: • support for existing ventures, particularly those with GAFRD land leases; • investment in aquaculture, particularly marine and intensive aquaculture; • technical support for improving traditional farms; • the supply of healthy fry and fingerlings at reasonable cost; • support for Nile tilapia hatcheries; • the production of balanced aquafeeds; • the establishment of joint ventures, especially in marine aquaculture, with partners from developed countries; and • non-conventional and integrated aquaculture.
Greece	The major Operational Fishery Business Plan allows for: • construction, expansion, modernization and relocation of aquaculture units; • new infrastructure for the development of coastal lagoons and other fisheries exploitation; • improvements (expansion, modernization, relocation) of existing infrastructure within the sector; • establishment of new units for the farming of new species with commercial value; • establishment of plans for fundamental research; and • rational organization of fisheries trade. • establishment of small businesses, adapted to the requirements and trends of the market, for new species (pilot and production phases); • integration of fish farming with tourism; • assistance in solving the problems in production administration and trading; • rationalization of trading networks; • promotion of quality standards and trademarks; and • establishment of a coastal lagoon administration system, in addition to the protection and improvement of income for those involved in coastal lagoon exploitation; • subsidies or partially subsidized loans for investment & running costs; and • ten-year tax exemption (for farms of at least five years establishment) on non-distributed profits.
Israel	Within the fisheries plan, calls for the: • development of offshore aquaculture; • intensification of inland aquaculture through recirculation systems to minimize water consumption; • use of desert saline waters for aquaculture; and • species diversification; These plans are reported to comply with Articles 9.1, 9.3, and 9.4 of the CCRF.
Italy	The two main sections of the plan, dedicated to "aquaculture and the environment" and "fisheries, aquaculture, tradition and culture", deal with: • the relationship between aquaculture production and environmental protection; • intensive aquaculture and pollution risks; and • the introduction of new species. Guidelines for research activities in support of the sector are defined, and include: • the conservation of the natural biological population; • the selection of new eco-friendly therapeutants; • product quality standards; and • aquaculture environmental impact. A special plan for freshwater aquaculture: • favors activities compatible with environmental conservation; and • regulates extensive aquaculture and re-stocking practices.
Malta Malta	• sets a maximum on the number and size of hatcheries, and limits their location; • sets visual impact and size limitations on large (>150 t) offshore facilities and their land bases; • limits the number and size of new large-scale units, and sets time limits for their initiation; • identifies six search areas for EIA for possible future aquaculture development; • defines a further fifteen conservation areas where aquaculture will only be permitted if it can be shown to enhance conservation management; • sets maximum numbers and size for new small-scale land-based units; • defines norms for management, rehabilitation rules, fish health, and personal responsibility; and • prescribes programmes for monitoring and reporting.
Tunisia	• the optimization of reservoir use to increase extensive aquaculture production; • the provision of support for intensive land-based marine aquaculture by assisting producers to achieve a competitive position in the EU market; and • promoting domestic bivalve mollusc consumption, increasing sanitary control, and developing oyster and clam culture.

Evaluation criteria for assessing requests for approval for aquaculture ventures (FAO, 1999):

Country	Criteria	Comments
Bulgaria	• Trout and sturgeon culture evaluated related to their export potential • No other or specific criteria described	• Some national sanitary requirements are said to be more severe than EU ones
Croatia	• New projects are evaluated according to the legislation, permits, etc. • Business takes the risk, insures, and raises finance	• Most development projects at present are regeneration projects • Sometimes national or local government loans are available but usually at commercial rates • Difficult to find a typical example; each venture is examined on a case-by-case basis
Cyprus	• EIA; • Environmental monitoring • Assess compliance with EIA provisions, terms and conditions of license, and legislative provisions • Assess the overall performance of the farms	
Egypt	• Definition of the land area • Ensure that the farm will not have a negative environmental impact • Assess the feasibility study of the venture	• Described in a GAFRD Directive
Greece	• Existence of suitable areas; • EIA • Water quality and quantity (land-based units) • Water depth • Project viability	• There is a specific law which protects the quality of water in which aquaculture units operate
Israel	• Compliance with the aims of national aquaculture plans • In the priority regions • Compliance with the rules of responsible fisheries • Approval from the District.	• These are the criteria for Government financial support
Italy	• No specific information	• There is a progressive harmonization between fisheries and aquaculture
Malta	• EIA; • Conforms with the Malta Maritime Authority Act relating to shipping issues; • In an approved "search area"; • Approval of related authorities	
Morocco Morocco	• a "simple" technical and economic study of the project • the company profile • in the case of coastal projects, proof of its social acceptability	• responsibility in resource use, access to credit, a licence, and insurance is not considered, because the aquaculture sector is still small
Romania	• Production target is realistic and can be achieved • Farm has an effective plan for fingerling supply or production; • Adequate measures for environmental protection; • Project fits Romanian and EU regulations on product quality; • Production makes use of local resources (services, personnel, etc.) • Credit is not available from another source	• Credit can be obtained through the Romanian Fund for the Guarantee of small and medium-size producers, which will reasonably protect investors. The criteria for considering the enterprise for support are shown on the left
Spain	• Aquaculture must not create conflicts with other productive activities. Local as well as national development policies are taken into account	
Tunisia	• Authorization granted by an interdepartmental commission; • EIA; • Technical and economic viability (including species to be reared); • Satisfactory investment plan	
Turkey	• Mandatory EIA; • Credits approved according to general guidelines set by government for agriculture and livestock production	• Checked by MARA according to technical and economic feasibility.

International Ocean Policies in the 1990s, by Strengths and Weaknesses

(Source: WorldWatch Paper 145, 1999)

U.N. Global Driftnet Moratorium, 1991
Strength: U.N. General Assembly passed global moratorium on high-seas driftnets in 1991. Use of this gear has virtually ended on the world's oceans.
Weakness: Eliminating this particular type of gear has led fishers to use longlines and other damaging fishing methods to evade the specifics of the moratorium, often with effects on marine wildlife similar to those of driftnets.

Oceans Chapter 17, Agenda 21, Earth Summit 1992
Strength: Addresses the sustainable use and conservation of marine resources and habitat areas. U.N. Commission on Sustainable Development addresses oceans and seas in 1999.
Weakness: Language with respect to conservation is weak, lacks specific commitments.

FAO High Seas Fishing Vessel Compliance Agreement, 1993
Strength: Global binding agreement. Countries whose vessels fish on the high seas must ensure that those vessels do not under-mine accepted fishing rules; requires countries to provide FAO with comprehensive information about vessel operation.
Weakness: Not yet in force. Only 12 of necessary 25 countries have ratified it.

U.N. Convention on the Law of the Sea (entered into force in 1994)
Strength: Global agreement provides comprehensive framework for ocean development. Calls for balance between use and conservation; 130 nations have ratified it.
Weakness: Conservation obligations weak.

FAO Code of Conduct for Responsible Fisheries, 1995
Strength: More than 60 fishing nations have agreed to it. Contains principles for sustainable fisheries management and conservation; highlights aquaculture, bycatch, and trade.
Weakness: No punishment for ignoring this voluntary code. No mention of subsidies.

U.N. Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks, 1995
Strength: Prescribes precautionary approach to fishery management both inside and outside EEZ, vessel inspection rights in accordance with regional agreements. Provides binding dispute resolution.
Weakness: Not yet in force; falls short of the required 30 ratifications. Only four of the top 20 fishing nations have ratified it.

Jakarta Mandate, Convention on Biological Diversity, 1995
Strength: Adopted guidelines and general principles that call for the protection of marine biological diversity and sustainable use of marine and coastal resources. Puts ocean use in broader context of biological and social goals.
Weakness: Guidelines too vague to be enforced.

Attachment 3

Guidelines for Sustainable Aquaculture Development in Croatia

Presented are draft guidelines for sustainable aquaculture development within Adriatic islands, costal and marine ecosystems, with preference given to the extensive polyculture practice: integrating native species of shellfish, seaweeds, urchins, crabs and finfish.

Vision statement

Aquaculture development has to be advanced in a manner that is environmentally sustainable protecting the quality of the environment for other users, while it is equally important for society to protect the quality of the environment for aquaculture. Adherence to both aspects requires effective and transparent research, adaptive management, monitoring, enforcement and incentive. The Government-approved and industry/stakeholders-led 'Environmental Codes of Practice' and National Aquaculture Plan will support this approach through the Integrated Coastal Zone Management implementation.

Relevance and importance of sustainable aquaculture development

Aquaculture is one of the fastest growing sectors of the world economy. Around the world, sustainable aquaculture has proved to be a revitalizing economic force in rural island and coastal communities – areas where sustainable economic development is often difficult (Frankic, 2002). In such communities, however, the introduction of aquaculture into areas traditionally used largely for commercial fisheries and a variety of recreational activities have sometimes coincided with impassioned user group conflict. To overcome this imbalance for the benefit of Croatians, a planned, balanced and inclusive community approach to rural economic and social development is required. Through effective research, development, monitoring and incentive programs that maintain ecosystem integrity and balance human values, economic development can be attained in an environmentally and socially sustainable manner.

Policy, Legislation & Regulations

Sustainable use of Croatia's coastal and aquatic resource base requires an appropriate and enabling regulatory framework that is supported by clearly delineated national, county and local roles and responsibilities and transparent accountability agreements. At all levels, the roles of agencies involved with aquaculture should be clarified. Central themes should include site access, property rights, food safety, productivity, competitiveness and environmental sustainability. Incorporating a planned approach to resource use and management, a streamlined and inclusive review process would provide a practical mechanism for timely conflict resolution. Moreover, such a framework would be conducive to the development of a balanced and objective public service culture with respect to aquaculture and other users of the islands, marine and coastal resource base, such as fisheries, tourism, nature conservation and agriculture.

National Codes of Conduct and Practice

Codes of practice amount to generalized and agreed forms of mitigation for the impacts of a sector, sub-sector, or individual farm. They should also serve as standards against which aquaculture siting, design or operation may be assessed. There is an increasing interest in codes of practice on the part of international organizations, governments, and the industry itself. This provides an incentive for the aquaculture industry (and supporting governments) to further promote adoption of environmentally and socially responsible farming practices through appropriate standards or codes of conduct. Examples range from general to specific and include *the FAO Code of Conduct for Responsible Fisheries*, and the associated *Technical Guidelines*; the *Global Aquaculture Alliance* (a newly formed international industry association) Codes of Practice. Countries that are engaged in aquaculture development should develop and implement their national aquaculture plans and codes of conduct.

Sustainable development criteria

Planning for sustainable uses must be a process that comprehensibly and holistically analyzes islands, marine and coastal systems: natural resources conditions, human uses and socio-economic aspects. Socio-economic sector conflicts can be managed simply by controlling where certain activities are undertaken (e.g. different types of agriculture, tourism, aquaculture, fisheries, nature conservation etc), but sustainability can only be attained when environmental conditions are appropriate. This means that choices should be based on environmental requirements and suitability for the activity and the activity's interactions with the environmental resources. Site suitability assessment and implementation must incorporate physical, biological as well as socio-economic, and cultural factors.

The concept of sustainable development is simple and important, but translating it into specific standards or criteria is difficult and often subjective. Although many specific sustainability criteria have been proposed there is no single universally agreed set. In assessing the sustainability of any activity, consideration should be given to at least the following:

- environmental impact;
- the sustainability (or continuity) of supply, and quality of inputs;
- the social, environmental and economic costs of providing the inputs (e.g. depletion of resources elsewhere);
- the long-term continuity (or sustainability) of production;
- financial viability;
- social impact and equity; and
- the efficiency of conversion of resources into useful products.

In general, islands and coastal ecosystems sustainable development strives to maintain or restore a balance between natural and human environments. Therefore, sustainable development, in this case of aquaculture, will involve management in time and space of the constant interactions between ecological and economic, and social and natural variability, supporting co-existence of ecosystems and lifestyles side by side. Natural and cultural components of the islands heritage are inseparable and could not be addressed independently of each other, neither in development planning or conservation efforts.

Benefits of Aquaculture

- increase household food supply and improve nutrition
- increase household resilience through diversification of income and food sources
- strengthen marginal economies by increasing employment and reducing food prices
- improve water resource and nutrient management at household or community levels
- preserve aquatic biodiversity through re-stocking, and recovering of protected species
- reduce pressure on fishery resources if done sustainable
- improving/enhancing habitats
- stimulates research and technology development
- increase education and environmental awareness;

Risks of Aquaculture

- sediment hypoxia/anoxia resulting from organic enrichment (generally local but occasionally far-field)

- carbon/nutrient enrichment of the water column and benthos (leading to reducing conditions and hypoxia) (often with far-field implications)
- reduced levels of dissolved oxygen in a water column (as a result of eutrophication) (often with far-field effects)
- chemical, pharmaceutical, and toxicant inputs to sediments and water column (with local and far field effects)
- "debris" from foods, aquaculture structures, support vessels, consequences of "redistributions", including bioinvasions, pathogens and disease (often as a consequence of crowding), changes in natural community structure, and introductions of genetically modified culture stocks
- directly causes negative impacts and pressure on mangroves ecosystem changes in trophic ('food web') interactions and productivity
- changes in biodiversity;

Social impacts

Social impacts or effects are "alterations in the way people live, work, play, relate to each other and organize to meet their needs, as well as changes in the values, beliefs and norms that characterize their 'group' and guide their individual and collective actions" (UNEP, 1996). Social impacts may be categorized as follows:

- demographic impacts such as changes in population numbers, population characteristics (such as sex ratio, age structure, in-and-out migration rates and resultant demand for social services, hospital beds, school places, housing, jobs etc);
- cultural resource impacts including changes in archaeological, historical and cultural artifacts and structures and environmental features with religious or ritual significance; and
- socio-cultural impacts including changes in social structures, social organizations, social relationships and accompanying cultural and value systems (language, dress, religious beliefs, rituals).

Information on most of these impacts should be collected through the public involvement program. It is recommended that social scientists, preferably with considerable local knowledge, lead any public involvement program and analyze the information generated related to social impacts. However, they should work closely with biophysical scientists or economists working on the team.

Aquaculture Zoning

Zoning is one of the few available approaches for *avoiding* or *pre-empting* issues of resource use conflict. The alternative, where resource use conflict may be an issue, is a conflict resolution. In practice the two are related, since zoning may be a solution or mitigation measure proposed through the conflict resolution process. Furthermore, public involvement should play a key role in the definition of zones (e.g. County physical plans and public reviews/inputs), and agreeing the rules or procedures that should apply to such zones. Zoning can be undertaken most effectively as part of a broader integrated coastal planning and management initiative, since rational allocation of land or water to specific activities requires a thorough assessment of the strengths and weaknesses of alternative uses. Zoning may be used to define exclusive zones for particular activities, priority zones, or mixed zones. The approach should depend on local circumstances. If a zone is allocated to aquaculture and/or other activities, the issues of biodiversity conservation, pollution and water quality can be addressed systematically. First, environmental quality standards (EQS) for the zone should be set. One example of such standards relating to major coastal ecosystem types is presented below. This addresses one of the main problems- the need for consistent criteria against which impacts can be monitored and evaluated.

Environmental Criteria that have to be considered but are not limited for aquaculture zoning and site suitability selection (based on PAP/RAC, 1996; and Frankic, 1998):

- Land use/land cover
- Species types (finfish, shellfish, algae, herbivorous, autochthonous)
- Exposure
- Depth (bathymetry)
- Currents (velocity, direction, surface and through water column)
- Wind (fetch, speed and direction)
- Coastal topography (slope, geology, pedology)
- Substrate (benthic type and quality)
- Suspended matter
- Trophic status (e.g. oligotrophic)
- Water quality (%0, temp, ppt, coliforms, heavy metals, nitrate, phosphate, chlorophyll, etc.)
- Fouling
- Predators (e.g. birds, other marine species, etc)
- Threatened and endangered species, habitats
- Protected areas, MPAs
- Buffer zone for aquaculture sites (related to pollution, protected species, use conflicts, etc)
- Accessibility (related to transportation, roads, etc)
- Site carrying capacity (environmental capacity) (maximum number of users/species which can be supported by a natural or manmade resources without producing negative environmental consequences to their future productivity, structure and quality)
- Finfish feed quality and quantity (strict regulation of GMOs);

Aquaculture Siting

Environmental conditions present constraints and opportunities in the siting of island, marine, and coastal aquaculture operations. Consideration of environmental conditions is important to anticipate and avoid many adverse impacts that could result from establishing an aquaculture activity. Multiple criteria analysis must be considered when determining the suitability of a site for aquaculture. Regions characterized by poor circulation, extensive accumulations of sediment organics, overwhelming recreational and commercial endeavors (marinas, race-courses, diving, fishing, port activities, etc.) will, generally, not be effective sites. An understanding of other human activities in the area, as well as weather, surface waters, underground springs (vrulje), shoreline processes, ecosystems quality, migratory birds and species at risk must be applied to the site selection and ultimately the environmental assessment of an aquaculture project. In support of an environmental assessment, the location of the proposed project should be clearly identified on detailed topographic maps along with any inlets, springs, or small bays. An integrated GIS of the site(s) should be prepared which includes the coordinates (GPS, latitude and longitude) and dimensions of the lease and its relation to the shoreline to allow reviewers to visualize the layout of the proposed development.

Siting in particular is difficult to change once an aquaculture development project is proposed, since it will be initiated largely on the basis of the availability of a site. Sector environmental assessment of aquaculture should identify opportunities for mitigation of the impacts of the aquaculture within a particular area (for example a bay, estuary or watershed). If possible, they should be brought together within the framework of an aquaculture development plan, ideally as part of an Integrated Coastal Zone Management Plan (ICZMP).

Assessment and Classification of Aquaculture Areas

Government agencies are responsible for monitoring bacterial water quality in shellfish growing areas. Based on results from water surveys, recommendations should be made on the suitability of coastal waters for the harvesting of shellfish. Surveys are based on the sanitary and bacteriological water quality conditions and areas will be classified as approved, conditionally approved or closed to shellfish harvesting. Shellfish contamination can also result from the build-up of chemical substances such as metals, pesticides and chlorinated organic chemicals. This approach also promotes pollution prevention, remediation and restoration of shellfish growing areas. It is necessary to continuously provide regular testing of commercially harvested shellfish for bacterial contamination and maintain a marine biotoxin surveillance program of shellfish growing areas (e.g Mali Stone Bay, Limski channel, Novigradsko more).

The assessment should document and take into account the following potential influences on the proposed project based on past and existing human use of an area:

- Areas of known or suspected contamination;
- Land-based sources of pollution including point and non-point sources;
- Existing infrastructure;
- Proximity of other aquaculture operations;
- Current and potential water-based activities and uses;
- Disposal at sea sites.

Effects of the environment on aquaculture

Among the environmental parameters that can impact marine aquaculture operations are those related to climate and meteorological conditions and water temperature. Climatic conditions are important factors in selecting a site for an aquaculture facility. They can also influence the choice of materials, sizing and placement of structures, and possibly, seasonal accessibility. The following factors should be investigated as part of the assessment:

- Temperature - abrupt or drastic changes in the ambient water temperature can induce physiological stress on the cultured animals. Changes in production levels and incidents of high mortality rates have been attributed to water temperatures outside the seasonal norms;
- Waves - fish containment structures must be designed and built to withstand repeated wave action and large waves that may result from storm events. Additionally, growth rates, food-conversion efficiency, and resistance to disease can be impaired by mechanical stress such as wind-generated wave action;
- Currents - excessively fast currents will stress fish, reduce growth rates, pose strains on gear and moorings, and may resuspend and release contaminated waste material to down drift areas;
- Precipitation and Runoff - seasonal fluctuations in precipitation can affect the volume, availability, and quality of the water supply in and around cage sites;
- Fog - thick fog may hamper operations and constitute a hazard to navigation;
- Wind climatology including the frequency of wind speeds above operational thresholds, as well as the return periods for extreme and design events.

Physical and biological changes in the environment, which may be shaped by the effects of potential climate change scenarios could have implications for the aquaculture industry. Based on current climate change predictions, aquaculture activities could be affected by changes in hydrological variability, such as:

- Changes in precipitation leading to changes in water quantity and quality;
- An increase in average ambient air temperature may increase the temperature of surface water sources. This may result in lower water and dissolved oxygen (DO) levels, which could subsequently promote increased growth of algae and bacteria.
- Changes in aquatic habitats may affect fish production and aquatic biodiversity.

Hydrology and Shoreline Processes

There are a number of physical characteristics of a water body that will influence both the productivity and potential impacts of a cage culture facility. The following hydrological characteristics should be investigated for the proposed site and considered in the assessment:

- Shelter conditions, bathymetric data, water depth and volume. Adequate depth (more than 50 m is suggested) which is important for keeping accumulating fish wastes away from the cages and for maintaining adequate circulation through the cages;
- Current speeds, directions and flushing times;
- Dispersion characteristics of the site and an assessment of near-shore currents and littoral/drift-bed load processes. This information will allow the extent of the potential zone of influence including impacts to shorelines processes to be determined.

Water and Sediment Quality

Water quality is of primary importance to the health and sustainability of aquaculture operations. Cages must be placed in uncontaminated waters and it is equally important that the quality of the waters below and adjacent to cages not be degraded as a result of aquaculture activities. Baseline

information should be evaluated in relation to predicted changes resulting from the proposed aquaculture facility and other inputs to the receiving waters. Any published water and sediment quality objectives should be referenced as applicable. Among the important parameters that should be discussed in the assessment are:

- Dissolved oxygen (DO). DO is the most important chemical parameter influencing fish productivity. (e.g. in general, DO levels should be above 5 ppm);
- Seasonal temperatures (water and air). Temperature affects activity levels, feeding, growth, and reproduction;
- Suspended solids. High levels of suspended solids can decrease water clarity and impair invertebrate and vertebrate feeding;
- Redox potential (Eh). Measures the degree of oxygenation in the sediment. This along with sulphide levels will help to predict the ability of the sediment to metabolize organic wastes;
- Nutrient and biological characteristics influencing water quality which should be assessed include:
  - Nitrates, nitrites, phosphorus and ammonia;
  - Vegetation cover and general riparian habitat;
  - Propensity for algal blooms;
  - Types and abundance of aquatic biological communities;
- Other parameters (e.g. metals, organic compounds) that may be present depending on the other activities and discharge sources that have been identified.

If there are other aquaculture operations, agricultural and/or other industrial activities (or if there are likely to be in the future) contributing discharge or runoff to the receiving water, the **assimilative capacity** of the water-body should be considered. Assimilative capacity can be determined by a number of physical, chemical and biological factors. Chemical factors may include nutrient levels (e.g. nitrogen, phosphorus) and the nature of industrial discharges. Biological factors include plant composition and abundance; fish types and abundance; and the composition of invertebrate populations (e.g. in benthic ecosystems).

Migratory Birds, Species at Risk and their Habitats

Interactions with and conflicts between aquaculture operations and wildlife species have become significant management issues for proponents and regulatory agencies. In general, the expanding aquaculture industry is increasingly using more coastal migratory bird habitat important for feeding, staging, wintering, and nesting. At the same time, concentrations of easily accessible fish are a tempting food source for a variety of migratory birds and mammals. The attraction of predators can result in direct competition for the habitat of species at risk.

Avoidance of any area where migratory birds and species at risk may be impacted by the construction and operation of an aquaculture project is the preferred approach. In support of this strategy, the description of the proposed project area (site suitability analysis) should include information on the terrain, biological settings, habitat types, and wildlife use. The site map should identify all environmentally significant areas and other types of protected areas within a **1 km radius** of the proposed site that have been established, in part, to protect migratory birds, species at risk and their habitats. Among the designated areas that should be identified are:

- Ramsar Sites, as identified by the Ramsar Convention (Convention on Wetlands of International Importance, etc.)
- Important Bird Areas; National parks, other protect species and habitats

a) Migratory Birds
Attention should be given to:
- Species of migratory birds likely to be present, their seasonal occurrence, relative or absolute abundance, and population trends;
- Areas of migratory bird concentration such as breeding areas, colonies, spring and fall staging areas, and wintering areas;
- Ongoing or proposed recovery, rehabilitation, remediation, or improvement plans for migratory birds.
- Food sources and/or feeding areas for migratory birds.

b) Species and Habitats at Risk
Several provincial jurisdictions have enacted regulatory protection for species at risk and pending federal legislation are intended to provide a legal definition of their habitat. Priority should be given to identifying any species at risk that are using the proposed site either permanently or temporarily. Specific attention should be given to identifying:
- Presence of species at risk listed with, or under review by MEPPP, international conventions ?
- Ongoing or proposed recovery, rehabilitation, remediation, or improvement plans for species at risk
- Food sources and/or feeding areas for species at risk.

Reducing Interactions with Migratory Birds

Even if migratory birds are not present at the time an aquaculture facility is established, they may be attracted to a site if it provides a food source, safe breeding and loafing, or shelter. Design options and alterations that reduce the attractiveness of a facility to birds include:
- Eliminating safe roosting and perching places;
- Increasing the depth of the containment units below the surface of the water to reduce the attraction of surface-feeding birds such as gulls;
- Locating young/small stock which are more vulnerable to predation to an area where they are less accessible to predatory birds;
- Placing a good quality protective netting on the sides and tops of cages to protect fish stock from bird and mammalian predation. Top nets must be placed, installed and adjusted so that they do not sag under the weight of preying birds, enabling them to more easily reach the fish;

Management Options for Wildlife Interactions

Even when all feasible avoidance and design features have been incorporated, the concentration of potential food within a fish farm remains an obvious attraction to predators. This can result in a number of problems for the operator including:
- The direct loss of fish from consumption, injury, or stress;
- Damage to holding facilities by predators and a possible increase in fish escapes;
- Interference with feeding (predators consuming food or disturbing the feeding process).

The presence and activities of migratory birds in the vicinity of the operation should be regularly monitored. The species, approximate numbers, behavior, and time of year should be documented and proponents are encouraged to report information to the responsible agency and seek advice as appropriate. It is important that measures be implemented as soon as the presence of birds begins to interfere with the operation of the aquaculture site. Opportunities for improving feeding and husbandry practices that will reduce the attraction of birds to the site should be considered. Scare techniques should also be considered on a contingency basis.

Aquaculture Facility Design

Inherent in choosing a suitable location is ensuring the project fits site conditions. The environmental assessment should include a review of preliminary design details including the identity of the species to be cultured (provide common and scientific names) and the nature of the lease (e.g. new site, expansion or alteration, renewal). Mitigation measures that can be incorporated into the design should also be discussed such as those that will reduce interactions with migratory birds and species-at-risk and deal with extreme weather events.

Cage Structure and Material

The type, material, size and number of cages to be placed at a site should be indicated. Cage structures should both effectively protect fish from predation and prevent the escape of cultured species (including meeting any recognized Codes of Containment or other applicable standards established by law). Cages should also be designed to withstand climatic and sea state conditions.

Location and Placement of Cages in Water

Cages should be located where water circulation will allow adequate waste dispersion and maintain high levels of dissolved oxygen. It is important that there be adequate clearance between the cage and the water bottom. Waters with cages placed too close together are more likely to have low dissolved oxygen levels and reduced circulation. Along with referencing applicable siting criteria, the following suggestions for cage placement should be considered:

- Avoid shallow areas and areas with aquatic vegetation;
- Place units in an area where there is good current action. Current action facilitates water movement through the cage system that removes metabolites and replenishes oxygen. Current measurement data should be provided;
- Depending on the direction of prevailing winds and currents, orient the cages so as to prevent debris from collecting between them;
- Locate cages where disturbances from people and animals can be minimized.

Site Preparation and Construction

As discussed, along with the grow-out cages, a variety of facilities and infrastructure such as access roads, buildings and docks may be needed to support an aquaculture operation. Preparation for the construction of such facilities can involve clearing and grubbing of vegetation, excavation, dredging, infilling and grading. The following information should be provided in support of an environmental assessment:

- Time-frame and schedule for site preparation and construction activities;
- Areal extent of any disturbance both in-water and on-land;
- Methods, materials, and equipment to be used;
- Provisions for storage and handling of materials and response measures for spills or releases;
- Provisions for waste management.

Environmental Effects

Machinery, equipment, and personnel associated with construction activities represent sources of sensory disturbance (e.g. noise, light) to migratory birds and species-at-risk. Depending on the time of year, the result can be altered feeding patterns and disrupted breeding and staging activities. Certain species (e.g. cliff-nesting birds, colonial birds) are prone to panic and even temporary abandonment of nests by adult birds can cause an increase in predation of unguarded eggs and young. Species at risk are much more sensitive to disturbance and it is important that all activities

be carried out so that adverse effects on these plants and animals are avoided. In-water work such as dredging and installation of cages and on-land disturbance leading to erosion, can degrade water quality. Materials and wastes pose hazards to environmental quality, migratory birds and species at risk.

Building Best Practices into Project Management

Strategies for enabling compliance with applicable regulatory provisions protecting migratory birds and species-at-risk and for mitigating potential impacts should include:

- Maintaining a buffer zone where no activity occurs in proximity of important habitat;
- Scheduling site preparation and construction activity outside of the breeding season for migratory birds and species at risk;
- Avoiding concentrations of migratory birds when using boats and other machinery;
- Educating construction personnel on measures to be taken in avoiding the disturbance of migratory birds and species at risk.

Maintaining Water Quality

All activities associated with establishing an aquaculture operation should be carried out in a manner that ensures compliance with the general prohibition against the deposit of a deleterious substance into waters frequented by fish. This recommendation suggests that human activities should not cause suspended solids levels to increase by more than 10% of the natural conditions expected at the time. In addition, it is recommended that no solid debris including floating or drifting materials or settle able matter be introduced into marine and estuarine waters. An erosion and sedimentation prevention and control plan should be developed and implemented to facilitate mitigation of adverse impacts on water quality.

- Scheduling construction activities to take into account seasonal constraints and to avoid periods of heavy precipitation (e.g. consult extended range [3-5 days] forecasts);
- Installing sedimentation control structures prior to any land disturbance and monitoring captured water prior to release;
- Ensuring natural water and drainage flows are retained and maintaining vegetated buffer zones.

Management of Materials and Wastes

Construction activities may involve the use of hazardous substances such as petroleum products, fresh concrete, concrete additives, preservatives, paints, solvents, process chemicals, and cleaning agents. Hazardous wastes such as waste oil and residual chemicals may be generated as a result of using these products. A strategy for the management of materials and wastes should reflect consideration of the following best practices:

- Placing a priority on using nontoxic products;
- Storing materials, refueling and maintaining equipment and machinery in a designated area away from any water bodies/wetlands and in accordance with applicable regulations;
- Developing contingency plans to enable a quick and effective response to an event following the accidental spill or release of hazardous materials and substances. All spills and releases should be reported to the appropriate 24-hour emergency response line;
- Incorporating careful planning and purchasing to reduce the volume of surplus and waste material (e.g. order only the amount of material that is required, purchase pre-fabricated structures);
- Placing a priority on opportunities for reuse or recycling of products. Waste and surplus material should be disposed of at approved sites and in accordance with applicable provincial and municipal regulations.

Aquaculture operation maintenance

The day-to-day activities at an aquaculture operation should be guided by good operating practices that are focused on the maintenance and management of equipment and environmental controls. Following these practices can help to reduce stress in the cultured fish and possibly the requirements for chemical applications thus reducing potential impacts on aquatic systems. Among the practices that should be incorporated into the operation of a facility are:

- Monitoring water quality parameters including dissolved oxygen, pH and temperature and making operational adjustments as appropriate;
- Monitoring sediments beneath the cages and at predetermined locations away from the cages;
- Avoiding unnecessary disturbances of the fish by restricting activities around the cage site;
- Avoiding unnecessary or excessive handling of fish;
- Promptly removing diseased and dying fish.

As part of the ongoing operation and maintenance of off-shore aquaculture operations there are continual inputs of food, medications and other chemicals to the culture environment. Consequently, large volumes of unconsumed feed, residual chemical substances, and fecal and metabolic matter may be present in the water column and sediments directly below and adjacent to cages. In sufficient quantities, these materials will contribute to the degradation of ambient water quality by decreasing oxygen content and increasing the concentrations of suspended solids, ammonia and nitrogen compounds, organic matter and metals. Other periodic or intermittent operational and maintenance activities which could generate adverse environmental effects include harvesting, cleaning of equipment, and reapplication of preservatives. The assessment should include the identification of products to be used at the facility and a description of operational and maintenance procedures that incorporate best management practices and opportunities for pollution prevention and reduction.

Disease exchange and stock movement protocols

Many social and economic benefits as well as environmental affects have accrued from the importation of aquatic animal species for aquaculture. Therefore, requests for importation of fish, shrimp ad other species for an aquaculture project need to be given special attention in environmental assessments. The main concerns are introduction of diseases (which may impact aquaculture and wild fisheries) and impacts of introduced species on indigenous biodiversity resulting from escapes of aquaculture species. Following an appropriate quarantine strategy can minimize the risk of introducing new diseases. **Although, the Guidelines are being developed relating to these issues (FAO/NACA 1998), the Government of Croatia and responsible Ministries should as well develop and establish detailed responsible guidelines and regulations for existing and potential aquaculture species (e.g. Code of Practice)!** Guidelines on procedures for assessing the risk of ecological impacts, including those on biodiversity, are given in the ICES/EIFAC Code of Practice on the Introduction and Transfer of Marine Organisms (ICES/EIFAC, 2001).

Management of the Cultured Species

The assessment should include a brief description of proposed management and production regime of the cultured species during operation, including:

- The proposed stocking rate with reference to relevant guidelines;
- Initial weight, and anticipated harvest weight (in kg);
- Estimated mortality rate (percent per year).

Feeding

Developing and maintaining an efficient feeding regime requires an understanding of interactions and relationships between a number of variables including: fish size; feed type and formulation; feeding rates and methods; and, loading densities and water temperature. The selected feeding regime and quality feed type have very important implications for environmental impacts.

Environmental Impacts Related to Feeding

Two general types of waste are produced from feeding fish, as well as underneath aggregations of cultured bivalves (specifically mussels):

- Solid material, suspended solids, which may include faeces, pseudo faeces, uneaten feed, organic matter, and nitrogen-phosphorous containing compounds.
- Soluble material including dissolved nitrogen and phosphorous that originates from fish metabolism and the breakdown of wastes (solid material). In their soluble form these nutrients are difficult to remove from water. Nitrogen tends to be quickly transported out of the system in soluble form, while phosphorous is more readily incorporated into the sediments and slowly released in soluble form. One of the problematic nitrogen based compounds is ammonia, which is excreted into the water as waste. Excessive ammonia levels may harm aquatic life by altering metabolism or increasing body pH.

Dispersion of wastes in the water column depends on several factors including the current regime, tidal action, depth, and the sinking velocity of solid particles. Abundant or extensive waste accumulation can have adverse effects on the surrounding aquatic environment and should be addressed in the assessment. The build-up of solid food waste on the ocean floor increases the activity of aerobic bacteria, which, if prolonged, could lead to deoxygenating of the sediment. This may lead to the growth of anaerobic bacteria, which can produce noxious gases potentially impacting both the cultured fish and aquatic life in the surrounding environment. Therefore, the environmental impact assessment should demonstrate an ongoing commitment by the proponent to selecting feed formulations that can have the least environmental impact. For example, fish feeds that are nutrient-dense and high in energy have improved feed conversion efficiencies (the amount of feed required to produce one pound of cultured animal), which results in less waste.

Environmental impact assessment should consider:

- Utilizing feeds with low nitrogen and phosphorous content, which achieves a higher feed conversion efficiency ratio and a reduction in excreted waste. Feed that is high in lipids (fats) relative to proteins can reduce nitrogen excretion;
- Supporting and where possible participating in research directed toward reducing the percentage of fishmeal in cultured fish. This can help relieve the pressure on wild fisheries, which comprise a large proportion of fishmeal and can also reduce the phosphorus content. Substitutes that might be considered include soybean meal, corn gluten meal and blood meal;
- Utilizing feeds with a low percentage of fines (inedible pieces of feed) and free of low digestibility binders and fillers; and
- Ensuring proper storage to maintain the nutritional quality and palatability of feed.

Fish feed is available in a variety of types with either wet or dry, and floating or sinking pellets being the most common. Characteristics considered in feed selection include pellet formation, size, digestibility and palatability. Selection of the type of feed, in terms of physical attributes, can also greatly influence the amount of waste produced at a facility and the resulting environmental impacts. The following should be considered in the selection of feed types:

- Floating (extruded) feeds allow the operator to visually monitor fish as they come to the surface to feed. With sinking feeds, it is more difficult to determine what proportion of the fish are feeding;
- Floating and dry pellets have greater stability, which enables the pellet to remain intact longer;
- Selecting the appropriate pellet size for the age and size of fish will help reduce feed wastage.

Feeding Regime and Techniques

The amount of and rate at which feed is given to a batch of fish, and the manner in which it is given can help to maximize efficiencies and reduce waste production. As with feed particle size, there are a number of variables that will influence feeding regimes. Given the seasonal variability of many parameters, the quantity and timing of feeding may change frequently. The following factors should be considered in optimizing feeding regimes and techniques as well as to reduce potential environmental impacts:

- Adherence to manufacturer's guidelines and feed charts for recommended feeding rates;
- Evaluation of different feeder types and feeding techniques;
  - Hand feeding allows the operator to better monitor the behavior of fish and more quickly detect health problems and stress factors;
  - Automated feeders are less expensive for larger operations and can be set to dispense feed more evenly over the entire water surface;
  - Demand feeders help to ensure fish eat when they are hungry and can reduce feed wastage;
- Avoiding the use of mechanical feeders that produce fines, or considering the use of on-site re-pelleting technologies (sieving the pellets through a vibrating screen and then re-pelleting the collected dust and particles);
- Feeding smaller amounts more often to prevent overfeeding;
- Using technologies such as video surveillance or hydroacoustics that can detect when feed has reached the bottom.

Chemicals in Aquaculture

In general, chemicals should not be used in sustainable aquaculture practices! However, a variety of chemical substances are used during the operation of an aquaculture farm. The purposes for chemical use include water treatment, feed formulation, manipulation and enhancement of reproduction, growth promotion, health management, and promoting added value to the final product. Efforts in chemical management should first be directed toward reducing overall chemical use through preventative medicine techniques combined with good husbandry and operating practices. To reduce the environmental impacts of chemical use, procedures should be in place to ensure their safe and effective application. This includes developing health management plans, educating site personnel on product knowledge and health and safety procedures, as well as the appropriate selection, handling and application of chemical substances.

Medicinals, also called chemotherapeutics, therapeutants, or pharmaceuticals, includes:

- Antibiotics - used to treat infections caused by a variety of bacterial and fungal diseases. Commonly administered by mixing with feed or applying topically in a bath;
- Vaccines - usually administered by injection to produce or increase immunity to particular diseases;
- Anesthetics - used to sedate or immobilize during handling or transportation;

Additives

- Water treatment and conditioners - include flocculants and conditioners to reduce turbidity. Lime may be used to control pH of the water and zeolites may be used to remove ammonia;
- Vitamins - vitamins C and E are often added to fish feed;

- Hormones - added to fish feeds to control sex, growth rates and ovulation;
- Colorants - dyestuffs and organic pigments added to feed to produce artificial coloration in the tissue and flesh.

Disinfectants are chemicals used primarily for cleaning growing structures and other equipment. The most common disinfectants used are chlorine and chlorine compounds and formaldehyde and iodine derivatives. Other preservatives and other chemicals associated with structural materials such as plastics, treated woods, and some metal compounds. Pesticides, PCB's and other chlorinated substances like dioxin can hurt the ability of fish to reproduce, affect hormones, decrease the chances of survival for the offspring and cause skeletal deformities and devastating defects in heart development.

Environmental Effects of Chemicals

Whenever chemicals are used or applied, residual amounts of the substance may enter the aquatic environment. Chemical releases to the environment through routine inputs of feed and faeces containing various additives are likely to occur continuously at low concentrations. An understanding of the persistence of chemicals in the aquatic environment, potential toxicity to non-target species, and inhibition of microbial activity in the aquatic environment are key to assessing potential impacts.

Direct and indirect exposure of contaminants to other fish, wildlife, and plant-life may result when chemicals are improperly stored, handled, or applied. For example, birds may eat feed mixed with chemicals, and fish can absorb pesticide particles through their gills. Exposure to contaminants may also occur via the release of waters containing chemicals. Non-target species can become sick, exhibit growth or reproductive problems, or die as a result of chemical exposure. For example, it is known that pesticides used to kill some parasites are also lethal to many other invertebrate species, and may have acute and sub-lethal effects on phytoplankton, macroalgae, zooplankton, accumulate in fish tissue and interfere with physiological processes. Certain chemicals have the tendency to bioaccumulate, or build-up, in the tissues of species. High concentrations of contaminants in a species can sometimes lead to toxic effects on growth, reproduction and survival. As well, certain bioaccumulative contaminants can also biomagnify or increase tissue concentrations in higher trophic level species such as predatory fish, birds, mammals and humans.

The microbial communities of aquatic sediments degrade organic matter and recycle associated nutrients. Rates of oxygen consumption, ammonium and sulphide production in sediments are all highly dependent upon microbial activity. Accumulation of antibacterial residues in sediments has the potential to inhibit microbial activity and to reduce the rate of organic matter degradation.

Preventative Medicine Practices

Implementing preventative medicine practices is important to maintaining healthy fish stocks. Along with optimizing nutritional requirements, feeding strategies, and hygiene conditions, preventative medicine practices aimed at reducing chemical use and associated environmental impacts include:

- Stocking certified fish that are free of pathogens and parasites
- Minimizing the risk of introduction and spread of infectious disease agents, through adherence to standard fish introduction and transfer policies and protocol
- Maintaining optimal stocking densities. This will be species specific and should also be reflective of ambient environmental conditions such as water current velocity and consequent oxygen levels and exchange rates

- Separating year classes at the facility. The practice of stocking only one generation of fish at the site at one time can reduce the risk and spread of disease and parasites from parents to progeny
- Avoiding the overuse of antibiotic drugs to prevent rather than to treat a disease. The potential for development of antibacterial resistance can reduce the long-term efficacy of a drug
- Implementing a vaccination program. Vaccinations are routinely used as a tool for disease prevention and to promote good health in aquaculture species. Any vaccination program must be administered under the advice and direction of a licensed veterinarian
- Regularly monitoring fish growth and behavior and adjusting feeding strategies and stocking rates accordingly.

Waste Management and Disposal

In addition to the sludge, which accumulates beneath cage sites, there are other types of solid and liquid waste that require additional considerations for containment and disposal. In particular, mortalities, bloodwater and offal generated during harvesting and processing must be dealt with in accordance with a variety of municipal, provincial and federal requirements. Nonhazardous solid waste will also be generated as part of the operations of an aquaculture site. Some of the management options, which should be considered in the assessment, include:

- Prompt collection of mortalities and disposal at an approved site. Composting should be considered where facilities are available. Disposal sites and methods that will minimize the attraction of scavenging birds and wildlife should be selected;
- If harvesting takes place on-site, containment and disposal of bloodwater and offal should be in accordance with appropriate regulations (e.g. fish processing plant, approved wastewater treatment facility, approved landfill site);
- Purchase feed and supplies in bulk and consider opportunities for recycling and reuse;
- Securely store solid waste and dispose regularly at an approved location.

Fish escapes, alien species and GMOs

Aquaculture operations, particularly those in open waters, are always susceptible to some stock loss as a result of storm damage and predators. Losses can also occur during grading and harvesting activities. Relevant laws and policies should strictly regulate introduction of alien species, as well as use and introduction of GMOs and transgenics! The issues associated with fish escapes include:

- Competition for habitat and resources;
- Alteration of the genetic characteristics and, potentially, the genetic diversity of wild stocks;
- Establishment of self-sustaining populations by introduced species;
- Introduction of new species may also lead to introduction of diseases.

The following preventative steps should be addressed:

- Identifying indigenous species and especially the population status of any species at risk;
- Design infrastructure to withstand extreme climate and sea state conditions;
- Incorporating additional preventative measures for higher risk activities such as fish transfer, grading and harvesting;
- Developing and formalizing inventory control systems and regular maintenance and inspection programs for equipment;
- Developing a recovery plan for escape events, which includes notification procedures.

Transgenic or genetically modified fish are produced by artificial transfer (microinjection) of rearranged genes into newly fertilized eggs (Arai, 2001). This method has produced transgenic fish with enhanced growth rates in common carp, northern pike, Atlantic salmon, coho salmon, rainbow

trout and cutthroat trout (Delvin, 1998; Delvin et al, 1994; Hew and Fletcher, 2001). It is a short cut to achieving genetic change for fast growth, disease resistance that cosigns rapid genetic improvement of aquaculture stocks. Despite all the benefits for aquaculture, GMO technology involves ethical, religious, cultural, social and most importantly environmental risks. Should we alter our natural food that evolved over millions of years? Farmed fish tend to escape from fish farms into oceans and compete in the wild and ecological relationship is unknown. These effects could be uncontrollable, permanent, and irreversible, therefore proper risk management practices and policies need to be applied on national and international levels. Major concern is the escape or release of genetically managed aquaculture stocks and their genetic and ecological impacts on the wild populations and habitats. Another concern is the food safety of the public, causing all types of national and international policies and regulations in order to control GMO production.

Impact prediction and follow-up

Impacts on the environment can be avoided or at least minimized if provisions are made to incorporate the applicable best management practices into the siting, design, and operation of an aquaculture facility. However, even with implementation of best management practices, aquaculture facilities will likely result in adverse environmental impacts and these should be predicted for key environmental resources of concern. The information needed to predict impacts on these resources of concern should be identified if they are already not!!

In general, impact predictions:

- Should be presented as differences between the condition of a suitable environment without the project, and the condition of a suitable ecosystem/environment with the project, over a timeframe that takes into account the life span of the proposed facility;
- Must take into account **cumulative effects**. This requires consideration of how other past, present, and reasonably foreseeable projects and activities could combine with the impacts of the proposed aquaculture project;
- Should be expressed quantitatively where practicable with uncertainties clearly recognized.

Mitigation measures that build on the best practices already integrated into provisions for project management should be identified and implemented to alleviate the predicted impacts. With attention to these recommended guidelines, however, the potential for impacts to be significant should be minimized and the need for mitigation should be reduced.

A follow-up program should be designed to verify impact predictions, to establish the effectiveness of the mitigation measures implemented and to enable timely adjustments to management of the project. In light of the uncertainties in predicting impacts and in the effectiveness of mitigation, alternate management approaches and contingencies should be reviewed and prepared. In managing a project that is allowed to proceed, impact predictions should be adjusted to reflect changes to the project (e.g. adding more cages) and changes in the environment (e.g. warmer water temperatures) that can lead to 'different' environmental effects. Repetitive and systematic monitoring of variables indicative of actual effects is important to follow-up.

Water quality monitoring at marine sites should provide a representative sampling of the water body in terms of depth, circulation patterns and seasonal variation. A number of variables have been broadly recognized as being the most appropriate to evaluate the water quality. These include: temperature, suspended solids, dissolved oxygen, biochemical and chemical oxygen demand, total nitrogen and phosphorous, and ammonia.

Sediments should be tested (using a benthic grab) beneath the cage site and at predetermined locations away from the cages to determine the spatial impact of the operation and to verify predicted dispersion characteristics of the site. Sediment sampling and evaluation should be designed to meet the requirements of appropriate permitting and licensing conditions and should include grain size analysis, total organic carbon, ammonia, sulphides, redox potential (Eh), pesticides, and trace and heavy metal contaminants such as cadmium, lead, mercury and copper.

Comprehensive environmental performance assessment

An environmental impact assessment, and management plan coupled with an appropriate monitoring programme, and possibly environmental audit, may form the basis for comprehensive environmental performance assessment, and possibly associated certification and/or product labeling (very important for marketing of Croatian products!). Although this may be an ambitious target for aquaculture enterprises, some forms of coastal aquaculture (e.g. shrimp farming and marine finfish), are supported by high value international markets with significant quality and environmental awareness (EC, 2002). An annual cycle of reporting and review is usually necessary to meet regulatory requirements or quality standards. Examples of existing standards include environmental management systems ISO 14000 series and BS 7750, and quality assurance ISO 9000 series. These or other standards may be linked to labeling initiatives resulting in a price premium. If this premium can be passed down to the producer, there will be a strong incentive for compliance and willingness to accept inspections. This approach has the enormous advantage that the market may ultimately bear the bulk of the cost. There has been a worldwide interest in developing such standards, and linking them to a variety of environmental management initiatives related to coastal aquaculture, including infrastructure (high quality water supply and waste water treatment) and codes of practice. Aquaculture operations may be certified as producing culture species based on recognized organic standards. International Federation of Organic Agriculture Movements (IFOAM) Basic Standards provides organic production standards for agriculture and aquaculture worldwide as a framework for development of certified criteria. IFOAM includes criteria for: rearing of fish and servicing of cages; water quality; feeding; health; fish re-stocking, breeding and origin; propagation of fish stocks and breeding; and transport, killing and processing (IFOAM, 2003).

Environmental certification is followed by eco-labeling of the product and often requires the implementation of a documented Environmental Management System (EMS). ISO's 14001 EMS has been used by many organizations as a basis for environmental certification. One such organization is the European Eco-Management and Audit Scheme (EMAS). EMAS is a management tool for companies to evaluate, report and improve their environmental performance. Participation is voluntary and considers private and public organizations in the EU (EMAS, 2003).

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Table 1. Example of Shellfish Aquaculture Protocol (based on Spencer, 2002)

Suitability Indicators	General	Oysters	Mussels	Hard clams
pH	6.0-8.5	6.75-8.75	7.0-8.5	6.75-8.75
Temp. (°C)	18-28	Opt. 15-25		Opt. 21-31
Salinity (%?)	20-35	25-35	20-35	Opt. 18-20
Suspended sediments (mg/l)	<10	10 - 20		
Dissolved oxygen (ppm)	>5			>3.64
Chlorophyll (ug/l)	2-8		4-8	
Bathymetry (m)	>1			>2
Bottom/habitat type		Solid, firm substrate	Solid substrate	Softer sediment sand, mud
Exposure/ water movements (cm/s)	Sheltered areas with tidal flow 1-2 knots (50-100 cm/s)	50-100	20-50	
Facilities and Areas of activity		Mainly subaqueous fixed structures, longline, rafts	Rafts, longline	
Accessibility (nearest boat ramp, roads)	500-5000 meters			
Other physical attributes in land (land use/land cover)	Prefer riparian areas, and wetlands; Exclude residential areas; Exclude SAV and protected areas			
Regulatory Factors				
Species type	native			
Fecal coliforms Cfu/100 ml	14			
Nitrate mg/l	0.8			
Phosphate mg/l	0.08			
Dissolved oxygen (ppm)	> 5			
Turbidity NTU	< 25			
Heavy metals (mg/kg flesh)	Mercury 0.5 Cadmium 2 Lead 2			
Buffer zone around facilities	??			

Table 2. Example of finfish Aquaculture Protocol (based on PAP/RAC, 1996; Frankic, 1998; Katacic and Dadic, 2000)

Suitability indicators	**GOOD**	**MEDIUM**	**POOR**
BATHYMETRY (m)	= 50	30 - 50	< 30
TOPOGRAPHY (SLOPE)	≤ 30	30 - 45	> 45
WATER QUALITY (fecal coliforms MPN/100ml)	≤ 14	14 - 88	> 88
SUBSTRATE	SAND or GRAVEL	MIXED ROCK	MUD
SUBMARINE SPRING	EXISTING	EXISTING	NOT EXISTING
EXPOSURE	PARTIALLY EXPOSED	SHELTERED	EXPOSED
PHYSICAL ACCESS	WITHIN IDIENTIFIED BUFFER ZONE		
WATER TEMP. (ºC) MAX. MIN.	 20 – 24 12	 24 – 27 10	 > 27 < 6
OXYGEN (%)	100	70 - 100	< 70
SALINITY (ppt) ‰	28 - 35	15 - 28	< 15
Dissolved oxygen (ppm)	> 5		
Chlorophyll (ug/l) ??	2-8		
Suspended sediments (mg/l)	< 10		
Heavy metals			
TROPHIC STATUS	OLIGOTROPHIC	MESOTROPHIC	EUTROPHIC
EROSION	LOW	MODERATE	HIGH
WATER DYNAMICS (CURRENTS) (m/s)	0.2 – 1.0	1 – 1.5	> 2
WAVES (m)	1	1 – 3	> 3
SPECIES SELECTION	NATIVE		
SPECIES TROPHIC ZONE SELECTION	POLYCULTURE	MONOCULTURE	MONOCULTURE
Buffer areas between facilities	Present but how big?		

Table 3. Example of management issues, options and outcomes in aquaculture suitability siting.

Aquaculture Suitability Siting			
Adjacent Coastal activity/use	**Management issues**	**Management options**	**Outcomes**
<u>Terrestrial:</u> Residential Agriculture commodity (e.g. crops, livestock; organic farms)	Water quality (NPS urban runoff, storm water runoff, wastewater runoff) Socio-economic issues – aesthetics, vision, smell, etc.	Zoning, and buffers: 1) exclusive use zones 2) zoning with multiple uses	Suitable if buffers exists; Socio-economic cost benefit analysis (advantages and disadvantages of management options)
	Water quality (agricultural runoff, pesticides, nutrients, erosion, sedimentation)	Type of Buffers and their area? (Riparian, wetlands)	
Industry	Wastewater discharge, Sediment contamination	Zoning, buffers Designating priority uses	Environmental and socio-economic assessments
Marina	Water quality * (wastewater discharges)	200 m buffer? zoning for marina sites clean marina initiative	Suitable outside buffer but depending on water quality
Navigation (potential conflict everywhere)	Water quality	Buffer?	??
Piers	Recreational fishing and boating; Water quality	Buffer area (?)	Suitable outside buffer area
Beaches(public); and bare areas as potential	Water quality (pathogen contamination)	2 m in shore buffer; offshore buffer (?); with public facilities	Suitable or optimal with adequate facilities and water quality;
Recreation (hunting, rec. fishing, boating, jet skiing) Wild harvest (e.g. crabbing)	In vicinity of residential areas; water quality issue; Physical/spatial issue	Designating priority use	If aquaculture than nothing else?!
Protected areas, Sanctuaries, MPAs	Habitat restoration/protection: Clams (brood stock area) Oyster reefs Blue crabs, SAV	Buffers/zoning	Vicinity is a plus/optimal outside buffer areas

* bivalves as bio-indicators for water quality, and potential 'nutrient sink'; also consider clean marina initiative;

Table 4. Marina site suitability indicators (based on Virginia Marine Resource Commission, http://ccrm.vims.edu/marinasiting.htm)

Suitability Indicators	Desirable	Undesirable
Water quality	Closed for direct marketing of shellfish; no potential for future productivity	Approved, seasonally approved for shellfish harvesting
Fecal coliforms Cfu/100 ml	200	> 200
Salinity (%?)	Unsuitable for shellfish growth	Suitable for shellfish growth
Nitrate mg/l	1	
Phosphate mg/l	0.1	
Suspended solids/ sediments (mg/l)	10	
Mex. Wave height (m)	< 0.5	> 0.5
Dissolved oxygen (mg/l)	> 5	< 2
Current/exposure	< 1 knot	> 1 knot
Bathymetry (m)	> 1	< 1
Proximity to natural or improved channels	< 50 feet to navigational channel	> 50 feet
Threatened or endangered species and habitats	Absent	Present
Designated shellfish grounds	No present or planned private lease or public ground within affected area	Private lease or public oyster ground in proximity
Dredging	Does not require dredging	Requires frequent dredging
Adjacent wetlands	Suitable buffer could be maintained around marine site	Cannot maintain suitable buffer area
Existing use of site	Not presently used for recreational, tourism uses, fishing, crabbing, etc.	Presently used for recreational activities and fishing, crabbing
SAV	Absent	Present
Shoreline erosion	Shoreline protected by natural or planted riparian vegetation	No shoreline stabilization
Finfish habitat	Unimportant area for spawning or nursery for any commercial or recreational species	Important spawning and nursery area

Table 5. Tourism site suitability indicators (based on Frankic, 1998)

Environmentally Suitable Indicators	**Excellent**	**Good**	**Poor**
Beach area capacity (m^2/person)	8 -10	6 - 8	< 6
Sea Temp. (°C) for swimming	> 25		
Water supply (l/day/person)	200 – 250	100 - 200	< 100
Dissolved oxygen (mg/l)	> 5		
Water quality (E.coli) Drinking Swimming (*)	0< 100	40 - 50 100 - 200	> 50 (MPN/100 ml) > 200 (MPN/100ml)
Suspended solids/ sediments (mg/l)	> 5		
Bottom type	Sand, small gravel		mud
Current/exposure	Sheltered bays		
Bathymetry (m)	0-5		
Shoreline slope (%) topography	2-5		
Beach area access (buffer zone 2000m)	Within buffer zone		
Energy supply	Sufficient, solar and alternative resources present		
Sewage systems (Waste water treatment)	Present		
Protected areas, Nature Reserves, MPAs	Present		
Cultural Heritage Preservation	Present		
Food Supply, local mariculture, autochthon products	Sufficient and present on site		
Sustainable Infrastructure & landscape Design	Present		

Figure 1-2. Environmental assessment includes data from satellite images.

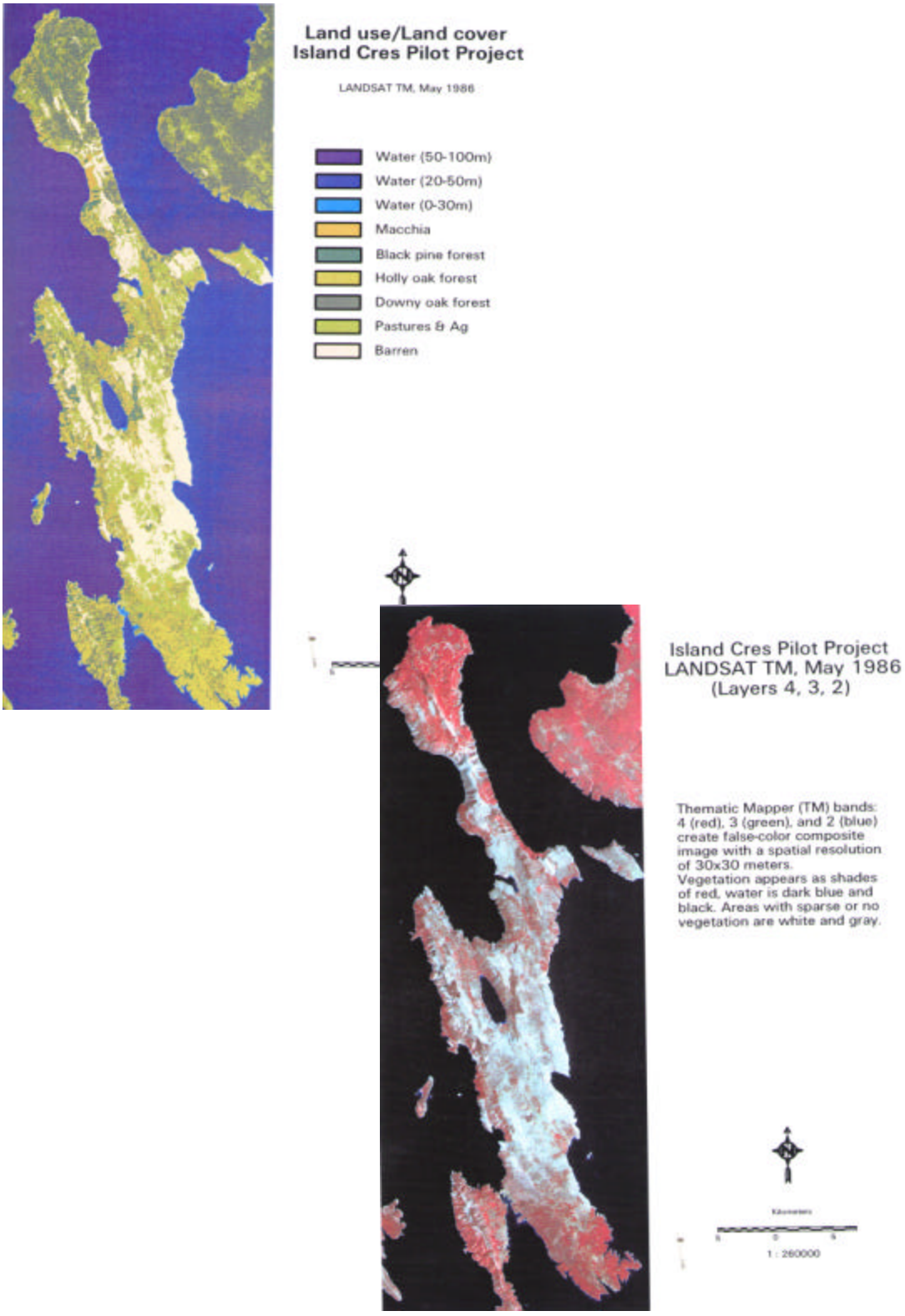


Figure 3-4. GIS mapping assessed existing environmental data. (Source: A. Frankic, 1998)

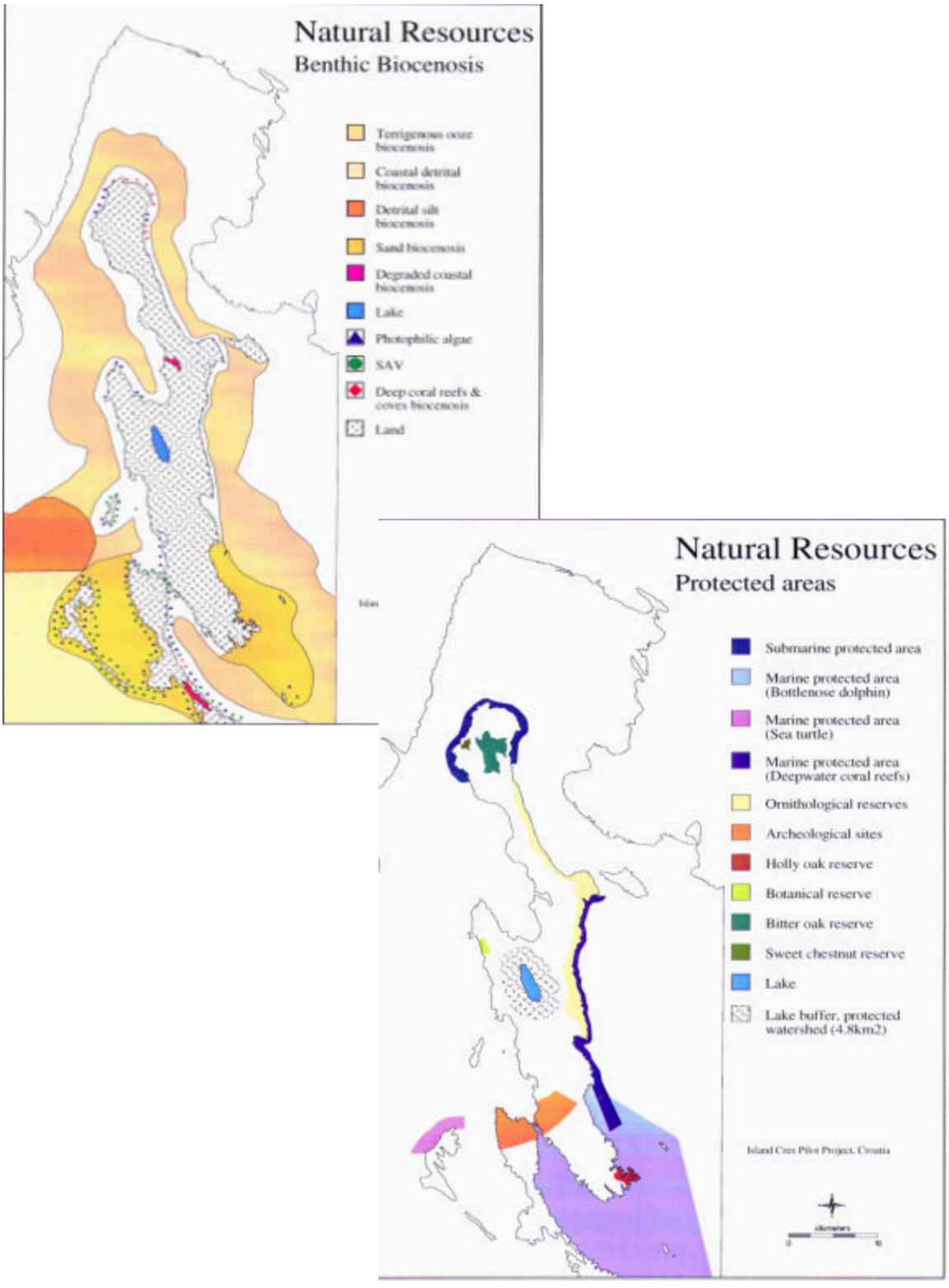


Figure 5-6. GIS mapping of assessed existing environmental data. (Source: A. Frankic, 1998)

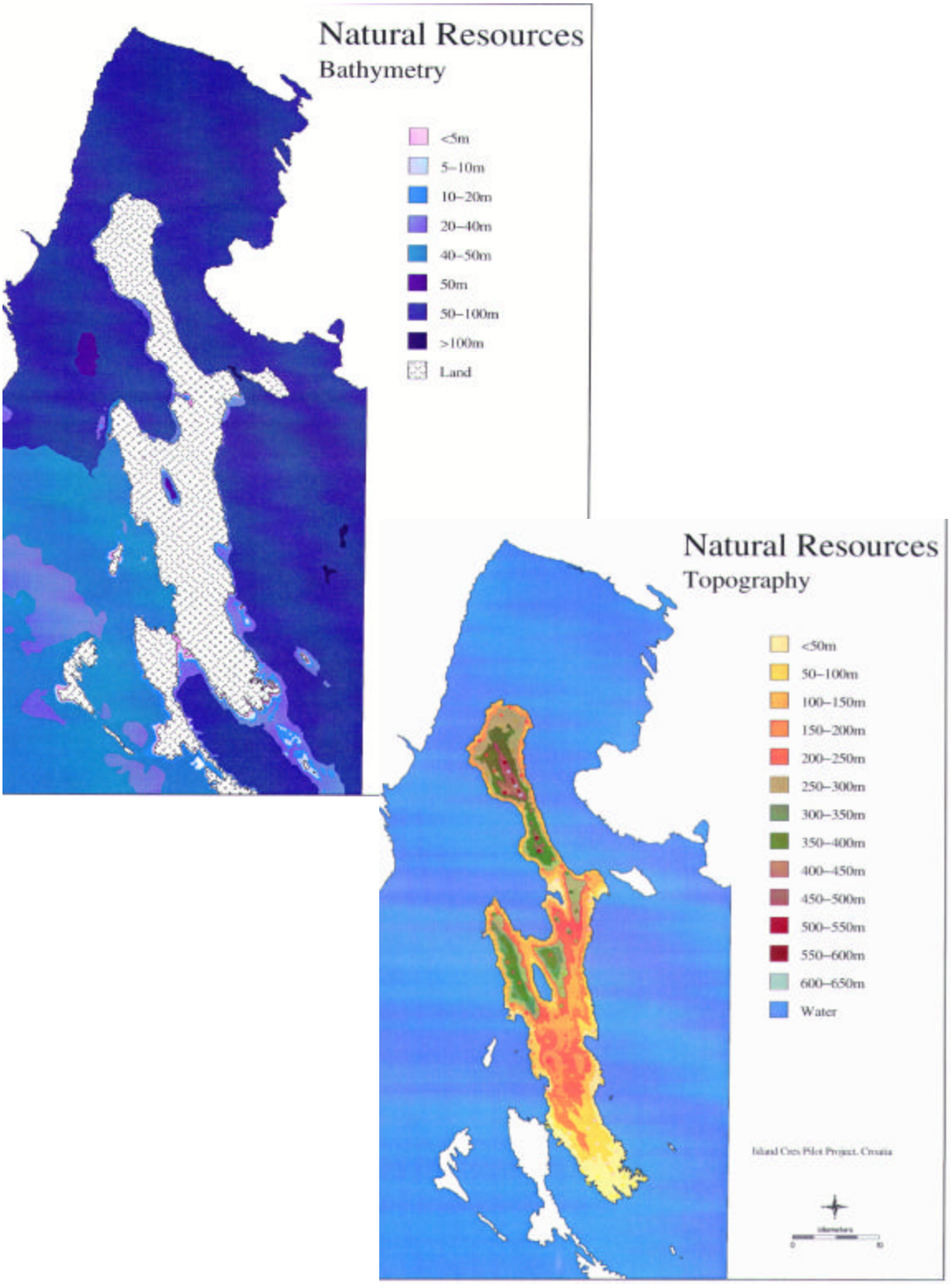


Figure 7-8. GIS mapping of existing and planned activities and uses. (Source: A. Frankic, 1998)

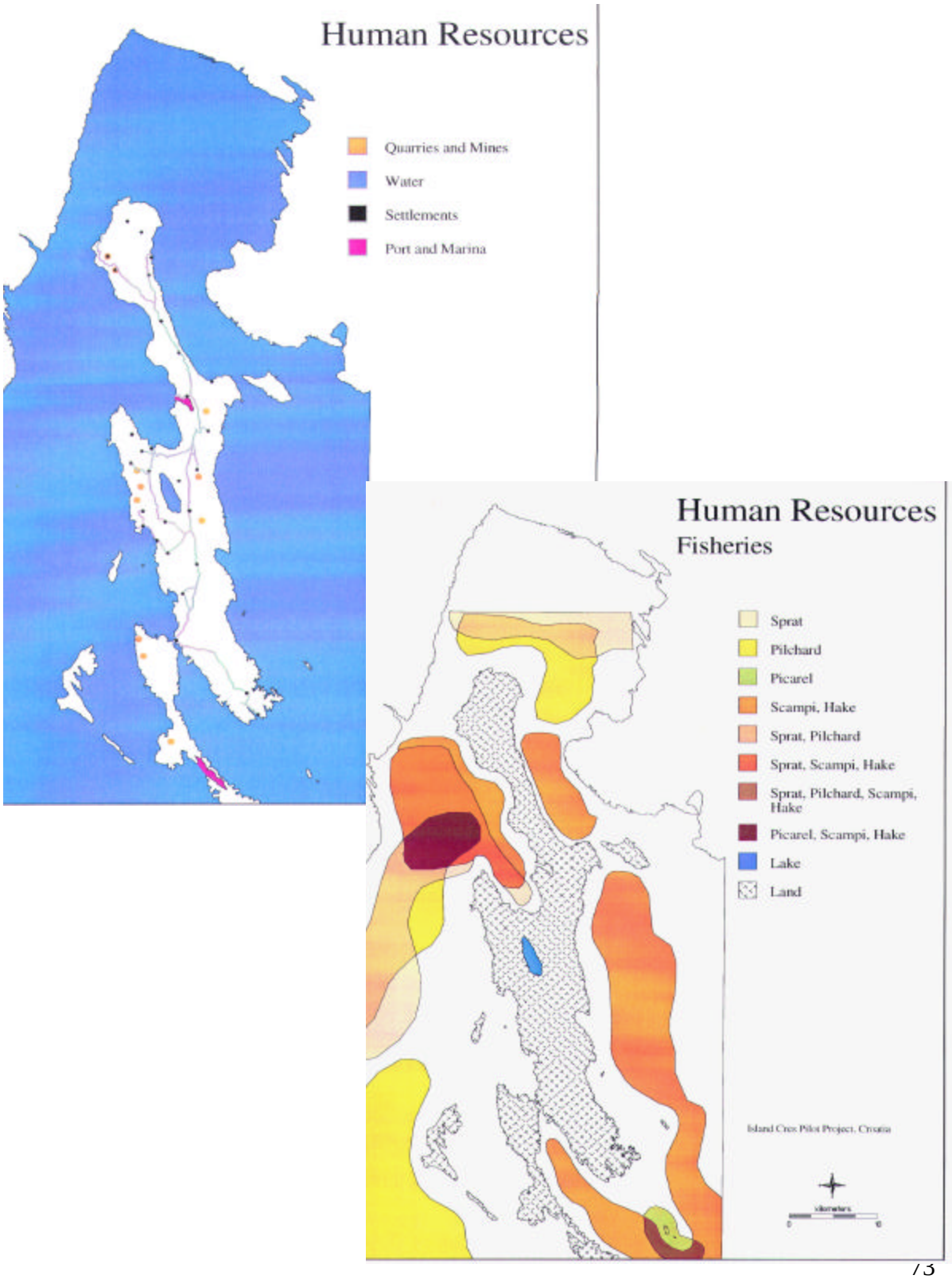


Figure 9. Example of IGIS site suitability analysis and modelling - small local area. (Source: A. Frankic, 1998)

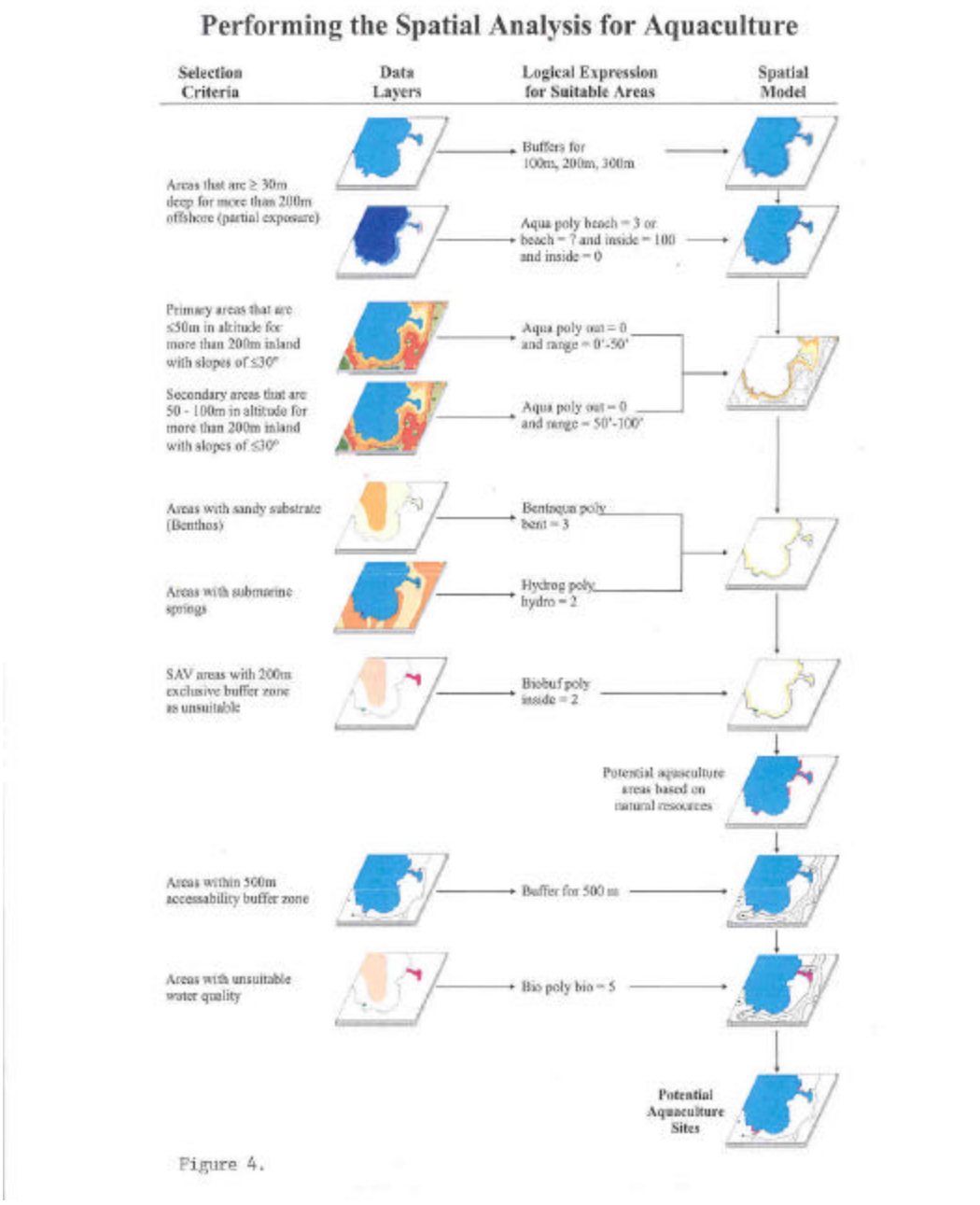


Figure 10-11. Examples of IGIS use conflict analysis and modelling, resulting in identified suitable sites for aquaculture (red points).

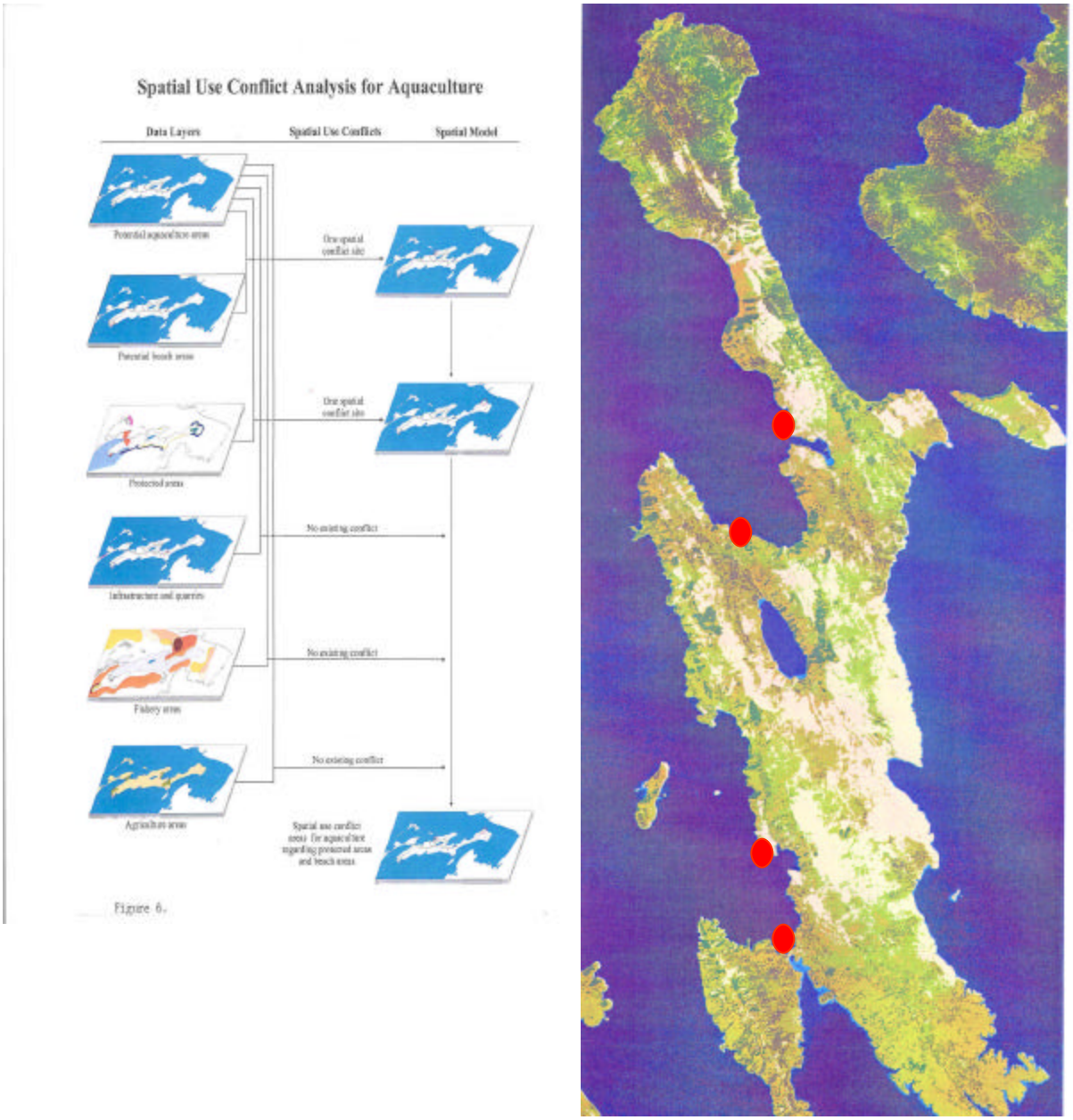
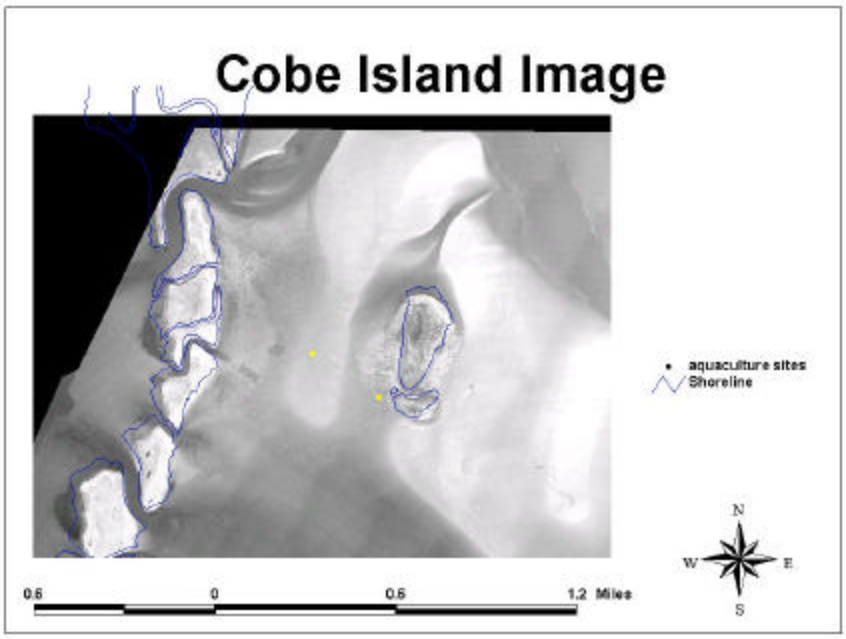


Figure 12. Example of hard clam aquaculture activities in Chesapeake Bay (Source: VIMS/CCRM)

Figure 13. Aerial photo of hard clam aquaculture sites and GIS analysis is showing that sites are in optimal site suitability area for aquaculture. (Source: VIMS/CCRM, A. Frankic)



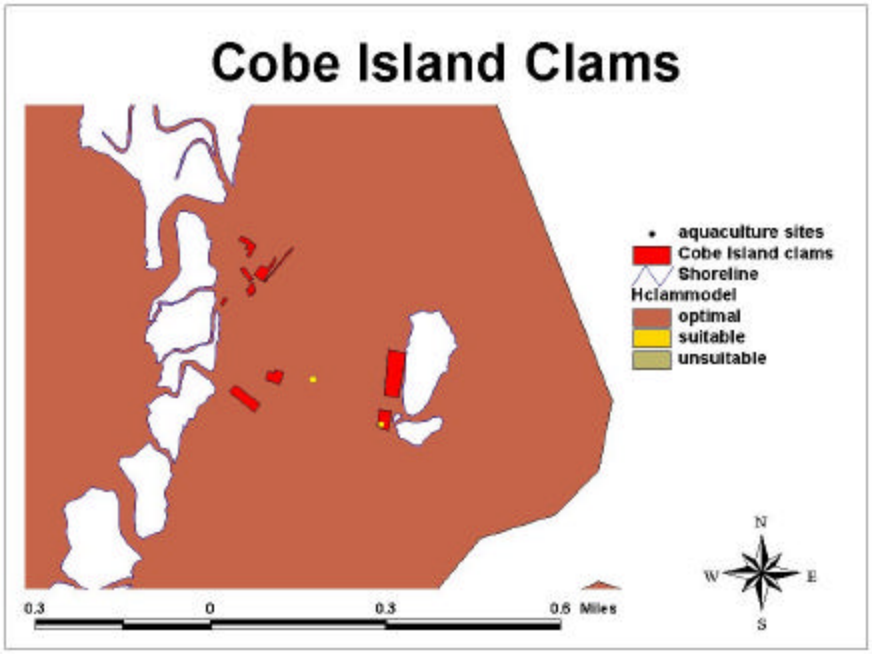
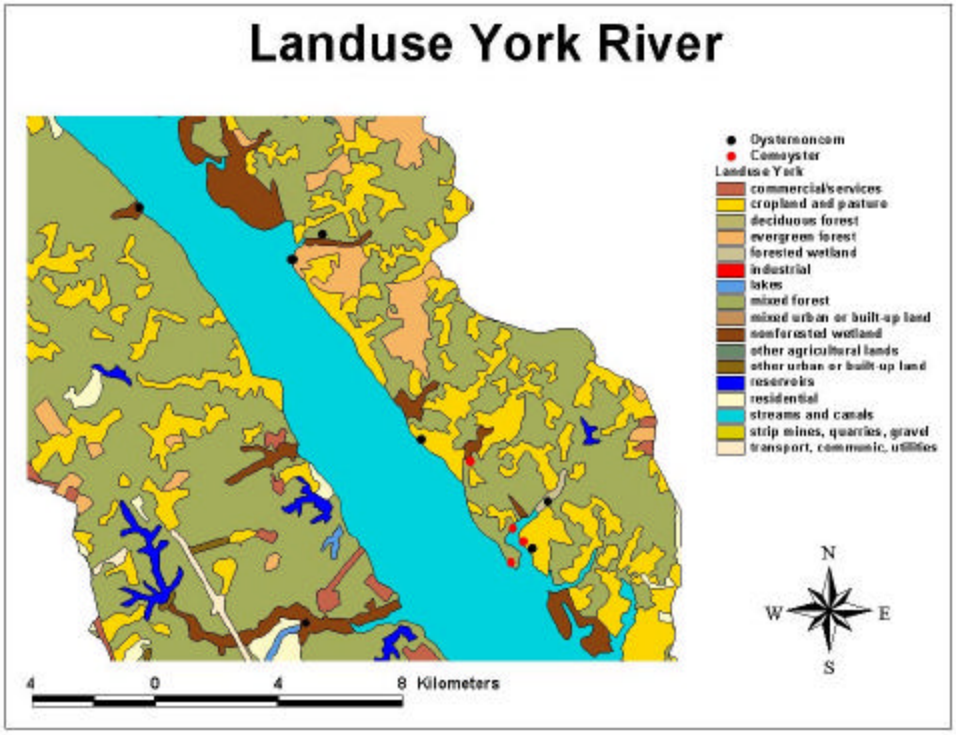


Figure 14-15. Example of identified land use for aquaculture site suitability analysis (Ch. Bay, Virginia) (Source: VIMS/CCRM, A. Frankic)



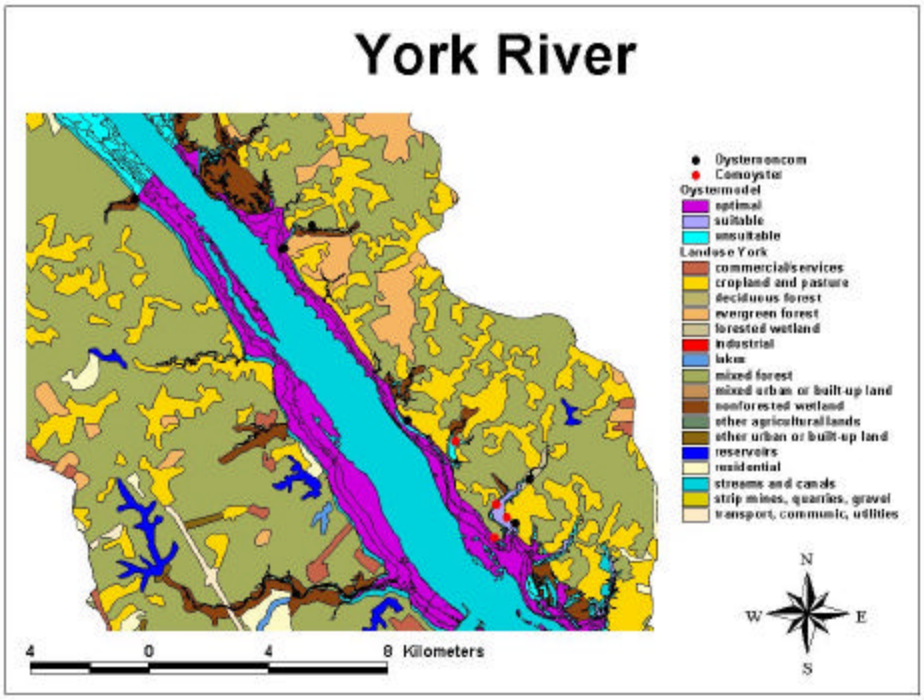
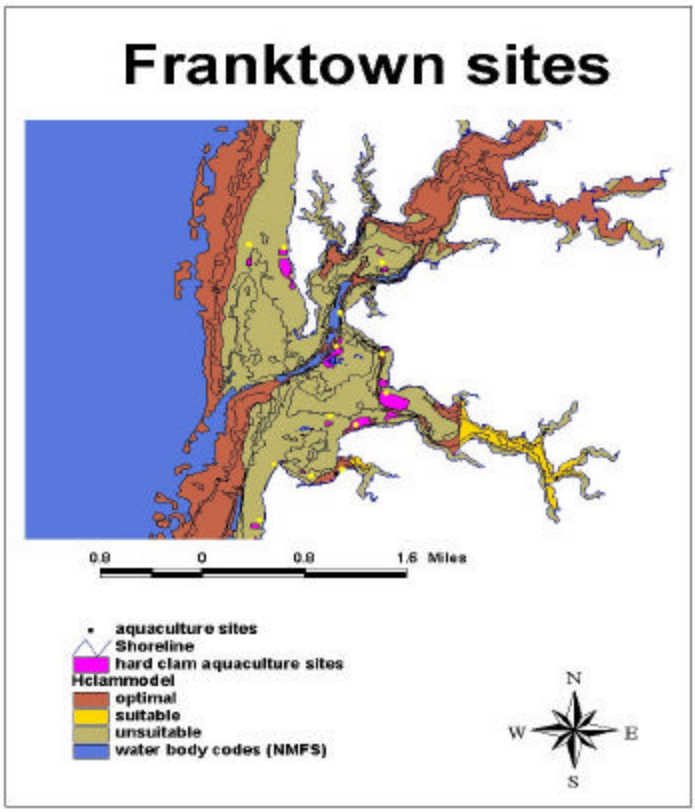


Figure 16-17. Site suitability analysis for existing aquaculture activities for hard clams and oysters in Chesapeake Bay, Virginia; (Source: VIMS/CCRM, A. Frankic)



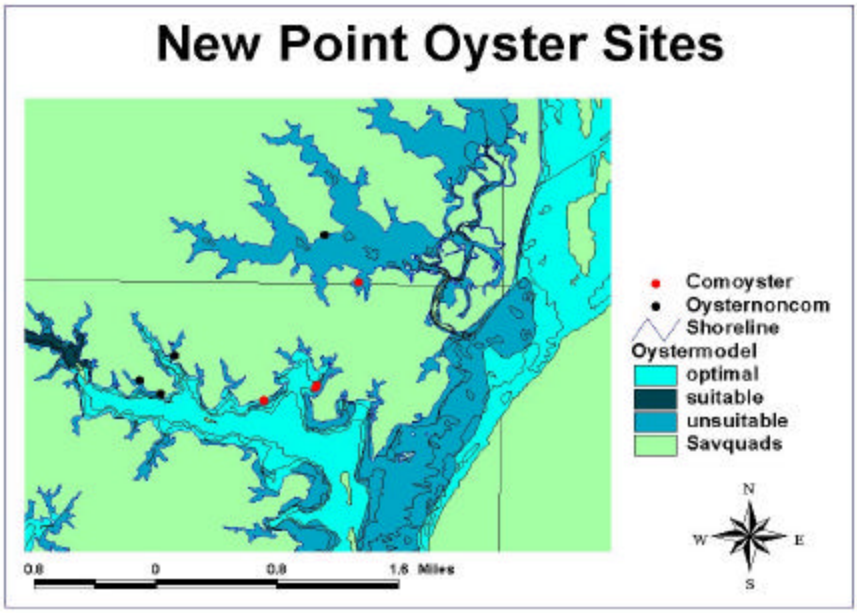


Figure 18. Existing aquaculture sites in Virginia (include mainly oysters, h. clams and soft clams) (Source: VIMS/CCRM, A. Frankic)

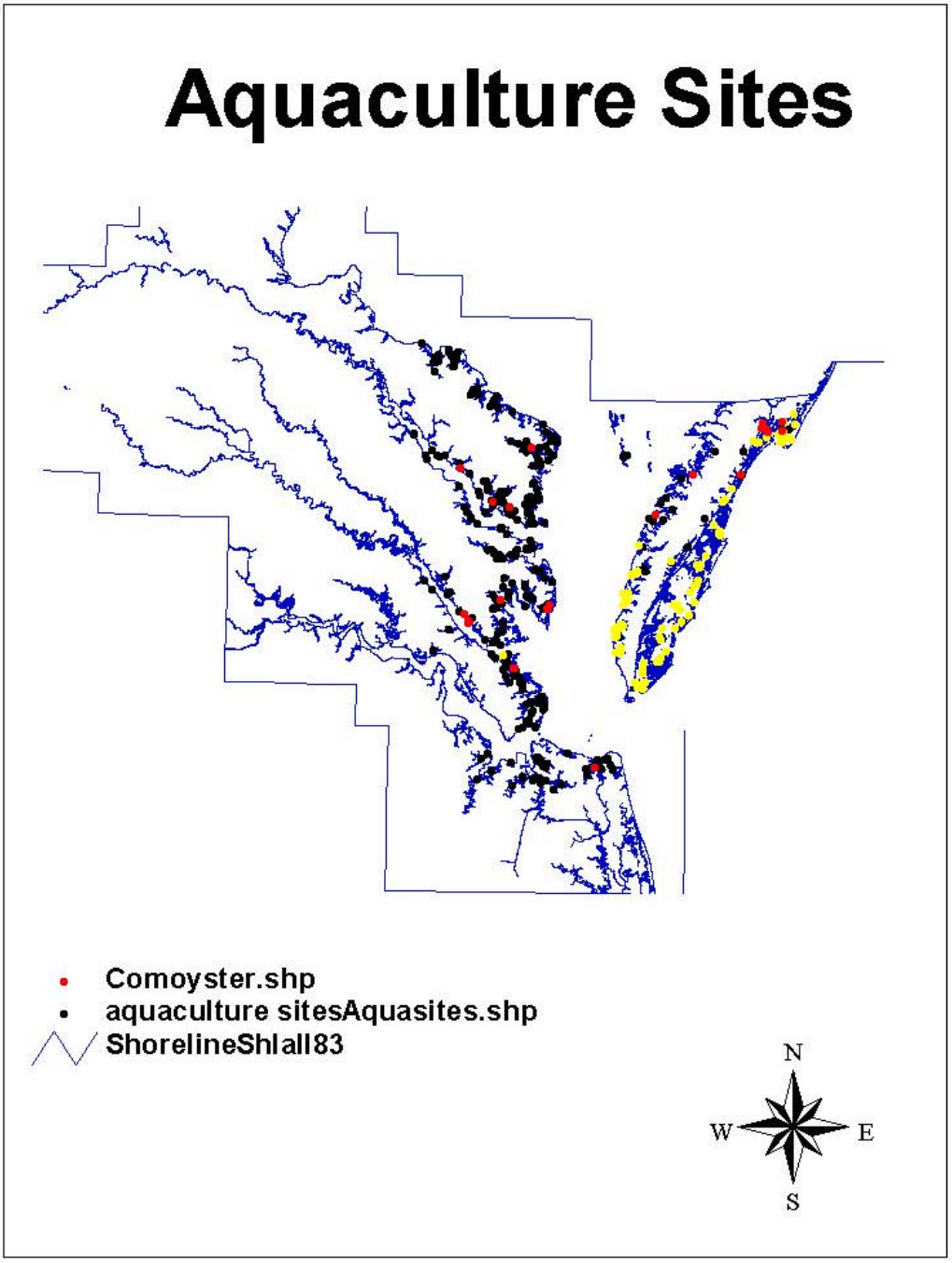


Figure 19. Will show existing and suitable aquaculture areas in Croatia
(Source: Results of the Project- ICZM and mariculture development in Croatia)