MEDITERRANEAN ACTION PLAN
PRIORITY ACTIONS PROGRAMME

UNITED NATIONS ENVIRONMENT PROGRAMME

ENVIRONMENTAL ASPECTS OF AQUACULTURE DEVELOPMENT IN THE MEDITERRANEAN REGION

ASPECTS ENVIRONNEMENTAUX DU DEVELOPPEMENT DE L'AQUACULTURE DANS LA REGION MEDITERRANEENNE

DOCUMENTS PRODUCED IN THE PERIOD 1985-1987

DOCUMENTS ETABLIS PENDANT LA PERIODE 1985 - 1987

MAP Technical Reports Series No. 15

UNEP
Priority Actions Programme
Regional Activity Centre
Split, 1987

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This volume is the fifteenth issue of the Mediterranean Action Plan Technical Series.

This Series will collect and disseminate selected scientific reports obtained through the implementation of the various MAP components: Pollution Monitoring and Research Programme (MED POL), Blue Plan, Priority Actions Programme, Specially Protected Areas and Regional Oil Combating Centre.

Ce volume constitue le quinzième numéro de la série des Rapports techniques du Plan d'action pour la Méditerranée.

Cette série permet de rassembler et de diffuser certains des rapports scientifiques établis dans le cadre de la mise en oeuvre des diverses composantes du PAM: Programme de surveillance continue et de recherche en matière de pollution (MED POL), Plan Bleu, Programme d'actions prioritaires, Aires spécialement protégées et Centre régional de lutte contre la pollution par les hydrocarbures.

PREFACE

The United Nations Environment Programme (UNEP) convened an Intergovernmental Meeting on the Protection of the Mediterranean (Barcelona, 28 January - 4 February 1975), which was attended by representatives of 16 States bordering on the Mediterranean Sea. The meeting discussed the various measures necessary for the prevention and control of pollution of the Mediterranean Sea, and concluded by adopting an Action Plan consisting of three substantive components:

- Integrated planning of the development and management of the resources of the Mediterranean Basin (management component);

- Co-ordinated programme for research, monitoring and exchange of information and assessment of the state of pollution and of protection measures (assessment component);

- Framework convention and related protocols with their technical annexes for the protection of the Mediterranean environment (legal component).

All components of the Action Plan are interdependent and provide a framework for comprehensive action to promote both the protection and the continued development of the Mediterranean ecoregion. No component is an end in itself. The Action Plan is intended to assist the Mediterranean Governments in formulating their national policies related to the continuous development and protection of the Mediterranean area and to improve their ability to identify various options for alternative patterns of development and to make choices and appropriate allocations of resources.

The Priority Actions Programme (PAP), a component of the integrated programme of the Mediterranean Action Plan (MAP) promotes the exchange of experience in the fields of integrated planning and management of resources in the Mediterranean coastal areas.

The starting point of the PAP activities is the awareness that the protection and sound management of the environment can only be implemented by means of a rational development which translates into an optimum exploitation of natural resources. The notion itself of environment in a broader sense and especially in the Mediterranean context is at the same time the most precious resource of the Area.

Within the framework of the definition of the PAP activities, the representatives of the Mediterranean Governments, the Contracting Parties of the Barcelona Convention, have established the following priorities for the PAP:

- human settlements
- water resources management
- soil protection against erosion
- tourism
- aquaculture
- renewable sources of energy

In the abovementioned areas, the following activities are being completed:

- directories of Mediterranean institutions and experts
- water resources management
- integrated planning and management of Mediterranean coastal zones
- protection and rehabilitation of historic settlements
- land-use planning in earthquake zones
- soil protection against erosion
- solid and liquid waste management, collection and disposal
- development of tourism harmonised with the environment
- aquaculture
- renewable sources of energy
- environmental impact assessment
- balance between the hinterland and the coastal zones

The United Nations Agencies, many international organisations and almost all Mediterranean countries take active part in all these activities.

This volume, which is the 15th in the Mediterranean Action Plan Technical Reports Series, contains selected documents concerning the Priority Action entitled "Environmental aspects of aquaculture development in the Mediterranean region" covering the 1985-1987 period.

PREFACE

Le Programme des Nations Unies pour l'environnement (PNUE) a convoqué une réunion intergouvernementale sur la protection de la Méditerranée (Barcelone, 28 janvier - 4 février 1975) à laquelle ont pris part des représentants de 16 Etats riverains de la mer Méditerranée. La réunion a examiné les diverses mesures nécessaires à la prévention et à la lutte antipollution en mer Méditerranée, et elle s'est conclue sur l'adoption d'un Plan d'action comportant trois éléments fondamentaux:

- Planification intégrée du développement et de la gestion des ressources du bassin méditerranéen (élément "gestion");

- Programme coordonné de surveillance continue, de recherche, d'échange de renseignements et d'évaluation de l'état de la pollution et des mesures de protection (élément "évaluation");

- Convention cadre et protocoles y relatifs avec leurs annexes techniques pour la protection du milieu méditerranéen (élément juridique).

Tous les éléments du Plan d'action étaient interdépendants et fournissaient le cadre d'une action d'ensemble en vue de promouvoir tant la protection que le développement continu de l'écorégion méditerranéenne. Aucun élément ne constituait une fin à lui seul. Le Plan d'action était destiné à aider les gouvernements méditerranéens à formuler leurs politiques nationales en matière de développement continu et de protection de zone de la Méditerranée et à accroître leur faculté d'identifier les diverses options s'offrant pour les schémas de développement, d'arrêter leurs choix et d'y affecter les ressources appropriées.

Le Programme d'Actions Prioritaires (PAP), partie du plan intégré du Plan d'Action pour la Méditerranée (PAM), a pour but de promouvoir des échanges d'expériences dans les domaines de la planification intégrée et de la gestion des ressources des zones côtières méditerranéennes.

Le point de départ des activités du PAP est la connaissance que la protection et la promotion de l'environnement ne peuvent être réalisées que grâce à un développement raisonné qui se traduit par une exploitation optimale des ressources naturelles. La notion même de l'environnement, conçue dans un sens plus large, et tout particulièrement dans des conditions méditerranéennes, constitue en même temps la plus précieuse ressource de la Région.

Dans la phase de la définition des activités du PAP, les représentants des Gouvernements méditérranéens, Parties Contractantes de la Convention de Barcelone, ont précisé les domaines prioritaires du PAP, notamment:

- établissements humains
- gestion des ressources en eau
- protection des sols contre l'érosion
- tourisme
- aquaculture
- sources d'énergie renouvelables

Dans les limites des domaines précités, les actions suivantes sont en voie d'achèvement:

- répertoires des institutions et experts méditerranéens
- gestion des ressources en eau
- planification intégrée et gestion des zones côtières méditerranéennes
- protection et réhabilitation des sites historiques
- aménagement du territoire dans les zones sismiques
- protection des sols contre l'érosion
- gestion, collecte et élimination des déchets solides et liquides
- développement du tourisme en harmonie avec l'environnement
- aquaculture
- sources d'énergie renouvelables
- évaluation des impacts sur l'environnement
- interrelation côte - arrière-pays

A toutes les actions prennent part les organismes des N.U. et de nombreuses organisations internationales, y compris la participation active de presque la totalité des pays méditerranéens.

Le présent volume le 15ème de la Série des rapports technique du PAM, englobe un choix de documents relatifs à l'action prioritaire intitulée "Aspects environnementaux du développement de l'aquaculture dans la région méditerranéenne" couvrant la période 1985-1987.

EDITORIAL

This technical report contains the documents produced in the preparatory phase of the Priority Action Programme in aquaculture. They will not be presented in their entirety, but in such a way as to describe the substance without superfluous details.

Since 1984 this action has, been initiated along with other actions by the Regional Activity Centre of the Priority Actions Programme (PAP/RAC) as one of the components of UNEP's Mediterranean Action Plan and carried out in cooperation with the Mediterranean Regional Aquaculture Programme (MEDRAP) and FAO.

The action is focused on aquaculture development which is predominantly dependent on selection of the sites suitable for aquaculture and on the quality of the environment. Therefore, the survey covers the existing Mediterranean aquaculture types as well as the conditions prevailing in coastal areas which are favourable for aquaculture. The second part of the report concerns environmental, macro-economic and socioeconomic issues. Information obtained through consultant missions in a number of sites made possible an appropriate evaluation of the needs and constraints of both a technical and scientific nature. Finally, the report ends with a programme proposal.

It is hoped that this publication will be useful in assisting the governments of Mediterranean coastal states to plan and carry out appropriate actions in the course of promoting aquaculture activities. Furthermore, the information contained in the report may be useful to professional institutions and experts in getting aquainted with the situation and possibilities for solving the problems of aquaculture in particular areas of the Mediterranean.

Dr. Ivan Katavic
Co-ordinator of the priority
action on aquaculture

EDITORIAL

Ce rapport technique contient les documents rédigés à la phase préparatoire de l'action prioritaire sur l'aquaculture. Ils ne seront pas présentés intégralement mais de manière à exposer avec concision leur sujet fondamental, sans les alourdir de détails superflus.

Cette action a été lancée en 1984 par le Centre d'activités régionales pour le Programme d'actions prioritaires (CAR/PAC) du Plan d'action pour la Méditerranée (PAM) du PNUE et exécutée en coopération avec le Programme régional méditerranéen d'aquaculture (MEDRAP) et la FAO.

L'action est centrée sur le développement de l'aquaculture, qui dépend principalement du choix des sites propices à l'aquaculture et de la qualité de l'environnement. En conséquence, dans la première partie du présent rapport sont présentés les types existants de l'aquaculture méditerranéenne et les conditions prévalant dons les zones côtières se prêtant à l'aquaculture. La seconde partie du rapport est consacrée à des thèmes environnementaux, macro-économiques et socio-économiques. Les données recueillies par des missions d'experts ayant visité un certain nombre de sites ont permis une évaluation appropriée des besoins et des contraintes de nature technique et scientifique. Le rapport se conclue sur par une proposition de programme.

Nous espérons que cette publication aidera les gouvernements des Etats riverains de la Méditerranée à planifier et à exécuter des actions appropriées visant à promouvoir les activités aquacoles. Les renseignements contenus dans ce rapport pourraient aussi être utiles pour les institutions professionnelles et les experts, leur permeltant d'appréhender la situation existante et les possibilités de résoudre les problèmes liés à l'aquaculture dans des zones précises de la Méditerranée.

Dr. Ivan Katavic
Coordonnateur de l'action prioritaire
sur l'aquaculture

CONTENTS/MATIERES

1. BACKGROUND OF THE PRIORITY ACTION IN MEDITERRANEAN AQUACULTURE

by

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Because aquaculture has been included in developmental plans of a number of Mediterranean countries, the endeavours of MAP/PAP to promote these activities are necessary and quite justified.

Aquaculture in the Mediterranean has been rather well developed, but the relevant activities have been restricted to individual countries and no exchange of information existed among them. Therefore, in order to enhance the efficiency and development of aquaculture, UNEP/FAO supported by the governments of the countries concerned established the Mediterranean Regional Aquaculture Project (MEDRAP) within the context of Technical Cooperation between Developing Countries (TCDC). These activities were initiated by MEDRAP in the second half of 1981 by establishing an aquaculture centre in Tunisia.

During the first phase, characterized by organizational activities, MEDRAP was not connected with either UNEP or MAP. However, the urgent need to establish communications between these two agencies proved indispensable, even more so since MEDRAP as a UNDP project did not cover all Mediterranean countries. At the same time MEDRAP's activities were rather focused on the bio-technological and educational aspects of aquaculture; they did not pay enough attention to the ecosystem itself, nor to the interactions between environment and aquaculture.

The need to coordinate MEDRAP and PAP activities, particularly regarding the environmental aspects of Mediterranean aquaculture was discussed in the meeting of NFP for PAP and Blue Plan held in Athens in 1984. Following the decisions taken then, the PAP/MEDRAP/FAO representatives held a number of consultative meetings where the fundamentals of joint long-term activities were defined. They aimed at formulating further undertakings concerning the promotion of Mediterranean aquaculture, with a special emphasis on environmental and socio-economic aspects. From an operational point of view, it envisages the following specific goals:

i) to disseminate information about the current activities in the field of Mediterranean aquaculture and provide the necessary conditions for the coordination of such activities;

ii) to identify, evaluate and protect localities suitable for aquaculture;

iii) to define the ecological criteria for rational aquaculture development in the Mediterranean;

iv) to improve existing programmes and current activities and to develop further activities now that MEDRAP has ceased being a UNDP project.

PAP together with FAO and MEDRAP prepared two basic documents ("Aquaculture and Coastal Planning of Coastal Zones in the Mediterranean" and "Ecological, Social and Economical Aspects of Coastal Aquaculture in the Mediterranean Region") and sent a number of fact finding missions to Mediterranean countries. On the basis of these two documents and the mission reports a cooperative project proposal was developed.

The project proposal focused on ecological criteria relevant to the development of aquaculture activities, departing from the fact that each site potentially suitable for aquaculture is a specific ecosystem. The objectives of the project are to define, calibrate and improve an integrated strategy of site evaluation and monitoring for the development and protection of aquaculture. It is hoped that communication among peoples and nations through the exchange of knowledge and experience will contribute to the promotion of Mediterranean aquaculture as a whole. The project will also benefit from the knowledge derived from other PAP activities such as: integrated planning of coastal zones; environmental impact assessment; solid and liquid waste management and renewable sources of energy.

2. AQUACULTURE AND COASTAL PLANNING IN THE MEDITERRANEAN

by

A team of MEDRAP-PAP/RAC experts: BRUNEL, G., CATAUDELLA, S., FERLIN, P., GUELORGET, O., FILIC, Z. and FRESI, E.

ABSTRACT

The introductory part of this paper offers general information on UNEP,MAP,PAP and MEDRAP which have provided a co-operative framework and made the effort possible. The paper points out the fact that aquaculture is dependent on the quality of the environment which is its basic resource, and that the available sites suitable for aquaculture activities are critically scarce thus needing to be inventoried, fully taken account of in the development plans and protected.

A survey of the various types of Mediterranean aquaculture is given along with an explanation of the degree of dependence of each type on the conditions the prevailing in the immediate and wider environment. The basic criteria are drawn up for the selection of suitable sites; furthermore, it is shown how aquaculture development programmes are linked with Environmental Impact Assessment procedures.

In conclusion, the paper gives decision-makers and physical planners suggestions and recommendations relevant to the development of aquaculture in the Mediterranean Region.

Introductory remarks

In recent years the potential of the Mediterranean coastal environment for the development of aquaculture has been fully recognized. As a consequence, almost all coastal countries have implemented or planned aquaculture undertakings.

This process has to be viewed in the broader context of "littoralization" which is affecting, at an accelerated pace, the whole Mediterranean area. Aquaculture, in fact, is but one of the many productive activities through which we exploit the natural resources of our coastal environments.

Contrary to this, the development of aquaculture has been viewed so far mostly in socio-economic and technological perspectives. Environmental problems have scarcely been considered and sometimes even totally neglected.

This phenomenon can be understood if we take into account the socio-economic pressures which have often prevailed over the careful consideration of environmental problems, the analysis of which is expensive and time-consuming. The lack of knowledge, however, has produced undesired effects, since a number of aquaculture undertakings has proved hardly suitable to the environmental conditions of various sites. Sometimes low compatibility and even serious conflicts with other types of exploitation of natural resources have arisen.

While the interactions and feed-backs between production processes of any kind and the characteristics of the ecosystems, where aquaculture projects have been implemented or are in the planning phase, remain largely unassessed, the idea that technological solutions would by themselves make up for the deficiency of environmental information has rapidly revealed its fallacy.

Guidelines and objectives of the paper

It is generally acknowledged that socio-economic, technological and ecologic aspects must be considered simultaneously in the planning of coastal zones where aquaculture is envisaged.

It is essential to frame the apportionment of the different types of environmental use into a matrix of potentialities and compatibilities to warrant equally viable developments.

This seems particularly true when biological resources are considered, as is the case with aquaculture. The promotion of natural production as well as its socio-economic issues depend, in fact, on the quality of the environment and its maintenance. In such a context aquaculture can represent one of the major keys for the conservation of the ecologic characteristics of the neritic biomass.

It is clear, however, that integrating aquaculture developments into such complex socio-ecosystems, like the Mediterranean coastal regions and their marginal environments, is not an easy problem. The parameters that must be considered are numerous and varied, not only as concerns their nature, but also in their scale of variability in both space and time.

This poses the problem of defining a strategy for the description of the system which would be operationally feasible, information-rich and mathematically tractable. It is clear, in fact, that while it is not profitable to ignore any really pertinent part of the vast amount of information when attempting to describe a system, pragmatically it is not possible to list explicitly all the information each time the system is described. The problem is therefore to choose the appropriate level of detail to match the specific purposes of the analysis. In other words, those variables should be selected that are significant to the overall structure and dynamics of the system in relation to the goal of the study and that can actually be measured with an acceptable degree of effort and through relatively inexpensive means.

From what we stated above, it becomes clear that an inter-disciplinary approach is necessary; such an approach would integrate, on the basis of general criteria agreed upon beforehand, the contributions of several different specialists.

Some questions must also be answered, such as:

1. What is Mediterranean aquaculture in the variety and complexity of socio-economic, technological and biological situations?

2. What are the environmental scenarios in which aquaculture exists or should be developed?

3. What are the interactions with other types of production use of the natural resources in the coastal zones?

Based on the above elements, one can further elaborate on:

1. The pertinent descriptors for site evaluation and monitoring for the specific purposes and needs of aquaculture;

2. The way in which to organize and analyze this information on the basis of a suitable scientific approach.

The scopes of this paper are therefore:

1. To provide basic information and recommendations for drawing up an inventory of coastal environments suitable for aquaculture;

2. To provide the elements for the selection, monitoring and timely protection of suitable sites, in the framework of national development policies.

An overview of aquaculture in the Mediterranean

Marine aquaculture is not a new activity in the region. For 500 or 600 years already fish and then shellfish cultures have been developed in selected areas, mostly in the northwestern part of the Mediterranean.

Mediterranean aquaculture is not completely isolated from world aquaculture but is linked through numerous aspects (technological, geographical, species, etc.) with European aquaculture production as a whole. It has however a certain individuality, due to the particular geographic and socio-economic conditions prevailing in the region.

Geographic and ecological factors

The Mediterranean region has particular geographic and hydrobiological characteristics which call for special forms of aquaculture especially suitable to the region.

Geographic characteristics

Three types of sites can be distinguished in the Mediterranean:

(a) lagoonal zones
(b) sheltered coastal zones
(c) estuary zones

Lagoonal zones

The Mediterranean coast has numerous lagoonal zones of various origins (tectonic, sedimentary etc.) but with variable salinity levels throughout the year. These lagoons are located principally in Egypt, Tunisia, Greece, Turkey, Italy and France. It is difficult to give an estimate of their total surface area as, on the one hand, marine and brackish-water lagoons often join up with freshwater systems and, on the other, the unitary surface areas themselves can vary according to precipitation and evaporation. This explains why the figures given range between 50,000 and 1,000,000 hectares for the entire Mediterranean periphery. The EEC studies and the UNDP/FAO/MEDRAP Project which are in progress should clarify this aspect.

Sheltered coastal zones

Certain parts of the Mediterranean coast (especially karstic zones) are bays or channels of relative depth which are very well sheltered from winds and tidal variations: the Dalmatian coast in Yugoslavia, bays in the west of Greece, the Aegean Sea islands. It is impossible to give a precise estimate of these surface areas which are however very suitable to aquaculture in floating structures (cage, rafts etc.), a type being expanded at present.

Estuary zones

The seawards estuary zones or deltas are interesting for aquaculture from two points of view: firstly, because there is no competition whatsoever for their use (soil salinity) and secondly, because brackish water is available, it is more productive in a semi-intensive system than pure sea water. There are numerous zones of this type in the Northern Mediterranean countries, covering thousands of hectares. In the south they are less developed with the exception of the Nile delta and the permanent rivers in the North African countries.

Ecological factors

The Mediterranean is low in nutrients and is reported to be the most impoverished sea in the world. Scientists have observed that only those areas under arctic ice or in certain tropical regions are less productive than the Mediterranean as a whole. However the waters in some parts of the Mediterranean are much more productive than in other parts. Also, more than one million hectares of shallow brackish-water basins and lagoons are found along the Mediterranean coast and most of them are highly productive.

Temperature varies usually between 5°C in winter and 27°C in summer, but the northern and western parts of the Mediterranean are colder than the southern and eastern regions. Salinity is usually high (between 36 and 38 g^{-1}). All these factors limit mariculture production to selected species, excluding species such as for example salmon and trout (temperature and salinity levels are too high) as well as tilapias (temperature is too low).

Historical and socio-economic conditions

Marine aquaculture development started in Italy (the Po delta) and Egypt (the Nile delta) many centuries ago through the progressive improvement of lagoon fisheries in which mullet, sea-bass, sea-bream and eels, that usually migrate into coastal lagoons at the juvenile stage in spring, were kept and caught as they attempted to migrate back to the sea in autumn. About a century ago, shellfish cultures were developed in similar areas in Italy, France and Spain.

These two activities mostly family-run were conducted on a private basis by using the natural productivity of the most productive areas in the Mediterranean (lagoons or semi-enclosed areas).

These conditions should be compared with those prevailing in Japan, where aquaculture started in the open seas, with intensive methods for fish culture (by using feed) and was carried out by cooperatives of fishermen (KUMIAI); conditions there are quite different and the prices also differ greatly from the ones in the Mediterranean, allowing for more expensive production technologies.

During the last 10 or 15 years, a new type of aquaculture was developed in the Mediterranean : intensive aquaculture. The difference between this type and the traditional ones resembles the difference between traditional farming and intensive animal breeding. In the first case you try to get optimum production from a farm field and in the second you try to get the largest production of one selected species even under factory conditions.

However, there are also various intermediate solutions.

Fish production and demand

Most of the Mediterranean countries are considered to be "rich" if compared with countries in other areas of the world (Africa, South-east Asia etc.). All Mediterranean countries are over the level of US $500 of GNP $inhabitant^{-1}$, $year^{-1}$, and the food and protein consumption per capita is usually high, with the exception of Egypt and Morocco. However, in the Mediterranean countries the question is not to produce protein, but fish. Demand is very selective and common coastal fish, like sea-bass, sea-bream, mullet etc., can fetch very high prices and the present production of these species is not very important in volume (8% of the total Mediterranean fish and shellfish production) but quite significant in terms of value (15 to 20% of total production value). Demand for the major aquaculture species is not met; this means that the estimated possible increase of 20 to 30 thousand tonnes during the next 10 to 15 years would not present major market difficulties within the Mediterranean region.

State of aquaculture in the Mediterranean region

Types of aquaculture

Several methods of fish, mollusc and crustacean culture which have a potential for the future are currently used in the region.

(a) Lagoon management

This system, traditional in the Mediterranean region, is based on the migration of sea-bass (*Dicentrarchus labrax*), sea-bream (*Sparus aurata*), mullet (*Mugil* spp.), sole (*Solea vulgaris*) and other species into coastal lagoons as juveniles and their return to the sea as adults. Eels (*Anguilla anguilla*) make a similar migration, but remain in the lagoons for several years. The fish are simply captured and all are sold regardless of size.

(b) Vallicultura

This system, developed in coastal areas of the Northern Adriatic, is an improvement on lagoon management. Water and salinity levels are controlled and fry collected in other areas are stocked in embanked places of lagoons which are called, "valli arginate". The fish are harvested and selected in complex weir systems called "lavorieri". Undersized fish are held back over the winter in deep trenches and released into the "valli" to grow for the following summer.

Progressively improved upon by fertilization and artificial fry restocking, as well as other methods, valliculture is at present the main type of commerical production of finfish. A new step in the development will be reached with the change of valliculture into "integrated aquaculture".

(c) Pond culture

Pond culture of fish is a recent development in the Mediterranean countries and is now practiced on a large scale in Israel, Italy, Egypt, France and Spain. Experimental pond culture is carried out in Tunisia. With this system, earth ponds provided with water at ambient temperature and salinity are stocked with fish (fry or fingerlings) or shrimp (post-larvae or juveniles) collected from the wild or produced in hatcheries. In some cases nursery ponds are used to rear the fish from fry to fingerling size, or shrimp from post-larvae to juvenile stage, before stocking the grow-out ponds. Supplementary food is usually provided, but for some species natural food is produced within the ponds by fertilization. When the fish or shrimp reach marketable size, they are harvested by seining or draining the ponds.

(d) Cage culture

The culture of sea-bass and sea-bream is a recent innovation in the region; it is now carried out on a semi-commercial basis in France, Yugoslavia and Israel and on an experimental basis in Cyprus and Tunisia.

In this system of culture, floating cages or fenced enclosures, usually made of synthetic netting or wire screens, are placed in protected areas to grow fish to marketable size. Fry collected from the wild or produced in hatcheries are held in the cages or enclosures and supplied with food, usually floating or sinking pellets or minced fish.

(e) Artificial environment sytems

These are the most sophisticated and intensive aquaculture systems in which fish are kept in tanks or raceways and supplied with high-quality water of satisfactory salinity and optimum temperature for year-round growth. Some systems include reconditioning and re-use of the water to reduce water and heating requirements. In some cases the tanks or raceways are insulated or enclosed in a building or a greenhouse to maintain satisfactory temperature. Artificial feeding is required. A high stocking rate is employed to maximize production per unit of surface area because of the high capital cost of these systems. France and Italy are the two countries in the region that have made some progress in this technology, particularly for the culture of sea-bream and sea-bass, as is done in Italy for eels.

(f) Mollusc culture system

Oysters and mussels have traditionally been grown in suspension in the Mediterranean region where the tidal amplitude is slight. Spat or juveniles are suspended in various ways from fixed structures (platforms, tables etc.) or from floats or rafts. Oyster and/or mussel farming is now carried out on a commercial or experimental scale in several countries in the region, especially Italy, France and Spain.

Clams are grown on-bottom in the areas where the substrata and water currents are suitable. Clam culture is carried out on a small scale in France and on an experimental basis in Spain, Italy and Tunisia.

Mollusc culture is the largest aquaculture production in the Mediterranean; total production stood at about 80,000 tonnes of oysters and mussels in 1985.

(g) Polyculture and integrated aquaculture

Recently experiments have started in the semi-intensive ponds with species that are good substrate utilizers (sea-bream and mullets in Egypt and Italy, mullets and tilapia in Israel). New systems, combining for example intensive raceway culture and semi-intensive pond culture, or cage culture and mollusc culture, are being developed in several countries. The main advantage of such systems is a better use of capital, layout and energy, re-use of wastes from the intensive culture etc.

(h) Other types of aquaculture

Two other types of aquaculture, combining one of the above systems and the use of effluents frome external sources, have been developed in the Mediterranean, i.e.

- Use of treated urban wastewater which can produce, without any supplementary food, up to 3 tonnes of fish (mullet) per hectare, per year. Such an experimental station (2ha) is operating in France and some new projects are in the planning stage in Algeria.

- Use of heated effluents, mostly for hatcheries and early growth stages, in order to accelerate the growth of larvae and fingerlings. Facilities operate in Italy and France, both on a commercial basis (eel culture) and on a semi-commercial basis.

Production from aquaculture

The total production in the Mediterranean is estimated at 95,000 tonnes in 1985 (fish and shellfish). The production of various species of fish, including sea-bass, sea-bream, mullet, sole and eel, is largely obtained from lagoon management or, as in Italy, from valliculture (about 12,000 tonnes). The production of oysters and mussels from mariculture makes up the major part of the region's supply of farmed products, with about 80,000 tonnes of oysters and mussels. Eel production (mostly in freshwater farms) is gradually developing, especially in Italy.

Intensive or semi-intensive production of marine fish is not very important (a few hundred tonnes, mostly from Italy and France), but has gradually been expanding in the last 4 or 5 years.

A classification of the Mediterranean aquaculture strategies

Mediterranen aquaculture includes many activities that have different characteristics and play different roles in the production strategies; they have a diversified impact on the economy and the environment in which they are carried out.

There are some forms of production that tend to cater to the local market, or that on the whole have a rather "social" character, since they tend to be integrated in the activities already existing. There are other forms of production that tend to achieve optimum profit through industrialized production.

This chapter concerns some production strategies of Mediterranean aquaculture and attempts to identify and classify the relevant activities. It is especially addressed to those who are responsible for defining management policy for the coastal environments.

Basics on the strategies

The recent development of modern Mediterranean aquaculture and the high level of diversification within this field call for an attempt at classification. This is also necessary because of the fact that many technologies and activities overlap and sometimes merge with the traditional activities known since antiquity. Another aim of this approach is to avoid generalizations which, even if applicable to certain particular situations, may lead to false evaluations, thus misleading those who have to manage, conserve and improve the environmental resources on which Mediterranean aquaculture is strictly dependent. Furthermore, the Mediterranean basin is a mixture of very diversified environmental and cultural situations where the continents of Europe, Africa and Asia meet, a fact that must not be neglected even when we discuss such a specific sector as aquaculture.

This classification of Mediterranean aquaculture strategies mainly concerns the rearing, through various technologies and methods of those marine and fresh-water species that are able to adapt to brackish water.

(a) Seed production for Mediterranean aquaculture

There are two forms of Mediterranean aquaculture which are based on seed collection in the wild and on seed production in hatcheries. Generally, there is a trend with technological and managerial groups to ignore seed collection in the wild although most of the aquaculture activities in the Mediterranean are still dependent on this type of stocking, both for molluscs and fish.

Many countries do not allow seed collection in the wild for aquaculture purposes, because they fear that this would further increase the capture of coastal populations which are already being overexploited. However, aquaculture experts report that survival rates of fry are much higher in fish farms. In any event accurate data on this are quite meagre, especially data on fry survival rates in the wild.

At present and on the basis of evaluations of environmental impact and conflicts among various activities, it should be taken into account that in the Mediterranean fry collection is carried out in all types of aquaculture and that artificial production of seed concerns only sea-bass (among indigenous fish), Paeneus japonicus (among penaeid crustaceans) and certain other species of shellfish (clams and oysters).

As far as sea-bream is concerned, breeding techniques are rapidly developing even if the capacity for artificial reproduction is still far from meeting the needs of aquaculture, i.e. tens of millions of individuals, whereas the current production of all Mediterranean hatcheries only reaches one million at most.

The dependence of marine aquaculture on wild seed collection places a constraint on its development. Hence, a considerable effort has been made in the last decade to improve the methods for controlled seed production. The results obtained give hopes that a model of Mediterranean aquaculture will be developed which will be independent of the natural environment as far as seed is concerned. At present, as in all transition phases, seed collection in the wild as well as production in hatcheries must be managed in an integrated way by improving the survival rates of seed collection in the wild and by increasing the present effort to improve seed production methods in order to obtain an independent, closed cycle in aquaculture, as is now the case with sea-bass, for example.

As far as planning is concerned, the origin of seed should clearly be identified in every development programme; this would facilitate both the assessment of the impact of Mediterranean aquaculture on wild populations and project implementation. Data would then be correlated with national survey programmes on fry resources for the species reared and with the possible effects of their capture on existing and potential small-scale coastal fisheries.

(b) Identification of traditional activities in Mediterranean aquaculture

Modern Mediterranean aquaculture has developed from a very old tradition that can be identified as fisheries management in confined coastal areas. Examples such as Italian vallliculture, the areas enclosed by earth dikes in the Nile delta lagoons and the fixed traps located in various lagoonal areas illustrate what can be classified as aquaculture rather than small-scale fisheries.

In the case of coastal lagoons, aquaculture activities can be defined as such if capture is integrated with:

- the presence of fixed traps which permit a seasonal control of migrating populations;
- activities of selective capture;
- control of lagoon openings and eventually of the hydraulic system;
- restocking with the seed of various origins.

The importance of including coastal basin management in aquaculture activities is recognized at both social and economic levels because only the improvement of such activities can guarantee a continuous control of the quality of the environment.

Lagoonal systems must be considered in their totality as environments to be managed through aquaculture methods, on the basis of strategies that make possible evaluations of existing cultures, or any improvements to be brought to them as well as estimates on production and amelioration of the living conditions of those who traditionally form a part of this environment. Such a management approach takes into account the collective interest and should therefore be regarded as having a high social value.

The lagoon basins can be used for many activities which should take into account the elements outlined above. This should permit a sound active conservation of the environment and all the benefits that derive from it, in addition to appropriate management of aquaculture.

Finally, some programmes of Mediterranean aquaculture, such as the stocking of marine species (mullets) in the artificial freshwater ponds and dams, especially in the warmer regions, can be considered traditional aquaculture activities.

(c) Rearing practices

Concerning rearing practices, the Mediterranean activities can be roughly classified with regard to (i) technology, (ii) environmental impact and (iii) social aspects.

In the Mediterranean region there are various situations stemming from diverse choices of development policy. If the Egyptian situation is taken as an example, there is a correct trend towards rearing those species that are good utilizers of the substrate and can meet the high internal demand for food. However, considerable additional research is needed although this method responds to the availability of large surfaces unsuitable for aquaculture. This corresponds to the horizontal development of aquaculture on the basis of the schemes already applied widely in other regions of the world.

The tendency in the other Southern Mediterranean countries is to produce the expensive species of seafood, part of which is exported to the Northern Mediterranean countries where there is a high demand for them. In such cases efforts are made to devise more advanced technologies and models which would allow the quickest possible beginning of production.

The limiting factor of such models is food availability on both qualitative and quantitative levels because intensive and semi-intensive strategies usually depend on heavy imports of feeding stuff.

The rearing models of the Northern Mediterranean tend to exploit small available areas through aquaculture activities by using more sophisticated technologies that have a greater environmental impact and are in a greater conflict with existing activities.

In recent years however there is a tendency to move towards a type of aquaculture that exploits environmental resources but with a higher level of social responsibility, even if the tendency to produce for the deluxe market still applies.

Generally speaking, it is now felt that aquaculture activities should be planned and located in such a way as to take full advantage of the given environmental resources available in each case. However, there is little experience in developing a mass-production approach where reliable production is based on realistic economic estimates. The lack of such an approach is not surprising because Mediterranean aquaculture in its current form is still recent in origin.

Major production strategies

(a) Management of coastal environments

These are strategies of "ecological" control in the confined coastal environments where man, through fixed traps and selective fisheries, controls the dynamics of the populations that are of financial interest. This strategy concerns extensive production where no food is administered and the control of the hydraulic regime can affect production. Restocking is made through natural migration of juveniles from the sea, but there is also a more advanced type of management where the seed is introduced by man.

As far as the production model is concerned, associations of species that are more or less balanced can be found (that includes predators); the production is generally recorded in 3g ha^{-1} $year^{-1}$. These models should be considered as highly profitable since they make possible the capture of the valuable product for direct consumption by making use of the environmental trophic energy.

In general, environmental control and protection imply high costs but bring with them relevant social benefits as well; fish production is only one of them. Therefore, such a model should be considered as socially beneficial.

(b) Shellfish production

It is a form of aquaculture, which in addition to some specific technologies, makes use of environmental trophic resources, both in the open marine environments and in the confined areas. From this point of view, such activities deserve special attention, as there are no intrinsic limitations in terms of space availability in the Mediterranean region and because they can be profitably combined with other kinds of intensive production (e.g. floating cages).

(c) Semi-intensive production in artificial ponds

This is a production method that is widely used in fresh and coastal waters.

The main criterion for site selection should be the level of the area, in relation to the sea, so that ponds can be emptied completely, in order to allow control of the productive cycle. In the framework of Mediterranean aquaculture, non ichthyophagous species should be favoured (mullet, sea-bream, shrimp) both in mono- and polyculture, species which exploit the natural trophic energy with or without manuring and with or without the addition of integrative diets. Thus the profitability of semi-intensive plants depends on whether food inputs are expensive or not.

The high costs of earth moving and pumping represent a constraint to the development of such plants. Some integrated systems (intensive/ semi-intensive models) are being developed, in which the wastewater from the intensive basins is used in the semi-intensive ones. It should be added that the semi-intensive models can use fresh water for the production of marine euryhaline species, especially mullet. For the time being the other constraint is the availability of fish fry. For crustaceans (Japanese prawns) the availability of seed seems to be rapidly increasing. The semi-intensive models have good prospects although further research is still needed.

From the point of view of environmental impact, the wastewaters of the semi-intensive plants have acceptable qualities, especially if the outlet channels are large enough to allow organic matter recycling if the appropriate species are reared.

The production unit is t ha^{-1} $year^{-1}$.

(d) Intensive production models

Widespread in the Northern Mediterranean, these model areas were planned for the production of sea-bass, eel and sometimes of other species. Intensive plants produce high biomass per space unit in compacted earth, concrete, plastic-lined ponds or floating cages, with the food entirely supplied from the outside and high water turnover. Such plants need a technologically

advanced management. From an energy point of view, they show an unfavourable balance since they require fairly high quantities of animal proteins. These plants are generally managed by private firms (sometimes public share-holders) and usually produce expensive products. Among the latter, sea-bass is recording a rapid development owing to seed production in hatcheries.

Environmental impact is considerable due to large concrete works and the amount of wastewaters generated. Food requirements and availability of suitable technologies can be the main limiting factors in some regions.

Such forms of aquaculture do not contribute to large-scale production, but can promote activities, such as food preparation in fisheries where minor species are grown. It should be added that some experiments are being carried out to integrate the intensive sectors within the primarily semi-intensive systems.

Interaction of aquaculture and other activities

Due to the fact that the Mediterranean region is an extremely favoured region with regard to the variety of human activities, aquaculture can either play a complementary or a competitive role. For the sake of simplification we shall group these activities into four main categories.

Aquaculture and fisheries

In the minds of the public and of the majority of political and administrative leaders these two sectors are closely connected. Not infrequently this creates confusion at the level of economic policy and decision making. As a matter of fact, except for some rare instances, there is only a minor link between them. Fishing in most countries of the world is based on analyses of natural resources and demographic studies, thus enabling the enterprise, at best, simply to crop the product.

Aquaculture, on the contrary, is an attempt to control the maximum number of parameters (physical, biological etc.)from the very beginning, thus orienting production towards one or more pre-selected products. To this fundamental difference we must add the fact that aquaculture, for the time being at least, is concerned with only a small portion of the marine environment, constituted by the coastal waters, while fishing activities involve the whole of the marine area.

The exceptions are few and limited to the coastal areas. In Japan the coastal zone is entirely in the hands of the cooperative companies, exploitation is carried out in a planned fashion, both through fishing and aquaculture. This type of cooperation is unique in the world.

Competition

In the Mediterranean region in the majority of cases, fishing and aquaculture are competitive in at least five ways:

- use of territory
- use of biological resources
- use of human resources
- use of financial resources
- marketing of product

Use of territory

In the Mediterranean region, there are different examples of appropriation of fishing territory for aquaculture. The most typical examples are in the development of mollusc cultures, especially in the lagoon zones, and in the more recent fish-rearing methods in floating structures (cages, rafts). These two techniques are not without a certain impact, not only because of the territory used by the equipment employed, and the obstruction created to the use of fishing devices , but also on account of the impact on the characteristics of the benthos. These conflicting situations, which may result in the deterioration or destruction of the installations, can be solved only with a clear delimitation of the territory (Nador Programme - Morocco), with retraining or converting the fishermen (shell fishermen at Thau, France), or with an outright abolition of the fishing activities (Limski channel, Yugoslavia).

Use of biological resources

Aquaculture can also come into conflict with fisheries due to the use of biological resources such as the natural production of fry, nutrient species or other production factors. The collection of fry for aquaculture could be considered by fishermen as the cause of a potential production decrease, although this need not happen if certain precautions are taken. Another example illustrating the conflict is a prohibition enforced in certain areaas for fishermen to pick the oysters from the natural reefs, in order to preserve the oyster spat for rearing. Because of the direct impact (wastes), that certain types of aquaculture have, it is possible that their development can transform the environment and consequently the production of fish.

Use of human resources

Fishing is an economic activity that can be very profitable but is still tough and dangerous. Aquaculture, on the contrary, is considered a steady and reliable occupation as well as a less primitive one. Even if this assessment is rather far from reality, it has an effect on the younger generation of fishermen similar to that of industrial job opportunities vis-à-vis aquaculture. This attitude, which is reinforced by improved education and training opportunities may however lead to a generation conflict.

Aquaculture can on the other hand profit from the pre-existence of a fishing-oriented social background (know-how, specialized commercial activities etc.).

Use of financial resources

Aquaculture absorbs a large part of the investments in the marine production field, not necessarily commensurate with its share in the actual output. This is mainly due to an overly optimistic publicity on development possibilities in this sector and on productivity and profitability expectations. This uncontrolled inflow of private and public capital generates a feeling of being neglected in those connected with fishing activities.

Marketing of product

In the initial stage, the marketing of aquaculture products not only has no impact on fishing product prices, but is dependent on them. This situation however changes with the growth of aquaculture production, which tends to reduce the price of the fish product, owing to the wider and more flexible marketing of aquaculture products; here producers can actually decide which is the best moment to put the product in the market and also possibly to stabilize the market.

Ultimately, fishing would not have any influence on the price of fish products (which are generally rather low); the latter would solely be controlled by the market supply of aquaculture products. A century ago this phenomenon did actually occur in France with oysters and mussels; twenty years ago with trout. Today the same phenomenon involves Atlantic salmon and there is a risk of experiencing it with sea-bass and the Mediterranean sea-bream.

Complementarity

As it has already been shown there is only limited complementarity between fishing and aquaculture: the mentality of entrepreneurs is different, the areas do not coincide and the equipment is specific to each sector (except in the preservation and processing fields).

However examples of complementarity can be found in certain restricted areas where integration of lagoonal fishing and aquaculture coexist: collection of fry, seed collection, re-population of shrimp post-larvae or seed from hatcheries, management of rearing cages, enclosures etc.

This integration, with complementary activities either at the level of supplying fry, or at that of feed, or finally, in the use of labour, can be implemented only at the level of artisan activity and requires a close cooperation between operators in the two sectors.

Conclusions

By its development, aquaculture can create some conflicting situations with fishing activities, in particular with coastal fishing. It is necessary to remember however that this competition is limited to certain zones and to specific species and that, in actual fact, contrary to what some believe today

aquaculture is not a replacement for fishing. Fishing deals with the exploitation of far larger areas and a much larger variety of species. A sound management should therefore aim at developing aquaculture and promoting fishing activities at the same time, while mitigating conflicts in the coastal strip, possibly through integration.

Aquaculture and agriculture

These two activities, in contrast to what was stated above, are inspired by the same vision: to orient production in an ecosystem towards one or several products of commercial value. This is why we find a more "agronomical" approach in aquaculture, which aims at extracting the maximum production out of a given environment, or also a more "zootechnical" approach consisting of a detailed study of species in order to secure a maximum controlled production. The rearing environment, however, remains different.

It is therefore quite understandable why a number of aquaculture activities (Italian valliculture, n-fish breeding etc.) are patterned after agricultural models. There is nevertheless occasional competition and conflict between these two activities.

Use of resources

Three types of competition can be expected at this level: land, fresh water, agriculture by-products.

Land

Some forms of aquaculture (semi-intensive, extensive) require areas of considerable size and are, therefore, liable to compete with agriculture on the land market. For that reason a sound planning policy should put at the disposal of aquaculture an area of relatively sterile land (briny or sandy soil) or such sites where the sea influence is felt (sea spray, saline zones), land that is where cultivation is impossible and stock breeding hardly advantageous (less than 200 - 300 kg ha^{-1} $year^{-1}$).

Similarly, streches of marsh land which are difficult to drain should be flooded and transformed into aquaculture zones.

It is estimated that dozens of thousands of hectares of such land are available all along the Mediterranean, with no adverse effect of aquaculture activities on agricultural development.

Fresh water

The best production in aquaculture has been obtained in water of medium salinity (20-25 °/oo); this is difficult to find naturally, which means that a source of fresh water has to be used to lower the usual salinity of the Mediterranean sea water (35-40°/oo).

In some regions, especially in the northern Mediterranean, this does not create any problems; however, in the Southern Mediterranean where aquaculture competes directly with agriculture because of fresh water shortage, the aquaculture priority use of fresh water cannot be justified.

The only remaining solution is to explore the possibilities of installations that would use water inadequate for agriculture, drilled-well water with a very high salinity (over 6°/oo) agricultural run-off water etc.

Agricultural by-products

Low technology aquaculture can be integrated very well with various agricultural projects and utilize by-products available: agricultural produce waste, wastewater, organic fertilizers etc.

Nevertheless, competitive situations can arise with respect to agriculture (fertilizers) or stock breeding (fodder waste). The decision on priorities will depend on the fact that aquaculture can often make better use of some types of waste, in particular of animal origin, than any other land culture. This is equally valid for the so-called "intensive" aquaculture which is totally dependent on external sources of food (fish flour, soya flour etc.), generally getting a better value for these supplies than most land cultures.

Conflicts

The conflicts arising from the competitive use of products are generated by the disturbance which the presence of one activity causes to the other. At present, there are two types of conflicting situations in the Mediterranean:

- impact of the pollution caused by agriculture (pesticides, insecticides, fertilizers) on the quality of water;

- impact of coastal aquaculture projects on the salinity of the neighbouring agricultural land.

The first type is found primarily in the northern countries, especially in the systems using fresh water from the coastal rivers. In the countries of the south, the use of chemicals in agriculture is still limited and it is even possible to utilize the agricultural run-off water for the fin-fish culture (Egypt).

Conclusions

As we have just seen, the inter-relation between agriculture and aquaculture is more of a commercial than of a conflictual character. It is however necessary to insist on integration wherever possible, in particular with regard to the use of by-products and the use of land not fit for agriculture, but suitable to aquaculture projects.

Aquaculture and tourism

The development of tourism which is favoured in the Mediterranean region, because of its particularly attractive weather and the historical and cultural interest, is not without impact on aquaculture activities in this area.

The inter-relations of these two activities are also of three types: competition, conflict and integration.

Competition

The competition between the two sectors is apparent in the use of land in coastal strip. In fact, both of these activities need stretches of territory of the same quality (temperature, easy access etc.). It should be stressed, however, that in practice some aquaculture systems can prosper in the less attractive zones, especially on marshland and lagoonal zones. Competition is likely to arise in such places as closed bays or narrow caves well suited to the use of floating structures predominating in the northern part of the Mediterranean (Yugoslavia, Greece).

Conflict

An overly pronounced development of one or the other branch of activity can provoke a risk of conflict such as:

- impact of wastewater pollution from tourist developments on water quality;
- interference of tourisme in aquaculture operations;
- restrictions imposed by aquaculture with regard to tourist activities and the resulting waste disposal;
- visual impact of aquaculture installations on certain sites etc.

Consequently, planning and zoning are equally important here in order to move from the initial competitive situation to an integration.free of conflict.

Integration

Various forms of integration between tourism and aquaculture can be developed:

- on the level of infrastructure, in particular with regard to access roads, electrification etc.;
- concerning labour, more important to aquaculture during winter and to tourism during summer.
- with regard to marketing, the aquaculture product can be almost entirely absorbed by the tourist population.

Conclusion

Contrary to the ideas expressed by some, tourism and aquaculture can coexist perfectly well, even integrate. Everything depends on the way in which tourism and aquaculture development is conceived, on the will to integrate, on the lowering of pollution hazards etc. It should be emphasized that several integration projects are already in existence demonstrating reciprocal benefits derived from integration (Yugoslavia, Corsica).

Aquaculture and urbanization

Urbanization, industrialization, development of harbour activities or construction of a large tourist complex in a coastal zone have a fundamental and irreversible impact on it. These projects follow from the political and socio-economic decisions and have little in common with an aquaculture project. That is why it is difficult to speak about any possible relation between these two sectors, unless one wants to underline the fact that, apart from some rare exceptions (the use of heated water and of treated wastewater, utilization of the zones protected by a plan etc.), an aquaculture project can hardly adapt to the requirements of urbanization and should thus be installed in a less affected zone.

Aquaculture and environment

Although environmental protection is not an activity but rather an attitude, it is at present manifested in the form of actions that can affect aquaculture development.

The relations between aquaculture and environment cover a large number of different elements such as water quality, protection of sites, protection of animal and vegetal species and frequently the political and administrative decision-makers are not familiar with them.

These problems will be dealt with in a special document.

Sites and productive models: problems and identification criteria

Lagoons

Lagoons are traditionally the environment where Mediterranean aquaculture was born. Every lagoon, although different in character, is a potential aquaculture site unless the quality of the environment is irreparably degraded.

Planners have to take into account and study the existing elements of lagoonal zones as well as the characteristics which determine the production goal as a result of aquaculture activities.

The modern management of lagoons tends to consider them as aquaculture environments rather than fisheries fields. The lagoons, where both the products (through efficient fixed traps) and the water flow can be controlled, may be considered as suitable environments for extensive aquaculture. Management criteria in the lagoons appear to be more complex since these environments attract many versatile interests. They should also take into account traditional fisheries activities.

These criteria are based on the control or on the attempt to control the ecological parameters. Ecological characterization can yield fundamental elements for determining the type of production (more profitable production through better utilization of the available trophic energy which often remains unutilized for lack of adequate users.

This new approach which is advocated by the majority of ecologists and aquaculturists may be initially applied in the small or medium-sized sites where the methodologies could be improved. Here there is much to do in terms of scientific research on the environment, taking into consideration the wide available areas hitherto unexploited, which is really the foremost objective to be achieved.

If only the capture of the non-commercial size fish could be reduced or eliminated, production would very easily double. But it is clear that this would necessitate selective traps, integrated aquaculture activities, structures on land, technologies etc. All this however is not easy to achieve. In addition to considerable research efforts, it requires trained fishermen and operators.

For example, there is an annual capture of many tonnes of small under-sized sea-bream in the whole Mediterranean region and this leads to the scarsity of sea-bream fry.

Management criteria for lagoons, therefore, must take into account many aspects (starting from the simplest) which must be considered as a whole. This is true for those environments that are still abundant in fry, whereas in other more exploited and imperilled regions, the strategy recommends seed production for restocking purposes.

Once the environmental potentials have been identified, the problem of producing fry of species suitable for restocking should be tackled.

(a) Identification criteria

As far as lagoons are concerned, even more important than determining the aquaculture sites, is setting up the appropriate general strategy for each separate type of environment chosen.

Aquaculture is in fact only one among many activities carried out in the lagoonal environments, especially in those with the highest level of eutrophication. However, the only identification criterion for defining the aquaculture activities to be improved upon or introduced into the system emerges from a global study of the system.

To put it in a nutshell, both the characterization of the areas and the identification of the methods of management should be based on the inventorization of the following groups of items:

- geographic, geomorphological and hydrobiological aspects;
- ecological characterization of the systems;
- identification of the human activities already existing in the given system.

Choice of sites for semi-intensive aquaculture

Semi-intensive aquaculture in the Mediterranean is carried out in earth ponds. Such production units concern species that are able to exploit the biological substratum which can be improved upon with various types of fertilizers. Production includes fish, crustaceans and molluscs. One of the main characteristics of the system is the fact that the ponds can be emptied completely, which allows appropriate management. The semi-intensive system can be combined with the intensive model through the use of the latter's wastewaters or with an autonomous hydraulic system.

Hydrography

For a site to be considered suitable for the development of semi-intensive, coastal aquaculture activities, it must have a double water supply, both fresh and sea water in order to obtain maximum results. Therefore areas around the mouths of rivers and the terminal parts of areas undergoing solid melioration are in this category. A very important element is the quality and quantity of both types of water.

Climatology

Production in the semi-intensive systems depends to a great extent on external temperatures, a fact that conditions the nature of production cycles.

It is impossible to operate where the climate is harsh, for the simple reason that the species most suitable to semi-intensive rearing do not give good results at low temperatures. That is why, when judging a potential site, we have to consider the climatology of the zone and the annual evaporation rate.

Physiography

It is a fundamental aspect because the systems with horizontal development are based on the availability of large areas meeting the following requirements:

- large areas, not adjacent to important agricultural areas if salinity is very high;
- the land level permits easy earth removal;
- the nature of the land must be such as to enable easy water-proofing; the chemical quality of the waters must not be limiting for the biological phenomena.

Selection of sites for mollusc culture

Considering that molluscs are consumed raw and fresh, their rearing requires the highest category of water quality (cleanliness) and, depending on the technology applied, particular hydrographic and ecological conditions.

Physiographical conditions

Geomorphological conditions do not have a decisive impact on the rearing possibilities; they determine volume and production, choice of technology and techniques applied and exert an influence on the profitability of production.

In the Mediterranean rearing conditions where, as a general rule, "suspension" techniques are applied with the use of portable structures, racks and rafts, the rearing site should in particular:

- be sheltered from waves and winds in order to keep the installations safe;
- possess an even miry-sandy sea bottom for in-suspension rearing;
- be deep enough to make the installation of the floating structures possible and for attaining the volume necessary to obtain sufficient inertia in order to cope with the rapid hydrographical and ecological changes.

Ecological conditions

All conditions, in particular the hydrographical and ecological, should be managed in a flexible manner, in view of the fact that they exert an influence on aquaculture. They should be known and separately analyzed for each rearing site.

For successful mollusc rearing, it is desirable that sea water have the following general characteristics:

- lower salinity (25-35‰)
- higher temperature (above 8°C)
- sufficient quantity of oxygen (near saturation)
- a primary production marked by a well balanced and sufficient quantity of nutrient salts (to eutrophication limits)
- a phytoplankton population of adequate quantity and quality
- dissolved organic matter
- high dynamics of water exchange (currents).

It is desirable, although not a pre-requisite, that the areas chosen for the rearing should also be sites of reproduction and fixing of the mollusc spat in order to obtain a completely closed production cycle.

At the present time in the Mediterranean region, only oysters and mussels are actively grown.

Sanitary conditions

Regarding sanitary conditions, many countries apply the criteria stipulated by national legislation on the production and sale of molluscs. Legislation differs from one country to the next and it is therefore necessary to harmonize and standardize these laws within the entire Mediterranean region. Furthermore, the values of different parameters may exclude or on the contrary permit the rearing and sale (either directly or after treatment) of molluscs depending on the country involved.

Rearing grounds should be free of uncontrolled discharges of waste water and be immune if possible of temporary accidental pollution. The level of seawater pollution should be within the limits prescribed by law.

Selection of sites for fish culture in cages

The main criteria for selecting the sites should be the following:

(a) Physiographical conditions

For fish culture in cages the most suitable physiography is comprized of bays and gulfs sheltered against waves and gales, rather deep and with a fair exchange of water.

(b) Ecological conditions

In general oligotrophic water with major sea currents (exchange of water), with a high saturation in oxygen and with winter temperatures above 10°C, (8°C).

(c) Sanitary conditions

Conditions for the sanitary conformity of waters are more flexible for fish than for mollusc culture, especially the microbiological requirements.

Toxicological conformity of sea water is necessary because of the accumulation of pollutants in the fish tissues.

Selection of sites for the construction of hatcheries

(a) Sea

Considering that sea water is the main primary commodity for hatcheries, it is important that the water be of good quality and free of sediment, in sufficient quantities and without the critical low winter temperatures.

One of the most important running expenses of hatcheries is the heating (cooling) of sea water and it is therefore desirable to have a water column above and below the thermocline for the installation of pumps necessary to obtain the initial choice of temperatures (calories) in the periods without isothermy.

Deeper waters, that is a larger volume of water, result in more rapid changes in the system, something very important for the normal functioning of hatcheries.

(b) Land

It is indispensable, whenever possible, to have flat ground spread out along the sea line not far from pumping facilities. It is advisable that the hatcheries have near-by available space for the construction of installations for fish growing or for their intermediary stages.

In order to save on light, heating and phytoplankton production, it is necessary to have sufficient sunlight (photoperiod).

A naturally protected ground, sheltered from winds and bad weather is preferred, so that exploitation of the less costly structures and prefabricated equipment is made possible.

Grid patterns for the choice of sites per sector

In 3 (a) above, a number of criteria was listed concerning selection and monitoring of different environments, according to different production strategies, under different scenarios.

In this chapter we shall try to define more fully some of the descriptors that should be considered; we will then propose a scientific approach and discuss its practical implications.

Outlining a strategy

The descriptors which enter the procedure belong to two categories that define an equal number of sub-systems: the socio-economic and the technological descriptors on the one hand and the environmental resource descriptors on the other.

To each descriptor can be attributed numerical values on the basis of either the actual measurements or arbitrary scalars. The analysis design should also include the monitoring of the evolution in time of the relevant descriptors.

This information constitutes the inventory of the social, cultural, economic and environmental characteristics of the system under analysis. When the descriptors are organized in a metrical form (e.g. socio-economic elements vs. environmental elements) such as to describe the type and intensity of mutual interactions, a connectivity table is obtained that permits a global evaluation of the system. When the descriptor "aquaculture" is implemented, its position and role in the system can be specified.

It is clear that the above matrix does not necessarily need to be fully scanned when strong hypotheses or evidence already exist on the prevailing importance of a given subset of descriptors.

The compatibility of such a configuration with the new activities, which we wish to integrate into the system, can be assessed by introducing the pertinent descriptors. This will give some indication about the feasibility of the new development and the modifications (and their relevance and cost) that are eventually required for the system to incorporate them successfully. As far as aquaculture is concerned, we will be in a position to evaluate which kind of undertaking fits the system best and which is its optimum extent.

Operative elements

Even though much experience has been gained concerning various ecological and socio-economic situations, very little has been done in the Mediterranean coastal areas with specific reference to aquaculture.

Only recently have theoretical proposals been developed and practical application carried out, both paving the way for further experiments and improvements. The available examples however concern almost exclusively the lagoon environments where a strong scientific tradition, as well as an empirical one (e.g. Italian valliculture) have already produced the bulk of basic knowledge.

It must be added that generally only a limited number of descriptors (mainly biological) has been considered; some of them are neither measured nor measurable. The idea of "confinement" (Guelorget and Perthuisot, 1983) for instance which indicates the degree of "separateness" of a basin from the sea, has proved very useful in the classification of the Mediterranean lagoons and has provided the framework for a new ecological interpretation of these environments. The idea holds however only from the qualitative standpoint as it involves the concept of a manifold ecological gradient which is virtually not measureable as such.

The analogy approach can be very fruitful in producing hypotheses, but these must be tested whenever possible with more formal means in order to avoid the risk of wrong interpretations.

Along these lines of thinking, we may attempt to define the description of a system for aquaculture based on the combination of both the numerical and the analogy approach.

In the selection of a site, for instance, a first approximation to the choice of the appropriate descriptors could consist in considering some of them as reflecting the integral properties of the system under examination. They can thus provide information or allow inference on more general environmental patterns. The case of the ecological structures inferred on the basis of species-composition, which is a biological descriptor, seems particularly illustrative in this sense.

The dimentionality of the problem however requires that at least a cross-reference grid of such descriptors be established. In other words, the "integral descriptors" should be sought and considered in all the homogeneous matrices of the system. This should permit cross-checking of the hypotheses individually derived from each matrix, but concerning the same process or pattern. In a first approximation we can content ourselves with observing the correspondences among these descriptors when deciding on the validity of the hypothesis. Later we can look for correlations (in statistical terms), if necessary.

The problem of an assessment specific to the purposes of aquaculture has to be examined in connection with the various environmental scenarios and production models. It is clear, on the one hand, that different conditions can be expected if we are concerned with the sites that are subject to different levels and kinds of exploitation and stress. On the other, the situations we may have to deal with will vary depending on what and how much per space unit we want to produce, the scale of plants and the technology involved. The assessment of the socio-economic demands plays an important role in this contex.

Generally speaking, the environmental scenarios can be of three main types:

1. Sites which are not subject to significant exploitation of whatever kind;
2. Sites which are already exploited, managed or protected;
3. Sites which are exploited and under stress.

The first scenario includes the coastlines and basins which are away from urban and industrial concentrations of whatever size. No significant environmental stress is observed and the exploitation of resources is small. The development potential is therefore closely related to the natural resources. Only the latter should guide in the selection of the general options.

The main problem the planners have to cope with in this context is to make the fundamental choices taking into account not only the potential but also the fragility of the site being developed. On this basis a sound, long-term plan can be defined. It should include continued environmental monitoring, the intensity of which will depend on the type and diversity of the main development lines. It is understood that the above considerations apply to those situations where development is already in progress although plans had not been made on the basis of an assessment of the type being proposed in this document. In this case, the results of an environmental study may profitably be integrated into the original plans.

As far as aquaculture is concerned, its role in such a scenario can be of great importance. It can represent a promotion factor, as it is an important pole in a diversified production strategy. As such it should be a stabilizing factor in the general development of the site. This concept holds true if we consider that the pleas for ecological conservation largely coincide with the needs of aquaculture in the maintenance of the ecology of a site. It is for this reason, that the selection of the production model should be made on the basis not only of whether it is compatible with other types of development but also on possible mutual reinforcements.

The second scenario encompasses those situations where either one or several uses of the environment are already being carried out at a significant level. No serious stress is observed, but the ecological balance can be eventually broken if new exploitations are added or if the existing ones are expanded. This is a situation common to many areas in the Mediterranean.

In this case, the potential of the site for aquaculture must be evaluated and the production model designed mostly in terms of compatibility and of cumulative effects. The stabilizing role of aquaculture appears obvious in the light of what is stated in the previous paragraph. Extensive monitoring is important because of the multiplicity of interactions that must be expected.

The third scenario includes those situations where a strong environmental impact has been demonstrated or can be inferred. Ecological value is partly lost and this brings about a serious impact on the socio-economic configuration of the area. The natural potential however is not fully compromised as yet.

In such cases, aquaculture cannot be seen but as part of the restoration plans to re-establish the potential of the site. By no means can aquaculture represent a goal in itself; nevertheless it is important since it can introduce socio-economic considerations in the environmental recovery policy which is often not considered from this standpoint.

Patterns and procedures

The objective of this chapter is to propose an operation procedure for the assessment of the main patterns of a socio-ecosystem where aquaculture activities are being considered, or are alredy carried out. In this connection we must point out that the site analysis developed hereafter is designed to satisfy the specific needs of aquaculture. Therefore it cannot be retained as the overall best description of the system except in this precise context.

The analysis aims at describing the mass and energy exchanges within the ecosystem in terms of the biological and socio-economic expressions. In doing this, the system is broken down into the following phases grouping homogeneous descriptors:

-abiotic phase
-biotic phase
-socio-economic phase

The latter incorporates the social, economic and technological descriptors.

In general, the following descriptors can be proposed in site evaluation and monitoring for the purposes of aquaculture. It is assumed that the delimitation of the area has already been carried out.

a) Abiotic phase

1. morphology: values for area, depth, volume, sediment granulometry. The shape of the coast, as well as that of the basins and their inlets and outlets must be recorded, possibly in the form of digital maps.

2. climate: values for air temperature, relative humidity, wind frequency, direction and speed, rainfall, sky cover, irradiance. This information should be derived from the statistics obtained from long time series (e.g. 25 years) and is normally available, at least at regional scale, almost everywhere.

3. hydrography: values for current direction and speed, waves, water temperature, watershed, in-and-out flows. Generally speaking, the hydrographic parameters can be simulated by means of mathematical models, but they should always be validated through field observations.

4. chemistry: values for oxygen, salinity, nitrogen (different species and total), phosphorus (total and reactive), silica, total organic matter (water and sediments), other pollutants, if sources are detected. The dispersion of zero-mass tracers (concentrations) can be simulated but a data set of measured values is necessary. Nevertheless, interaction with the biotic component of the system must be taken into account.

b) Biotic phase

5. pathogenic bacteria: in principal, faecal coliform concentrations should be monitored. Other micro-biological forms should be identified when specific needs occur.

6. phytoplankton: values for total biomass (both as photosynthetic pigments and cell numbers), abundance and dispersion of the principal taxa, production.

7. zooplankton: values for total biomass, abundance and dispersion of the principal taxa.

8. phytobenthos: values for total bio-mass, abundance and dispersion of the principal taxa, production. Estimates of these values over the area under analysis can be obtained on the basis of a limited number of samples using interpolation techniques.

9. zoobenthos: values for total biomass, abundance, dispersion and biometry of the principal taxa. If we consider a number of relevant constraints (mobility, patchiness), these values can be predicted in the same way as for the phytobenthos.

10. necton: population parameters of the species having an economic interest should be obtained through the usual stock assessment and dynamic techniques. Gut contents (food item frequency) should be analyzed at least for each age class. In the case of confined environments, migrations should be studied.

c) Socio-economic phase

As for the socio-economic descriptors, there are severe difficulties in the definition and quantification of some of them. For this reason, the socio-economic phase has been listed here only pro memoria and will be dealt with in a separate paper.

The sampling strategy

The sampling design is the crucial point of the whole procedure since the final results will entirely depend on its effectiveness.

It must be stated right away that space and time scales must be adequate for the feasibility and cost of the observations, in relation to the desired accuracy, on the basis of the hypotheses that have already been formulated. This is true also in relation to the type of data analysis that is envisaged.

The theoretical upper and lower limits of the observation scales between which an optimal solution can be selected for practical applications must be defined. These solutions are obviously not the same for all descriptors.

As the sampling design has to be adapted to each individual ecosystem, especially when dealing with coastal lagoons, a general workplan cannot be established. Whenever possible, a preliminary survey should thus be carried out with the aim of defining the principal characteristics of the environment, on the basis of the information available and its critical assessment.

A pilot sampling should then be carried out on the basis of the results of the survey and of the numerical simulations that are possible at this stage. This pilot sampling should serve to select (1) the most relevant descriptors (also taking into account their "integration power"), (2) the suitable observation scale (space and time) for each of them and (3) the optimum sampling size for each biological compartment. A pre-validation of the simulation models could also be performed.

Generally speaking, the pilot sampling should consider at least the following descriptors in: (1) morphology (all items, with particular reference to sediments), (2) climate (all items), (3) chemistry (salinity and oxygen), (4) phytobenthos (species composition and biomass), (5) zoobenthos (see phytobenthos), (6) necton (observations on the dispersion of principal species, with particular reference to juveniles). Descriptors 2 and 3 should be collected along a tide cycle, at least every third hour.

The samples for sediments should be collected in the nodes of a grid whose mesh size is to be defined according to the extention of the study area. The benthos should be collected on the basis of the apparent physiographic heterogeneity of the environment, taking into account possible "confinement" gradients.

Conclusions and recommendations

Although the socio-economic aspects of Mediterranean aquaculture are yet to be dealt with and presented in a paper, it has been possible to draw the following conclusions and recommendations concerning spécifically the identification and protection of sites suitable for aquaculture activities.

(a) Aquaculture includes many types of activities which are linked with the environment in which they are carried out. The development of aquaculture is largely dependent on the availability of suitable sites. It is therefore necessary to identify, classify and determine the use of these sites and to protect them. All this should be regulated and defined within the framework of (i) national development policies and (ii) integrated planning of coastal zones in each Mediterranean country. Furthermore, when deciding on development strategies and priorities, the role and significance of aquaculture should be taken into consideration.

(b) It is necessary to draw up an inventory of available resources for the development of aquaculture and especially an inventory of suitable sites. The task should be entrusted to a competent multidisciplinary team of experts.

(c) Departing from the established development policy, and on the basis of the inventory of sites, a choice should be made among them for the development of aquaculture farms. In selecting the sites, the impact of existing or planned conflicting activities, as well as the impact of future aquaculture farms on the environment, should be investigated, preferably by applying suitable Environmental Impact Assessment methods. The results obtained will be decisive for the final choice of sites.

(d) The selected sites should be protected by the appropriate physical plans and other planning methods currently available. The implementation of planning decisions should be accompanied by effective control measures.

3. ECOLOGICAL, SOCIAL AND FINANCIAL ASPECTS OF COASTAL AQUACULTURE IN THE MEDITERRANEAN REGION

by

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Introduction

Contrary to freshwater pond culture, modern aquaculture (1) in brackish and marine waters is of relatively recent origin in the Mediterranean region. Pond culture of freshwater species like carp has been practiced in some Mediterranean countries since medieval times; today, freshwater aquaculture can be considered as a technologically and economically established field which is horizontally and vertically integrated in the primary production sector.

The culture of brackish water species, i.e. their growth under controlled conditions in marine and brackish water areas is, in most cases, neither established nor integrated in the sense indicated above. Traditional systems of extensive lagoon exploitation, which have existed for centuries in many parts of the Mediterranean littoral, co-exist, without great conflicts so far with sectors like capture fisheries and agriculture. Generally speaking, such systems have neither degraded their resource base, i.e. the aquatic habitat, nor endangered their economic viability by saturating markets, clogging distribution channels or creating monopoly situations.

The question this paper intends to examine is therefore the following: why have the considerable efforts of the last decades to raise the performance of the traditional patterns of lagoon exploitation, through the introduction of more intensive aquaculture systems, remained, (with some exceptions) an external element within their own geo-financial and social context? The hypothesis discussed here is that innovation concerning aquaculture systems in the coastal, lagoonal and estuarian areas of the region has almost always been understood and envisaged as a bio-technical task, with inadequate consideration of environmental, macro-economic and socio-economic factors.

Environment and aquaculture in the Mediterranean

The coastal zone constitutes the geo-physical resource for mariculture (2) in the overall sense. Out of this large geographical area, three types of environments are of principal interest for mariculture:

(i) lagoons
(ii) estuaries
(iii) sheltered coastal zones

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1. Historical records show that in ancient times both the Romans and the Egyptians practiced some forms of brackish water culture.

2. We will use the term "mariculture" in the wider sense here, including aquaculture in both marine and brackish waters.

Lagoons and estuaries have been exploited with a certain level of management for a long time in the region. Whether these traditional systems of resource management are subsumed under small-scale fisheries or labeled as rudimentary forms of aquaculture is perhaps a question of semantics. Their exploitation pattern has however evoked territorial use rights claimed by the respective user groups, limiting "open access" which is generally assumed in capture fisheries. They have also been the base of indigenous development of veritable aquaculture (valliculture in Italy, "howash" system in Egypt).

Protection of the environment for and from aquaculture

As a final remark we believe it important to stress that coastal aquaculture depends on an intact environment on the one hand, but can also endanger the same environment on the other. Even extensive systems of lagoon exploitation can reduce recruitment rates by non-selective harvesting and impede water exchange with the open sea if fish traps do not allow a sufficient rate of water flow. Intensive systems can, through unused feed residues, contaminate the waters and spread disease, if no strict sanitary control measures are taken. In order to establish a legal framework which would protect the environment from hazards created by aquaculture - and thus protect an aquaculture potential from aquaculture itself - it would be useful to analyze existing legislation in freshwater aquaculture. Schemes of environmental protection of coastal resources can possibly benefit from existing programmes and prevent repetition of past mistakes. Important areas to be regulated include the following:

(i) type of construction to be allowed;
(ii) areas to be used;
(iii) intensity of the operation;
(iv) sanitary standards and
(v) professional standards of the operators.

Macro-economic determinants of aquaculture development

For national economies and the decision makers aquaculture is one of the many possibilities of making use of physical, human and financial resources. As part of the primary sector, i.e. the sector of the economy which provides food, raw materials etc., aquaculture competes with the other subsectors for the use of these limited resources.

Whereas in a centrally planned economy the choice of how to use resources is made on the basis of centrally set priorities, in a market economy different interest groups are in competition. However, even in the most liberal political systems, the public authorities exercise an influence through legal measures, tax policies and subsidies. Whether centrally planned or indirectly steered and influenced, the choice of how to use the existing resources should take into account how the national economy will derive the greatest benefits (3).

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(3) It goes whithout saying that influence is not imposed only from top to bottom, i.e. from the government to the different sectors of the economy and their protagonists, but also vice versa from interest groups at the production level to the decision makers in public posts.

The use of the coastal environment, i.e. the physical resource for mariculture, is the object of competition of several interest groups from industry, tourism, fisheries, agriculture, human settlement and conservationists. In what way mariculture can offer an ecologically viable alternative or create potential hazards has been discussed above; in the macro-economic perspective aquaculture has an impact on two different levels:

(i) the production level: by producing fish and shellfish for human consumption, aquaculture yields potentially three categories of macro-economic benefits: (a) it supplies food for domestic consumption, thereby improving the food-balance; (b) it may substitute for imports and save foreign exchange, if the country is a net importer of fish and fisheries' products and (c) it may provide foreign exchange earnings, if the product is exported.

(ii) the producer level: by creating revenues aquaculture contributes to the overall performance of the economy; by creating individual income, it generates demand; i.e. it strengthens the internal market.

As in every concrete context, in the Mediterranean region too these ideal-typical formulae imply a number of "ifs". If there is a lack of proteins in the country and if the consumer groups in need of protein can afford the fish, aquaculture can contribute to the food balance (as is the case in Egypt). If aquaculture produces the species which, according to consumer preference, are imported, and if the produce is marketed domestically, foreign exchange can be saved (as, potentially, in Greece). If there is an export market for the species produced and if the revenues are in foreign exchange and recycled domestically, aquaculture can be of benefit to the balance of payments.

A similar set of conditions applies to potential benefits on the level of the producer. Aquaculture produces values which accrue to the Gross National Product; if however the costs to the national economy to achieve these values are, in the long term, dispropotional to the accrued benefit, the economy loses. Income and employment opportunities created through aquaculture can strengthen the internal market, i.e. the demand for other products, if their quantity (number of jobs) and quality (income levels) are significant and in some balance with economic costs. Again, it has to be underlined that in the Mediterranean, coastal aquaculture is a relatively new technology; efforts to introduce new systems cannot be measured with the same yardstick as efforts to improve long established systems. Innovation in this sense means investment with a perspective of long-term returns. Success however depends on adequate and realistic planning.

It is appropriate for example that a new and still experimental technology is publicly financed with respect to research and development infrastructure. It is hazardous on the other hand to finance the same unproven technology on the production level, not only because of the probable immediate losses but also because failure in the early stages of technological innovation may discredit a potentially valuable system which, given more time to mature, may show a positive economic performance.

Socio-economic considerations

The macro-economic background of aquaculture development is defined by the needs and priorities of the national economy and the relative (with respect to the different user categories) availability and nature of the physical resource. The decision of the individual producer to invest his capital and labour in coastal aquaculture is directly influenced by the investment climate.

However, whereas conventional production economics assumes this decision to be taken purely on the basis of the expected financial returns, the socio-economist takes a more globalview of how the individual and groups of individuals act and interact on the production level. While considering financial cost benefits on the farm level, the socio-economist looks at macro-economic and ecological determinants. Furthermore, he tries to avoid the reductionist view of many economists who understand the producer as a "homo economicus", i.e. an individual who acts solely with the aim of maximizing his revenues. Especially in primary production, tradition, values and social interaction are important determinants to be added to the set of economic and ecological variables which influence the path of development. This applies particularly to the developing countries bordering the Mediterranean to the south. In traditional systems of lagoon exploitation we often find systems intended to maximize socio-economic benefits, i.e. to provide a maximum number of families with an adequate income. These traditional ways of resource sharing, which to some extent are also found in small-scale fisheries, become u[illegible]able if the resource is not sufficient to meet the needs of local population groups.

In many lagoons, external effects like pollution and increased fishing pressure as a result of underemployment in land-based sectors of the economy have reduced yields and created competition and conflict. Better resource management and a progressive change to low/medium intensity aquaculture could increase yields and meet the needs of the user groups. Slow, progressive technological change could be tuned to the cognitive capacities of these groups and their ability to accumulate, step by step, the neccessary investment capital.

In the Mediterranean region this type of "appropriate" technological change has not taken place, (with few exceptions such as in Italy where however it was often accompanied by privatization and concentration of the means of production in fewer hands). The reasons for this are manifold:

(i) Traditional lagoon exploitation, like small-scale fisheries, was more often than not ignored or bypassed by the dynamic development of sectors like agro-industry, industry, tourism. It remained an unknown entity until it was rediscovered as the area for aquaculture development.

(ii) Modern systems of marine and brackish water cultures, although inspired by traditional shellfish cultures in Europe and indigenous fin-fish cultures in Asia were, and continue to be, largely a product of laboratories, lecture halls and academic institutes, i.e. an external element to existing traditional systems.

(iii) Being under pressure to demonstrate economic viability and to provide eventual benefits for the economic system that had financed the experiments, the aquaculture lobby only tried to find a habitat for the new technology, rather than to adapt the technology to the ecological, social and economic needs and conditions of a given area.

(iv) The selection criteria were predominantly bio-chemical, topographic and hydromorphological. Apart from the fact that many of the technologies were still in an experimental stage, economic considerations such as how to provide production inputs, cost-benefits and market aspects were ignored at least initially.

(v) In the absence of an adequate legal framework as well as medium and long-term development plans for the emerging sector in most Mediterranean countries, the predominantly bio-technical level of decision making led to an uncoordinated establishment of production units which often ignore their social and economic context.

(vi) Through over-optimistically subsidized finance opportunities investors were attracted on a scale which often did not correspond to either the financial or the economic feasibility goals which one could realistically expect.

Perhaps the most critical feature of the emerging marine and brackish water culture schemes is the general emphasis on intensive systems, which further aggravates most of the problem issues listed above. Dependency on ongoing research (as many of the bio-technical problems are not solved), technical assistance (which often has to be provided externally), expensive production inputs (like composite feed which most countries have to import) and foreign markets (which are not sufficiently known and cannot be controlled by the producers) makes the intensive systems very costly, especially for developing countries. Because of their cost structure both in terms of investment, and fixed and variable costs, these countries have to concentrate on high value species for which the domestic purchasing power, at least in the southern Mediterranean states, is not sufficient. The narrow profit margin between cost price and farm-gate price and the absence of domestic markets which can act as a buffer if export demand slackens make these ventures, from a marketing point of view, totally vulnerable.

Socio-economically speaking, intensive systems provide, in relation to the investment they represent, a minimum of benefits in terms of employment opportunities, i.e. positive effects on equitable income distribution. It could be said that in this respect, the socio-economic appropriateness of coastal aquaculture decreases as the intensity of the respective system increases.

From the above it is obvious that extensive and semi-intensive systems are, macro-economically and socio-economically, more adequate. Whether they prove equally preferable, with respect to competition for the use of coastal resources among the various sectors, e.g. tourism, industry, human settlements etc., will largely depend on regional and intersectoral planning.

Planning for aquaculture development

Since the development sequence outlined above has created a dual structure of coastal aquaculture (i.e. traditional extensive and modern intensive systems) in the region, concerted and dynamic efforts will be necessary to increase the homogeneity of the sector. At present there is an organically growing subsector which progressively moves from extensive to semi-intensive management. Only in some instances are these systems linked with intensive elements, such as artificially produced fry which is needed for stocking the semi-intensive systems in managed lagoons. This process, already advanced in for instance Italy, is only in its infancy in most other countries. On the other hand there are several intensive schemes scattered over the region, implemented mostly on an ad hoc basis and largely as a direct result of indirect or direct public or semi-public subsidies. In some instances the latter represent an obstacle rather than an impetus to the sector. Because of a certain affinity of governmental and financing agencies to sophisticated technology, such advanced technology schemes are given preference.

For the time being regional, national and local planning efforts must focus on the following priorities:

(i) a re-orientation of the development strategy towards improvement of existing extensive exploitation patterns and a step-by-step change to semi-intensive systems which have to be in line with the absorption capacity of the local target groups;

(ii) an adjustment, on the part of government and financing agencies, of the approach to promote intensive systems to the effect that the latter will either serve as pilot/demonstration units to pave the way for future development (in this case public support will be justified) or prove their economic viability as private enterprises in the market-place and within the framework provided for other ventures operating in the private sector;

(iii) the establishment of social and economic priorities designed to maximize medium and long-term benefits for the community, region or nation, in line with overall and parallel temporal and spatial development plans in order to make coastal aquaculture an integral part of the local production structure and the national economy;

(iv) the improvement of vertical integration of aquaculture by including the ecological dimension, i.e. to define, implement and enforce concerted action to ensure a rational and sustainable use of the coastal resources. In this context the social and economic priorities of the communities and the national economy have to receive increased attention, in order to provide a long-term strategy of resource sharing among the various sectors operating in the coastal environment, and

(v) the establishment of a regional information system to provide the producers with medium and long-term demand forecasts for aquaculture products.

Because the limited scope of this paper, it is not possible to go beyond suggesting various measures, e.g. by outlining planning methodologies. Perhaps as an unorthodox postulate we would however encourage an approach to planning which may counterbalance the philosophy employed so far. Until recently - and in an exaggerated sense - a given technology, after being developed on laboratory scale, was transferred to a bio-technically suitable environmental substratum under the assumption that markets could easily be found. In the Mediterranean context it could however be advantageous to look at the environment, i.e. the physical resource and its economic, social and cultural implications on the one hand and at the internal and external markets, i.e. consumer preferences, demand and price structures, dynamics and trends etc., on the other and then decide upon which technology would be the most appropriate. Appropriate technology in this sense would imply sustainable and participatory use of the resource as well as long-term maximization of social and economic benefits.

Regional assistance to aquaculture development

The role of international agencies is of particular importance with respect to the tasks indicated above. The collaboration of UNEP (through PAP/RAC) and the UN (through MEDRAP) has already yielded good results and will continue.

MEDRAP will organize, during 1986, a workshop with the aim of establishing a planning methodology, along the lines mentioned above. The project will further tackle the task of providing realistic market information. A possible further contribution to a more global approach to mariculture development would be constituted by an information medium, such as a newsletter, where different countries, agencies and individual contributors could communicate their experiences. With this and other measures intended to change the technocratic path of mariculture development, UNEP would play an instrumental role to safeguard the environment, i.e. the resource without which no primary production is possible.

MEDRAP, according to its terms of reference, will continue to promote aquaculture in the region, with new emphasis on marketing and socio-economic aspects.

Both programmes should, in the sense indicated in this paper, advocate the importance of the social and macro-economic dimensions in their respective fields of work, in collaboration with each other as well as with other international agencies or organizations (like the EEC). The overall objective would be a coordinated, integrated and total approach to coastal aquaculture development in the Mediterranean.

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4. REVIEW OF MISSION REPORTS ON THE SELECTED AQUACULTURE SITES

by

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Introductory remarks

In order to cover some of the most relevant environmental and production scenarios in the Mediterranean coastal areas, seven localities with different characteristics were preselected. Prerequisites for site selection were certain aquaculture activities either implemented or planned, the interest of public and/or private agencies, the existence of favourable logistic conditions and research facilities.

The first four mission reports (Turkey, Egypt, Spain and Yugoslavia) yielded sufficient information in order to reconsider originally drafted joint projects (not only the nature and the number of activities but also the architecture, timing and components of the budget). Following these considerations, the project has been reformulated and organized so as to include:

(a) a Pilot Programme, to integrate previous data, to prepare pre-models and to start the operational calibration of the Project;

(b) a Core Programme, including a minimum of basic activities that could be performed at all sites and

(c) Parallel National Activities (so-called Satellite Programmes), to perform, in individual Local Units, specific programmes which can be developed independently, but consistently with the Core Programme.

The recent missions to Morocco, Tunisia and Algeria have followed this reformulated scientific component of the project.

Mission objectives

The objective of the missions was to evaluate in cooperation with the local experts the feasibility of project implementation with the following terms of reference:

- to obtain and analyze existing data;
- to have an insight into various on-going or scheduled activities with particular reference to ecological investigations;
- to have an insight into on-going and/or planned aquaculture development, its form and expected production;
- to discuss project proposals with the local experts;
- to set up the Local Units.

General observations, conclusions and recommendations

It is a fact that the national development plans in all the Mediterranean countries visited pay great attention to aquaculture development. In almost all selected sites there is both a scientific basis and a beginning of aquaculture activities. Well developed scientific knowledge and farms operating on a commercial or semicommercial scale exist in Yugoslavia, Morocco, Tunisia and Egypt, while aquaculture development projects have been launched at the visited sites in Turkey and Algeria; they are being studied in Spain.

As for programmes related to the joint project they exist to a certain extent in practically every country. They are often linked to on-going or planned national aquaculture development plans for which it seems that local financial support is available everywhere. Motivation and a climate of cooperation are also positive factors. The interest to participate in such an international programme is also strengthened by the opportunities for academic output on an individual basis.

The priority needs of most countries are: identification and protection of sites suitable for aquaculture, proper management of such sites, specialized staff and finally research and production facilities. Almost everywhere there are numerous published and unpublished data concerning the ecological properties of the concerned equatory. However, most of these are of limited value due to variations in the space and time of sampling; some components or individual descriptors of the ecosystem have never been studied. Data for certain groups of descriptors are not available at all sites. Most of the data are only qualitative, even in recent studies. Expertise and manpower are unevenly distributed; proficiency is much to be desired in many cases.

Taking into account the above considerations, we can make the following recommendations: It is obvious that aquaculture must be based on scientific knowledge if commercial production is to be successful. It is indeed important to make possible the exchange of knowledge and experience among the various countries, but the methods proposed should be tested to determine their applicability under particular conditions. As aquaculture develops further in the various countries, it will become necessary to establish institutional training of fish farmers.

Assistance and guidance to local staff should be secured. This should be done not only by means of providing the necessary documentation but also by improving and promoting the motivation and willingness of participants through both financial and direct scientific support, including advanced training and related activities that can broaden individual experience and contacts.

As for additional data, they should be collected in a consistent manner by selecting those descriptors that on the one hand provide valuable information and on the other do not create technical or quality control problems in sampling or measuring. This will require a standardization and intercalibration of sampling and measuring techniques and of quality control procedures. Equalization of the instrumentation and laboratory/field facilities among participating institutions to a minimum common standard adapted to the proposed workplan is considered essential.

A N N E X

5. MISSION REPORTS

MISSION REPORT FOR PILOT OBJECT KAAR EL-BAHR LAGOON (MANZALAH LAKE, EGYPT)

by
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Site description

The Kaar El-Bahr lagoon is an integral part of lake Manzalah which is the largest of the four coastal lakes within the Nile delta system occupying a surface of 1350 km^2. The major basin has several direct connections to the sea, with the largest lake-sea communication at El-Gamil. Irrigation waters collected by a system of drain canals feed the lake indirectly from the Nile. It is thus a transition basin where active transformations occur between land drainage and the coastal Mediterranean waters.

The Kaar El-Bahr lagoon is located on the south-east edge of lake Manzalah. It has a south to north axis which is twice as long as the east to west axis. The lagoon was separated from the main lake basin by the construction of a dyke which extends from east to west along the Al-Kabouti passage. The greatest part of the land boarding the lagoon lies at present on the southern shore; it is partly under cultivation.

The lagoon shore line, particularly on the western side, is covered with submerged higher plants represented by Potamogeton sp. and Ceratophyllum sp. rising up to the water surface. This macrophyte subsystem has an essential function in the lake ecosystem: besides restoring healthy oxygen conditions it provides the substratum for a variety of sessile organisms and a feeding ground for many others.

Generally speaking, the lagoon is shallow, with depths that range from half a metre to 1.2 metres. There are a few submerged islands scattered in the lagoon.

Review of available data

Various abiotic and biotic aspects of lake Manzalah have been studied, with particular reference to hydrographic features, chemistry, plankton, fishery biology and sedimentology. Unfortunately, very few data concern the Kaar El-Bahr lagoon itself, even though its water has been used for farming; this is where the Rashwa Gray mullet farm is located; it was chosen as a MEDRAP pilot object.

The only field work in this lagoon was done very recently and concerned mainly the study of the lagoon water quality. This lagoon is also the supply source of the Raswa fish farm (Abess, 1986, unpublished data). A significant increase in salinity was recorded in the lagoon (about 22°/oo), compared to the Manzalah lake salinity (5°/oo). The concentration of ammonia and suspended organic matter showed a tendency to decrease from east to west. The records of plankton show the dominance of euryhaline forms with mixed populations of very different biogeographic origins. It was observed that fresh-water cladocerans and copepods mix with brackish rotifers and various coastal Mediterranean forms. Variations in the phytoplankton composition were also observed, with diatoms accompanied by some green and blue-green algae.

For the entire Manzalah lake it is believed that the heavy grazing due to massive proliferation of pelagic herbivores is the major factor controlling the time sequence as well as the extension of blooms in space and time. The abundance peaks of zooplankton are regularly followed by a drop in the phytoplankton standing crop.

As far as nekton is concerned, it was shown that mullet is associated with the pelagic ecosystem and Tilapia with the macrophyte system. Tilapia is predominant, with an estimated relative yield of 82%, compared to 7% of the mullet species.

Carnivorous fish contributed only 3% to the total. Productivity, as judged by the total fish catch, has doubled in the last 20 years; this would indicate a healthy condition of the basin, but a eutrophication trend as well, particularly in the south-east basin of the lake, where the Kaar El-Bahr lagoon is located. Increased phosphate and decreased dissolved oxygen is a general trend in lake Manzalah, occurring at an accelerated pace in the last decade.

Conclusions and recommendations

Among the six coastal lakes along the coastline, Lake Manzalah (1350 km^2) has been chosen by the Egyptian Authorities as the centre of marine and brackish water aquaculture development. Following this decision, the Rashwa fish farm was established near Port Said at the eastern edge of Lake Manzalah, in the vicinity of several private marine fish farms. With the approval of the Egyptian General Authorities for Fish Resources Development (G.A.F.R.A.D.), and after the completion of several FAO missions (MEDRAP TR 83/5; MEDRAP TR 85/5; MEDRAP TR 85/8), the Rashwa fish farm, located on the edge of the Kaar El-Bahr lagoon was selected as MEDRAP pilot object in Egypt.

Rashwa and the other fish farms in the surrounding area are provided with water from the Kaar El-Bahr lagoon (with a surface area of approximately 10-12 km^2) and their water is discharged into the same lagoon. Unfortunately, until very recently, the water quality in this lagoon had never been studied, and there is currently no continuous monitoring either in the lagoon or in the fish ponds of the Rashwa fish farm. There is also a lack of information on biotic factors, especially on phytoplankton and zooplankton populations.

El Gamil, next to the Kaar El-Bahr lagoon, is to date the most exploited site for wild fish fry capture, especially for mullet species cultured in the neighbouring farms. In addition to the need to improve management, particularly in terms of appropriate fertilization (time and quantity), capture, transport and handling of fry, it seems that the lack of environmental control in the lagoon is the principal problem.

Since the Kaar El-Bahr lagoon, as the site chosen for the joint FAO-MEDRAP-PAP/RAC project, is integrated in the already existing aquaculture development programme in this area, it is expected that the results of these environmental studies will be directly used by the production sector. Moreover, such a project could serve as a data and training basis for other lagoons in the Manzalah Lake area, as well as for other similar sites in Egypt.

Taking into consideration local conditions, particularly the professional staff and the equipment available, this joint project can only be implemented under specific conditions. Namely, the scientific staff of the Fish Nutrition Department, which will be involved in the implementation of the programme, is especially qualified to work in fish nutrition, water quality and soil analysis. Scientists from the Institute of Oceanography (Ministry of Scientific Research) might take part in the project according to specific needs, particularly in phytoplankton and zooplankton studies. If for any reason this should prove impossible, special training of the staff will be needed at least for phyto- and zooplankton studies. In addition, the scientific staff contribution should be complemented either on a permanent basis or through consultants both from Egypt and other countries especially in the field of sedimentology, phytobenthos and zoobenthos, pesticides and hydrocarbon analysis.

As concerns project implementation it must be stated that the laboratory is mainly equipped with instruments for hydrology and hydrochemistry (spectrophotometre, 4 sets of transportable multiprobes HACH), certain basic instruments, such as a high accuracy balance Mettler HP, 2 binocular microscopes and some basic equipment for bacteriology.

Thus, the programme contribution regarding equipment should include the following:

- inverted binocular microscope for Utermöhl procedure (1);
- sampling bottles, type Nansen or Van Dorn (3);
- zooplankton net, 250 um mesh size "Bongo" (2);
- Van Ven grabs 0.1 m^2 for sedimentology (2); and
- insulated boxes for the preservation of samples in the field.

Since the laboratory possesses no boat, which is necessary for research in the lagoon, we recommend that the Local Unit investigate the possibility of cooperation with other authorities for this purpose. If this should fail, a small boat with an adequate engine (6-10 HP) should be provided through the project.

MISSION REPORT FOR PILOT OBJECT TUZLA LAGOON (TURKEY)

by

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Site description

The Tuzla Lagoon has a water surface of approximately 320 ha and is connected to the sea by a channel which is 3km long and approximately 0.5 km wide. The depth of this channel varies from 13 m at the entrance to 2.5 m near the end where there is a net enclosure. Fresh water from the Kavaklar river enters the lagoon from the south-east. The influence of both sea water and fresh water provides the basis for typical euryhaline balances in the lagoon. According to the information available, the depth of the greatest part of the lagoon, which extends to the south and east of the net enclosure, does not exceed 0.5-1.5 m.

The shores of the lagoon are rather flat in the eastern and south-eastern parts, gently degrading in the other. Due to heavy rainfalls, the eastern part of the lagoon is liable to flooding.

Apart from a small fishing village, located on the shores of the channel halfway from the sea to the lagoon, there are no other human settlements. On the basis of the information available, no tourist development or human settlements are planned.

The lagoon is linked to the main road which runs 1 km east of it. This dirt road crosses the lagoon and runs along the shore up to the outlet to the sea. The road runs over five bridges which allow communication between the two parts of the lagoon.

Review of the available data

There is little information on the Tuzla lagoon. Some data, summarized in a national report with the title "Feasibility studies on the vallicultura system in the Tuzla lagoon" and including consideration of the possibilities for cage culture production of the gilthead sea bream in the Guvercinlik bay, illustrate some basic environmental features. Data on water conditions (temperature, dissolved oxygen, weather conditions and tidal situation are also available in the Marine Research Centre in Bodrum, but are unpublished as yet. Additional biological characteristics of the Tuzla lagoon (phytoplankton, zooplankton and necton) are available through the international project for aquaculture development in the Guluk area; this project aims at identifying the resources and suitable sites for aquaculture implementation with particular reference to lagoons. The latter project is carried out jointly by an Italian company (Agroteam, S.R.L.) and the Turkish Ministry of Agriculture, Forestry and Rural Affairs.

The climate of the region is temperate, with prevailing rainfall during the winter months. According to the data from the Bodrum Regional Meteorological Service, the annual average precipitation, calculated for 3 years, is about 700 mm.

During the warmest season (July) the monthly average of air temperature is 27.7°C, while the monthly average in the coldest period (February) is 10.5°C.

Water temperature ranges on an average between 13°C in winter and 28°C in summer. For a few days in February, the temperature can drop to 6°C, while in July, maximum values of up to 32°C have been recorded. In order to protect the fish population in the lagoon from the low winter temperatures, a winterising channel has been constructed recently.

Salinity varies depending on the season. Because of river influence it was approximately 1°/oo during winter (Agroteam, February 1985), while in December 1986, after a long period without rainfall, the measured values ranged between 28 and 33 °/oo (Mission measurement). In winter, the discharge of the river is consistent, approximately 6-8 m^3 sec^{-1}, and the level of the lagoon is frequently higher than the level of the sea. Since the river influence is not necessarily felt during the entire length of the year because of the use of the river waters for irrigation purposes during the summer period, the level of the lagoon tends to be lower than the level of the sea. Those two situations cause salinity variations in the lagoon.

The bottom of the Tuzla lagoon is covered by a stratum of very fine mud. Prevailing phytobenthic communities are Posidonia sp. and Zoostera sp.

As far as planktonic populations are concerned, both fresh water and sea water forms were reported from the lagoon. The dominant freshwater phytoplankton species are Chlorella sp. and Achromatium sp. Seawater forms are represented by two taxa: diatomea and dinoflagellates.

Rotifers, typical brackish water forms, are common zooplankton species in the lagoon. Due to the flow coming from the sea, a high number of marine zooplankton species occurs. Dominant taxa are copepods, with Oithona sp., Acartia sp., Temora sp. and Calanus. Cladocerans are represented by Evadne sp. Larval forms of Polychaeta, Cirripedia, Lamellibranchiata and Decapodes are also found.

The dominant, financially important fish in the lagoon are Grey Mullets, eels and different species of sparidae (Sparus aurata, Diplodus sargus, Puntazzo puntazzo and Boops salpa). As fingerlings they live in the lagoon and move to the sea when adult. The abundance of these species, particularly of the Gilthead sea bream fingerlings (Sparus aurata), is encouraging for its exploitation in aquaculture. Other species can be caught in the sea (Cuttlefish, red mullet, sea bass, sole and shrimp - Peneus Kerathurus).

Conclusions and recommendations

The Marine Research Centre of Bodrum is one of the best known centres for research on sponges, not only in Turkey but also at world level. With its advanced applied research on sponge stock assessment and processing treatment, the Centre can provide guidelines for other institutions and the sponge industry, which is an important socio-economic factor in the region. However, the involvement of the Centre in lagoonal research has only started in recent years, following the increased interest of the Turkish government in the development of an integrated strategy of fisheries management in the Mugla region. With the implementation of such a project, the Centre will make a major contribution to intensive research consistent with the plans adopted by the Turkish government.

One example of the activities planned is the assessment of fingerlings in the Tuzla lagoon, which will start in January 1987. This is a very important programme, since these fingerlings could easily be used in the future for intensive large scale net-cage culture in the Tuzla lagoon area. Furthermore, the Centre has already conducted studies on sea-bream cage culture in the Guluk bay; the experiment gave encouraging results. It is expected that the joint project will contribute to the stock assessment of the available natural population and provide guidelines for national management of the stock.

Six out of 35 staff members of the Centre are scientists; three of them are agricultural engineers and three are biologists. The scientists are greatly interested in the proposed project. Two scientists have already benefited from MEDRAP seminars on shellfish culture (Spain) and artificial reproduction of marine species under controlled conditions (Yugoslavia).

With regard to the successful implementation of the joint project, it should be noted that the personnel needs to be properly guided and adequately trained, either in courses abroad, or by experts sent to Bodrum. These possibilities have been included in the project and money has been earmarked for their implementation. Furthermore, the Centre should be provided with guidelines for standard measurements, which are to be carried out within the framework of the research programme for the Tuzla lagoon. Research equipment is at present limited to the basic but useful tools for hydrography (O_2, pH, salinity metre) and the devices needed for research on sponges. With the exception of a 6 m, high speed boat, not appropriate for lagoonal research, there are no other research vessels. However it seems that the Turkish authorities are willing to make further investments in order to boost research in the Mugla region, as can be concluded from the recent purchase of some modern instruments and the plans for the purchase of a research vessel.

The Centre possesses excellent diving equipment, very suitable for benthic studies within the framework of the Tuzla project. However the equipment of the Centre should be upgraded; in order to meet the requirements of the joint FAO-MEDRAP-PAP/RAC project, it is necessary to secure one multiparameter probe, five current meters, one echosounder, one sievet set for granulometry and one wind frequency-direction-speed metre.

MISSION REPORT FOR PILOT OBJECT LIMSKI KANAL (YUGOSLAVIA)

by

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Site description

The Limski Kanal is approximately 11 km long, 600 m wide, with a maximum depth of about 33 m. The shallow part is characterized by a significant influence of underground fresh water with organic matter and this makes it the richest part, suitable for oyster and mussel culture. There are plans for the deeper waters to be used for intensive cage fish culture. Even though oysters and mussels represent the most profitable products of mariculture activities in the Limski Kanal, this project is intended as an integrated system of parallel growing of shellfish and fish (primarily sea bass and gilthead sea bream). About 35 km of long-line culture of oysters and mussels have been established in a polyculture system. Two parallel lines have been stretched side by side to make the most effective use of the natural feed. Over 1 million oysters and 200 tonnes of mussels are currently produced.

For fish culture, a floating raft system is used; it is made of 16-18 cages, with a volume of 150 m3 each. Production is 1 - 1.6 tonnes of table size fish per cage, with the stocking density of about 8 - 10 kg m^{-3}. During a two-year cycle, these self-standing units can produce 18-27 tonnes of fish. Currently, the production of sea bass in cages stands at about 15 tonnes. In separate cages, conditioning of sea bass breadstock which is about five years old has been carried out and the produced eggs are regularly shipped to the CENMAR hatchery located in Nin (near Zadar). A hatchery for sea bass and sea bream production is under construction.

Manpower at the aquaculture project consists of 30-40 persons; the majority is involved in shellfish spat collection and cleaning of marketable shellfish.

The on-going mariculture programmes are presented well and documented. The global project is linked to the "Mirna" company which covers the catching, processing and marketing sectors. There is a fish-meal processing plant which was established in order to make use of the by-product of the cannery. In addition, the non-marketable part of the regular catch is also occasionally processed into fish meal.

Comments on the data available

The collection of biological data in Limski Kanal started in the third decade of this century. Systematic monitoring has been performed at one station within the Limski Kanal and one at its entrance. The remaining part of the Limski Kanal had not been covered by systematic studies until very recently.

Salinity varies during the year depending upon the amount of fresh water discharge into the bay; the range is between 9 and 38 ppm. Water temperature varies between 9°C and 25°C.

The fresh water impact is rather unpredictable, since it varies in space and time, but is mainly limited to the surface. On the other hand the hydrographical and chemical parameters are far less variable and show nearly typical coastal water characteristics. An increase of nitrate caused by the fresh water inflow has been noted. However, the increase in nitrate level is linked to anthropogenic causes.

There is a wealth of published data on benthic communities, marine fauna and flora, phytoplankton, zooplankton and marine sediments. Shellfish cultivation is also very well documented. However some of the available data are of limited value due to variations in the space and time of sampling. Certain essential parameters have almost been neglected such as: current speed, circulation patterns of the water masses, sedimentology, cartography of benthic communities, phytoplankton and zooplankton biomasses etc. There are unpublished data which might be usefull to the integrated programme; however for several reasons, the mission could not be provided with them. The mission therefore recommended that the most interesting of these data be included in the programme proposal.

Conclusion

The Limski Kanal is characterized by specific abiotic and biotic features which greatly favour intensive mariculture activities. Considering the existing and planned activities in mariculture development, it is strongly recommended that special attention be paid in order to avoid a negative impact of mariculture activities on the environment and on mariculture itself.

The local conditions, a large general programme carried out by "Mirna" and an ambitious mariculture production programme supported by the qualified scientific staff of the Centre for Marine Research of the "Ruder Boskovic", Institute promise successful implementation of the proposed joint FAO-MEDRAP-PAP/RAC programme in the Limski Kanal.

The infrastructure of the Institute is satisfactory (library, computers, aquarium, research vessel etc.). Standard equipment is mostly limited to general hydrological and biological studies with the main field of activities in the open Adriatic Sea. Certain specific instruments are needed to run this particular programme, such as a multiparameter probe, current meters and diving equipment. The Institute should be provided with guidelines for data collection and reference methods.

Certain junior scientists have already benefited from MEDRAP seminars on "Aquaculture and the Environment" held in Greece. Since the Institute staff has only recently started these specific ultraneretic studies, the young personnel needs to be properly guided and trained abroad or by experts sent to Rovinj.

MEDRAP has been involved in the Limski Kanal pilot project. Unfortunately, this project received the least field support, only about 1% of the total recorded.

MISSION REPORT FOR PILOT OBJECT MAR MENOR (SOUTH-EAST SPAIN)

by

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Site description

Mar Menor is a coastal lagoon with a surface area of about 135 km2. It is located in the region of Murcia (South-east Spain) and is separated from the open Mediterranean waters by a sandy barrier (Lido) which is 22km long. In the past there were three communication channels of which Encanizades o Golas was the most important. Following the increased tourist interest for use of the lagoon (navigation, sports, recreational activities etc.), a wider gate (1500 m long, 52 m wide and 4 m deep) was opened recently, locally named "Estacio". There is no continuous input of fresh water; only seasonal streams locally called "Ramblas" reach the lagoon.

Brief review of existing data

We will now give a summary of the results obtained from studies undertaken by the Mar Menor Institute of the Spanish Oceanographic Institute between January 1981 and March 1982. Oceanographic data were gathered once a month at three stations within the lagoon and one reference station in the open sea near the Estacio.

The climate of the region is arid. Only scarce precipitation with an annual average of 350 mm is measured. The rainfall regime, with nearly the whole amount falling within a few days, favours erosion.

During the warmest season, the average maximum air temperature is 29°C and in January, the average minimum air temperature drops to 5°C.

Salinity ranges between 42.7°/oo and 46.7°/oo, with the highest values recorded at the end of summer. Before the new gate was opened in 1973, the values were between 50.93°/oo and 52.34°/oo. The southern part of the lagoon is of higher salinity than the northern part.

The range of water temperatures is between 12.3°C in winter and 27.5°C in summer while dissolved oxygen varies between 4.5 ml^{-1} and 6.5 ml^{-1}.

The variations of the NO_3 concentrations are very high from July to January, ranging between 0.03 and 3.83 µat g $N\text{-}NO_3^{-1}$. From February to June, values range between 0.0 and 0.9 µat g $N\text{-}NO_3^{-1}$. The concentrations of NO_3 in the interstitial water are evaluated at between 7.9 and 30.0 µat g $N\text{-}NO_3^{-1}$.

Concerning phosphates, the concentrations are rather homogeneous with values between 0.02 and 0.24 µat g $P\text{-}PO_4^{-1}$. The interstitial water is enriched (0.38 - 5.38 µat g $P\text{-}PO_4^{-1}$).

Concentrations of silikates range between 0.74 and 19.6 µat g Si^{-1}. Maximum values have been found in November and minimum values in March-April. In the interstitial water concentrations range between 7.9 and 30.0 µat g Si^{-1}.

There are remarkable variations of the clorophyll A concentrations. In general, they follow the pattern of the nitrates.

The concentrations of organic carbon in the sediment have previously been estimated at 2%. Recent research has given concentrations above 5% at some sampling stations, but this can still be considered as relatively low.

The dumping of mineral wastes from the exploitation of mines in Sierra of Cartagena has heavilly polluted the lagoonal sediments with high concentrations of Pb, Zn, Cd, Mn and Fe. While Pb and Zn are accumulated by the bivalves, their concentrations in fish and water do not differ from other areas in the Mediterranean.

The sedimentology of Mar Menor is characterized by sandy mud. The coastal line is characterized primarily by a sandy bottom up to 1.5 - 2.0 m of water depth. The central area of the lagoon is mostly covered by sandy mud; the southern part of the basin is more sandy compared to the northern part.

The sanitary water quality is constantly monitored by the local Health Authorities. There are data on total Coliforms, faecal Coliforms and Streptococcus only for a few points near the largest tourist complex.

The phytoplankton populations have been mostly studied from the taxonomic point of view. There are some data on phytoplankton biomass which were irregularly collected at only a few stations.

The zooplankton communities were studied occasionally by the Mar Menor Laboratory of the Spanish Oceanographic Institute. Low diversity and homogeneity in the spatial distribution are the principal characteristics.

A community of Centropages - Acartia characterized by small-sized species comprises 94% of the zooplankton. The variations observed in abundance, biomass and in the community structure itself are related to indirect effects generated by rainfall of a seasonal character. Studies of the planktonic stages of Ostrea edulis are being carried out.

The distribution and biomass of the main phytobenthic species (Caulerpa sp. and Cymodocea sp.) in the lagoon have been studied and are presented cartographically.

As far as zoobenthos is concerned, the Mar Menor lagoon is characterized by a typical marine fauna. It has been pointed out that the total biomass of macrofauna is generally low.

Following the man-made intervention in the Mar Menor lagoon (communication with the open sea), the ichthyofauna has changed and has been enriched by some typical marine species. According to the statistical data available, a drastic decrease of total fish catch is evident levelling at about 300 tonnes.

Conclusion

The mission reported that the qualified and motivated staff of the Institute of Oceanography showed an outstanding interest in the implementation of the programme. Furthermore, the Institute is very well equipped with various instruments for studying most of the environmental parameters. There are research vessels, a gas chromatograph AAS, a spectrofluorometer, various microscopes, current metres, a sea level recorder, a meteorological station, etc. All instruments are properly maintained, but not used sufficiently since there are only four scientists (out of 25 staff members) working on a permanent basis.

The infrastructure of the Institute is satisfactory (computers, telex, library). There is a hatchery under operation, currently used for the reproduction of sea bass and sea bream.

Thanks to the specific organizational system of the Spanish Marine Research, i.e. a centralized organization with its headquarters in Madrid, staff and additional instruments can easily be exchanged with other programmes, in order to meet the specific requirements of any one of them.

There has also been productive international assistance (UNEP-MEDPOL, cooperation with the U.S.A.), particularly in studying hydrochemistry, physical oceanography and geology. As far as the national programme is concerned, the Institute is currently involved primarily in open sea investigations. Proper instructions should be given to the professional staff to run this specific lagoonal programme.

Since the Institute is very well equipped and all instruments are modern and properly maintained, the mission suggests that some project money originally earmarked for equipment be used to support additional personnel either experts on a permanent basis, consultants or short-term contracts with students.

Regarding Mar Menor, there will be a conflict between tourism and fisheries concerning the increased use of the lagoon in the future. A comprehensive strategy for the management of the environment is therefore needed. Both the tourist industry and the fishing industry are willing to cooperate in implementing measures, especially in terms of water quality control and management. The local demand for fish is increasing to a level higher than the actual supply from catches in Mar Menor (estimated at 300 tonnes year $^{-1}$).

Considering the above, a successful implementation of the joint FAO-MEDRAP-PAP/RAC programme in the Mar Menor lagoon can be expected.

MISSION REPORT FOR PILOT OBJECT NADOR LAGOON (MOROCCO)

by

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Review of on-going aquaculture and fisheries development

General remarks

Intensive mariculture activities started in the Nador Lagoon at the end of 1985 and covered productive sectors such as shellfish and fish cultures; at the same time extensive research activities were launched. The whole project is carried out by the MAROST company (260 employees).

Mollusc culture

The principal artificially reproduced species in the MAROST hatchery are: Ostrea edulis (150 million spat year^{-1}), and Tapes decussatus (50 million spat year^{-1}).

Commercial oyster production takes place in part of the lagoon; the system employed is longline-culture. The present production of 15-20 tonnes year^{-1} is expected to increase to up to 100 tonnes year^{-1} in the near future.

Pilot scale production of clams is carried out in the Beni-Ensar Bay. Installations cover an area of approximately 2 hectares. A larger area (about 60-80 ha) is earmarked for exploitation in the near future. In order to improve the circulation of water in this shallow area of the lagoon, the opening of a new communication with the sea is planned for the northernmost sector of the Lido. A treatment plant is planned for the vicinity of the abandoned steel factory near Beni Ensar, in order to ensure the sanitary treatment of the marketable production according to the WHO prescriptions.

Shrimp culture

A pilot scale production of Penaeus keraturus and Penaeus japonicus has been recently launched indicating better prospectives for the latter. The original pens covering one hectare each are now halved to facilitate their management. At present, a total area of 30 ha is exploited.

The large-scale production of Penaeus japonicus will be based on the construction of a hatchery with a total capacity of 10 million postlarvae month^{-1} to be located at Kariat.

Fish culture

Fish culture is currently based on the collection of wild fingerlings, principally gilthead sea bream. A significant improvement is expected in fry collection this year (80,000 gilthead sea bream were collected in 1986) and the first fattening unit has been installed at Atalayoun.

After their conditioning in raceways, the fingerlings are transferred to the fixed cages rearing unit for their fattening. At present, 10 cages of 160 m3 are stocked with yearly sea bream and sea bass.

A larger production is expected in the near future in this sector as well. In order to ensure the availability of fry the installation of a hatchery for the reproduction of 2.5 million fingerlings $year^{-1}$ is planned for the southern part of the lagoon (Kariat). For further details, refer to Ziesler and Freddi, 1987. However, eel production is also included in the MAROST fish culture programme because of the large quantity of eels available along the coast of Morocco.

Fisheries

The Nador lagoon hosts approximately 600 fishermen. Three hundred small-sized boats are used for fishing in the lagoon but they are also used for fishing outside it. Total production (Barhoumi, 1983) is estimated at 900 tonnes $year^{-1}$, including 200 tonnes of eel, 100 tonnes of red mullet, 60 tonnes of shrimp, 40 tonnes of gilthead sea bream. Fishing gear is still the traditional gear described by Aloncle (1961) and later by Catudella et at. (1985). One hundred and fifty fishermen have so far been employed by MAROST. MAROST itself has recently started to market part of the yield in the framework of a plan for the integration of fisheries in mariculture development. This plan also encompasses direct assistance for the improvement of fishing gear and techniques, and will be backed by direct supply of goods and services (tax-free gasoline, boat repair, nets etc.).

Supporting facilities

The production programme is supported by a number of facilities which were installed in order to provide autonomy to the production activities.

A plastic and fiberglass manufacturing unit has been built at Atalayoun in order to supply equipment such as floats for longlines or fiberglass tanks for fingerlings; a wood workshop and a metal manufacturing plant were also built. A large stocking hangar for spat collectors has been recently constructed at Atalayoun and a second one exists close to the shrimp pens (Kariat) for the storage of equipment.

As great importance was given to research activities, laboratory facilities exist for the control of production. This concerns bacteriological, histopathological and parasitological aspects, studies on reproductive physiology (principally shellfish), identification of local strains of pathogenic bacteria, as well as vaccine preparation.

The facilities of the MAROST project in Atalayoun cover all administrative needs (offices, meeting rooms, library etc.) including reception facilities for project officers and visitors.

A well equipped infirmary ensures first aid in case of accident.

Review of available ecological data

This chapter will consider available data on the Nador Lagoon with reference to descriptors retained in the joint Project Proposal as far as the Pilot Programme and the Core Programme are concerned. The relevant sources are listed in the bibliography.

Meteorological descriptors

Minimum and maximum monthly averages of air temperature, wind speed, direction and frequency, total radiation, evaporation and raintall are available in Lahlou (1983). The time series include the period 1976-1983 at the Nador Meteorological Station. Information derived from the time series 1933-63, Carlier (1971) and from other sources is found in Tesson (1977). Further data (not available to the mission) are found in Erimesco (1965). Atamane (unpublished) recently made an attempt to organize the above information and discussed on a number of parameters.

Continental hydrography descriptors

The major source of information is Tesson (1977). This paper includes data on the watershed and the morphology of the superficial hydrographic network, the structure of underground hydrology and estimates of annual freshwater inputs to the lagoon. Rough figures are also given in terms of underground water total salinity. A few data concern the geological nature of the watershed.

Data on inflows and estimates on water contribution from the watershed are contained in Lahlou (1983) where figures are also given on the Nador sewage treatment plant contributions. Estimates of underground water contribution were also given by Debrel (1911) as reported in Erimesco (1961).

Geomorphological descriptors

Bathymetric data (recorded in 1950) are reported by Tesson (1977). MAROST has recently (1982) produced a new detailed bathymetric map.

Data on the present outlet of the lagoon (the Bokhana) were updated by Guelorget et al. (Nov. 1986) and by Atmane (Dec. 1986), unpublished). The past evolution of the different passes which ensured the connection of the lagoon with the sea was reported by Ferlin (1985) and by Guelorget et al. (1985), on the basis of data obtained from Erimesco (1961) and Tesson (1977). The recent evolution of the Bokhana can be derived from the data included in several reports, most especially those of Vetillard (1982), Atmane (situation as of July 1984, unpublished) and Soufflard (1985). Estimates on the hydraulic exchanges through the present outlet are found in Vetillard (op. cit.) and Atmane (unpublished).

Physical descriptors

There are several data on temperature values in the Nador Lagoon. They concern surface and bottom temperatures at different stations and in different seasons of the year. Not considering the information which existed for the period prior to the opening of the present Bokhana (1981), water temperature values are found in Lahlou (1983), Guelorget et al. (1984 and 1985) and in Atmane (unpublished).

Data on turbidity (transparency) are on the contrary rather scarce, as only few figures are found in Lahlou (1983).

Chemical descriptors

Not considering reports prior to the opening of the present outlet, data on salinity (either by titrimetric or by conductimetric determination) are available for different sites and depths in the lagoon. Data can be found in Lahlou (1983), Guelorget et al. (1984, 1985) and Atmane (unpublished). The same applies to dissolved O_2 concentration data which are found in the above- mentioned works.

Biological descriptors

Phytoplankton biomass (as chlorophyll a and pheophytine) are found in Guelorget et al. (1985). This paper includes also cell counts on different taxa, identified down to the lowest level possible. The above data concern different stations in different seasons from 1982 to 1984.

No data of whatever kind are available on zooplankton. On the contrary, there are quite a few data both qualitative and quantitative on macrobenthos. The information concerns both the phytobenthos and the zoobenthos. Although papers by Erimesco (1961), Tesson (1977) and Brethes & Tesson (1978) contain useful descriptive data, the only available quantitative information is contained in Guelorget et al. (1985) where biomass as well as floro-faunistic spectra are given for different stations of the lagoon.

No data are available on necton population size structure. There is little information concerning the present yield of fishing activities in the lagoon and no parameters are available on captured items. Atmane (unpublished) gives rough estimates on catches and some estimates on the effort. These data, quite evidently derived from those given by Lahlou (1983), are also discussed by Cataudella et al. (1985) in their extensive work on the Nador fishery. The same authors made no attempt to give an estimate on fish catches.

Qualitative and quantitative distribution data for fish fry, including biometric and gut content analysis, as well as the correspondence of environmental typologies with the above parameters, are contained in Cataudella et al. (1985).

Other descriptors (Pilot Programme)

Data on sediment structure and distribution (lithological only) are found in Tesson (1977), in Tesson and Gensous (1981) and in Guelorget et al. (1985).

Information on $CaCO_3$ and TOM in sediment is also contained in Guelorget et al. (1985).

Lagoon water level variability is reported in Tesson (1977) and Vetillard (1982). Water velocity at the outlet has been measured by Vetillard (1982) and Atmane (unpublished).

Present ecological monitoring at MAROST

MAROST is currently carrying out regular ecological monitoring of the lagoon. Data are obtained in individual sectors (mollusc hatchery, fry first fattening, cage culture, Tapes culture, shrimp) as well as in the Research and Development department and the Ecological Laboratory.

The activities of the Ecological Laboratory represent the framework in which other monitoring programmes are included and with which they interact. The Ecological Laboratory is run by Dr. H. Atmane (ISPM) assisted by an engineer and a technician. At present four students are doing their thesis work on subjects concerning ecological aspects of the Nador Lagoon. Two of them receive financial support by MAROST in order to cover expenses for their stay at Nador. All students are given free laboratory space and expendable material.

The Ecological Laboratory is currently running extensive monitoring of some hydro-biological parameters.

Sampling has a weekly frequency and concerns a grid of 41 stations, 6 of which are located in the coastal waters bordering the lagoon and used as reference stations. Station points are arranged in a relatively regular grid in order to cover most of the surface of the lagoon. A sampling is carried out on two consecutive days at the same hour. Normally the lag between the first and the last sampling points is about 3 hours.

The following hydrological descriptors are regularly taken into account for surface water only: AT^{o}, WT^{o}, S^{o}/oo, O_2, pH, Chlorophyll a, pheopigments, seston, NO_2, NH_3, NH_4, Si, TIM, TOM. Records of meteorological descriptors such as MAT, MxAT, RH, RE, evaporation, total radiation, wind speed and direction are regularly made at the MAROST meteorological station.

Thesis students are working in the sectors of phytoplankton, zooplankton, benthos and microbiology. Their sampling plan consists of 5-10 station points where collections are made on a monthly basis. On-going research concerns species composition, biomass, diversity etc.

The Ecological Laboratory is at present equipped to cover the needs of the analyses that are currently carried out. Water samples are taken with simple bottles. In general, salinity measurements are performed both by Knudsen and conductivity cell, photosynthetic pigments are determined by a short light-path spectrophotometer which serves also for the determination of nutrients and seston. Determination is done according to Strickland and Parsons. Basic optics are also available.

As concerns measurements and determination of ecological descriptors performed in other sectors of MAROST,we should mention that micro-biological studies are regularly performed in the research and development department. The micro-organisms concerned are: Coliforms, Faecal Coliforms, Streptococci, Staphylococci, Vibrions and Salmonellae. Samples are taken at different stations, in water, sediment and molluscs. Sampling points are arranged in space depending on the location of detected and/or suspected contamination sources. Vibrio and Pseudomonas are recorded in the hatchery at inlet, basins and outlet. Regular measurements of T^{o}, S^{o}/oo, O_2 are performed in all production sectors.

NO_2 is monitored in the bottom water under the fish culture cages.

All of the above information remains at the level of raw data since no treatment whatsoever is regularly performed. There are plans to increase the regular environmental controls in the lagoon and the contamination control of the products. MAROST intends to improve laboratory space, equipment and manpower in this sector. In particular, plans are made to acquire equipment such as a high performance Liquid chromatographer and an Atomic Absorption Spectrometer in order to control Hydrocarbon, Pesticides and Heavy Metal contamination.

Evaluation of available ecological information

There is a good deal of ecological data concerning the Nador lagoon. However, only a limited part of the available information is really usable for the purposes of the Joint Project. As a matter of fact, sampling protocols, analytical techniques and time coverage are not only heterogeneous but also frequently inconsistent. On the other hand no sufficient attention has ever been paid to the problem of the scales involved in the ecological processes characterizing the lagoon. In general, space and time scales are largely inadequate. Some data sets concern a period in which the situation of the Bokhana was different from what it is now and thus the entire hydrology was, at least in principle, also different.

The on-going MAROST monitoring plan presents some problems with regard to the analytical techniques (e.g. nutrient determination) and the study of the vertical structure of the water mass. Too little attention has been paid so far to biological descriptors such as zooplankton and benthos.

Data on the characteristics of the watershed are very insufficient even though efforts have been made to estimate its influence on the lagoon. In this connection, it must be emphasized that an assessment of contributions from the watershed is of paramount importance for the protection of aquaculture in the Nador lagoon, not only in terms of salinity variations but also in terms of sediments, nutrients and pollutant inputs.

Data are missing (or scarce) on hydrodynamic patterns of the lagoon as well; this hinders the objective evaluation of crucial dynamics such as the exchanges at the contours of the systems as well as the exchanges within the system itself.

In conclusion, the information available is of limited use not only for the Joint Project, but also, more generally, for a correct understanding of the Nador Lagoon ecosystem structure and dynamics. In fact, the mainly descriptive (and poorly treated) data give very little help in making forecasts on the behaviour of the lagoon under present and future scenarios of aquaculture development and environmental management.

Nevertheless, of this, some of the data available can be used in the preparation of a preliminary modelling exercise concerning water circulation in the lagoon under different tide and wind conditions. This "pre-model" will form the basis of further simulations and will establish a reference point as far as the execution of the Pilot Programme is concerned.

Conditions for the implementation of the Joint Project

From the above it is clear that:

MAROST is concerned with monitoring and maintaining the present ecological conditions of the lagoon, in view of further developing aquaculture production under the forms that have been described in the previous paragraphs.

To implement these goals, MAROST is strongly committed to a large programme aiming at assessing the global conditions of the lagoon and of producing information useful for product quality control; such a programme is carried out both at the Ecological Laboratoty and at the different production sectors. Data from the Ecological Laboratory form the framework in which each sector considers (or uses as reference) the variables of its specific interest. Although most of the ecological information is used at the level of each production sector, such an organization allows a feed-back to the Ecological Laboratory as far as data interpretation is concerned.

Ecological monitoring is implemented with the help of relatively good laboratory facilities and of competent and motivated staff. Plans are made by MAROST to expand the ecological sector by adding space, instruments and facilities. It must be stated that this development will mostly deal with product quality control in terms of chemical and microbiological contamination.

The general philosophy of MAROST is to promote the qualifications of research personnel in the field of aquaculture; thus seven students are at present given supervision, laboratory space and facilities to perform their thesis work. Five students are integrated in the on-going research programmes on a permanent basis and MAROST has offered a yearly indemnity to cover their living expenses at Nador. Two students participate in research programmes on a part-time basis and do not receive financial support. Four students (two permanent and two part-time) are currently contributing to ecological work. MAROST plans to expand this activity in the future.

MAROST feels that the on-going ecological programme is well suited to its present needs. Nevertheless it is open to modifications and improvements in terms of sampling protocols and meaningful descriptors. Such modifications however would be acceptable only if the ratio between additional effort, implying extra cost, and additional information is minimized.

MAROST endorses both the philosophy and the scientific content of the FAO/MEDRAP/PAP-RAC Joint Project as it recognizes that the results of the Joint Project itself can be beneficial to the maintainance and protection of the Nador lagoon ecosystem and its present and planned aquaculture production. For these reasons MAROST is ready to support the Joint Project as far as the official representatives in UNEP Moroccan Focal Point are concerned.

MAROST feels however that the Joint Project would be more acceptable if the financial support allocated to the Local Units were better adapted to cover additional costs especially in terms of equipment and expendable material.

MAROST reserves the right to evaluate the performance of any expert designated by the FAO/MEDRAP/PAP-RAC Joint Project as far as his work in Nador is concerned. Furthermore, MAROST requests that the Joint Project takes into account its evaluation of the experts that have already participated in the activities carried out at Nador.

MAROST reserves the right to authorize the dissemination of the data produced by its staff. It is understood however that data and results of data treatment and modelling issuing from the activity foreseen in the Joint Project are in any case of a public nature.

On the basis of the above, it can be concluded that:

- there are highly favourable conditions in MAROST for the implementation of a Local Unit as described in the Joint Project;

- this means that the Joint Project activities are integrated in the on-going MAROST programme in a way as to minimize additional efforts by MAROST. It is believed that this integration can be easily achieved.

- a comparative analysis between the Joint Project workplan and the on-going MAROST activities indicates however that the latter should incorporate sampling and measurements concerning descriptors listed in the draft project proposal substituted by numbers d.2, f.1, f.2, f.4, f.5, f.6, which are not yet covered in the MAROST on-going programmes.

The possibility of implementing a Satellite Programme is definitely considered by MAROST. However, a final decision on the subject will not be taken until a future time.

Conclusions

MAROST agrees with the philosophy, the scientific content and the workplan proposed in the Joint Project and is willing to form a Local Unit to perform the research as planned. The Co-ordinator of the Local Unit would be Dr. H. Atmane (I.S.P.M.) who is in charge of the MAROST Ecological Laboratory.

Nevertheless, MAROST does not entirely agree with the proposed amounts and the budget formulation of the financial support to Local Units. In particular, MAROST does not agree with the budget formulation regarding equipment and expendable material, which is considered inadequate for the effort Local Units are requested to put into the Joint Project implementation.

MAROST therefore strongly recommends a revision of the budget, in order that it afford a greater flexibility in the use of financial support once the execution of the Core Programme is guaranteed by existing local means. In particular, MAROST suggests that the financial support towards the execution of an agreed upon Satellite Programme should be re-examined.

The Mission believes that this proposal is thoroughly considered and that efforts are made to incorporate it in the final formulation of the financial contribution to Local Units. In fact, it is the opinion of the Mission that such a proposal does not modify the philosophy under which the original budget was formulated.

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MISSION REPORT FOR PILOT OBJECT LAKE MELLAH (ALGERIA)

by

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Review of on-going fishery and aquaculture activities

General remarks

At present, the development of aquaculture in Algeria is under the responsibility of two agencies both belonging to the Ministry of Agriculture and Fishery: the Centre d'Etudes, Recherches et Documentation pour l'Aquaculture et la Pêche (CERP) and the Office National de la Pêche et de l'Aquaculture (ONDPA), both located in Bou Ismail; CERP handles research programmes and documentation while ONDPA takes care of production, both at experimental and at commercial levels. Research and development structures include the Pilot centres of Mazafran and Lake Mellah.

Both Agencies are in the initial phase of their activity and the financial support of research and development, as well as investments in production structures, are still very limited. Programmes on the contrary are already fairly developed at least in their basic form. These include a number of key projects which will allow the development of a strategy for the regular R and D programme. Key projects deal with coastal, lagoon and inland water resources and include the following items:

- establishment of an experimental station, including a hatchery, especially for fresh water species, in Mazafran;
- completion of the marine fish hatchery and the pre-fattening system at Lake Mellah;
- establishment of a laboratory for the protection of resources (environmental control);
- research on Artemia and Daphnina production;
- research on floating cage culture in both lagoon and artificial fresh water reservoirs;
- research on fish food preparation;

Research on the last three items are currently carried out at CERP, Bou Ismail. Subsidiary projects are:

- restocking lakes and fresh water reservoirs, the study of population dynamics and experimental fishing techniques;
- the study of natural restocking in lake Mellah;
- identification of suitable sites in lagoon and coastal environments.

For the implementation of the above programmes, it is recognized that a strong effort should be made on training qualified personnel at all levels, in particular concerning those in natural resources management e.g. of lakes, lagoons and artificial reservoirs. National, foreign and international agencies should help in this connection through direct cooperation, exchange of experts, seminars etc.

Fisheries

Algeria has very extensive marine resources which, if developed to an optimum sustainable yield, would bring about significant benefits to the country.

Generally there is a low level of technology and a lack of specialized personnel, particularly evident in aquaculture. Important in this regard are the figures indicating the origin of the catch i.e. 80% pelagic fish represented mainly by sardines, anchovies and thonids compared to only 15% of demersal fish. An analysis of fisheries in Algeria shows evidence that currently the fishing fleets operate mostly along the coastal area and do not venture out in the open waters.

Fishery activities are practiced along the coastal line with fishing gear such as gill nets, small trawling nets, various traps, harpoons, fish-hooks etc. A special type of fishing activity is being developed in the El-Kala region (eastern part of Algeria close to the Tunisian border), particularly in the two lakes, El Mellah and Ouberia.

Aquaculture

Consistent with the Mission's agenda, a site survey of the El-Kala area was performed; land-water utilization and its characteristics were examined. All available documents and some historical data at national and regional levels were reviewed. The sites visited were Lake Ouberia, the Mazafran Aquaculture Unit and El Mellah.

Lake Ouberia

Lake Ouberia which covers approximately 2200 ha and has a maximum depth of 50 m is characterized by typical freshwater fauna. With regard to its potential Lake Ouberia is a still underexploited site with a total catch of about 200 tonnes. Carp and eel are the most important fish species that inhabit Lake Ouberia; catches are 50 tonnes and 30 tonnes respectively. Gray mullet species, Mugil cephalus and Liza ramada have recently been introduced to Lake Ouberia. A hatchery for fresh water fish restocking is planned and when fully operational it is expected that the level of exploitation will increase up to 250 tonnes.

Fishermen with both permanent and temporary licences are involved in fishing activities in accordance with legal provisions. Most of the production is channeled to the local market, while eel is exported to Italy.

Aquaculture unit in Mazafran

This aquaculture unit was established in 1974 as an experimental station including a hatchery designed for the reproduction of fresh water fish, primarily Ciprinus carpio and Micropterus salmoides. The outdoor facilities are composed of 40 raceways for pre-fattening, a pond where integrated fish and duck culture is practiced and several 3 ha earthen ponds. Unfortunately, it is very difficult to manage the ponds properly since they cannot be emptied. A frequent oxygen depletion associated with ammonia toxicity hinders the survival of fish, so there is practically no production for the market.

Significant interventions are needed at the Mazafran Aquaculture Unit. Due to the lack of adequate water sources, a global hydrotechnical project should include the installation of a water recirculation system. The hatchery has to be redesigned and common equipment employed. The ponds should be redone so that they can be emptied, dried and fertilized. The water quality will be significantly improved if airlift pumps could be installed. Tropical fish reproduction could be the most promising aquaculture activity in Mazafran.

Lake Mellah - General characteristics

The lagoon is about 865 ha with a maximum depth of 6 m. It is connected to the sea in the north, through a narrow channel 900 m long which significantly restricts exchange with the sea. However, the lagoon receives not only salt water flows but also fresh water from small oueds, such as Er-Rik Bit, El Mellah, El Belaroug and Sata. The channel linking the lagoon with the sea has a lot of debris. Tremendous silting was recorded; it has resulted in deep layers of mud and sand up to 4 m. This progressively reduces the exchange between the lagoon and the sea. A low water exchange and the settling of suspended matter gradually turns even deep zones into anoxic. Oxygen depletion up to 1 ppm O_2 is found over a large surface area where there are large mud deposits (Bakalem et al., 1981). The temperature of the lagoon water does not differ from sea temperature. The minimum level is about 10°C in the winter and about 27-28°C in the summer. Salinity ranges from 20 to 35 ppt with the minimum at the end of May and the maximum at the end of September. The southern part of the lagoon is influenced much more by fresh water, so its salinity drops greatly during floods.

Lake Mellah is characterized by a typical coastal marine water fauna and commercially important fish species, among which the most important are gray mullet, eel, solea, sea bass and various sea bream species. Present production does not differ very much from the data available for the past 10 years and reaches about 50 tonnes.

Aquaculture programme in Lake Mellah

The first attempt for shellfish culture was made in 1976 by introducing oysters and mussels into Lake Mellah. Encouraging results were obtained at the very beginning. Production however, has never reached a significant level; present production, including both mussels and oysters, does not exceed 15 tonnes . Production is based on fixed parks, but floating longlines are foreseen for the future.

Fish culture will be expanded in the near future. In order to ensure the availability of fry, the installation of a pilot scale hatchery for the production of 300,000 to 500,000 fingerlings and marine fish hatchery pre-fattening raceways is under way. To support the hatchery operation, the permanent availability of brook stock from the lagoon should be ensured. In addition to the routine study on fry availability in the lagoon, the production of sea bass fingerlings under controlled conditions is planned. Unfortunately, the lack of expertise and technical assistance prevent the completion of the hatchery in time. In order to ensure a reliable source of fry for future production, immediate action has to be taken for the completion of the hatchery.

In this connection, external raceways for the pre-fattening and raceways for commercial production are being constructed. For hatchery operations brood stock from the lagoon should be permanently available. The main objectives of such a project are to conduct feasibility studies on the fish farming system and to train personnel.

It has been stated that the deeper zones of Lake Mellah could be used for intensive fish and shellfish production by employing floating installations (Vincke and Ruer, 1983). However, it seems that deep zones act as a settling pocket whose matter in suspension is progressively accumulated thus resulting in depleted oxygen or even anoxic conditions (Semroud, 1983). This situation is encountered over a large surface area of the lake, where there are large mud deposits.

Review of available ecological data on lake Mellah

This chapter will consider available data on the Mellah Lagoon with reference to descriptors retained in the Joint Project Proposal, as far as the Pilot Programme and the Core Programme are concerned. The relevant sources are listed in the bibliography.

Meteorological descriptors

Minimum and maximum monthly averages of air temperature are available in Semroud (1983); data on rainfall are available in Semroud (1983) and CROP (1979); information on wind speed, direction and frequency are found in Seltzer (1946); total radiation (as number of hours day^{-1}) is reported in Semroud (1983); data on water turnover, including evaporation, are available in CROP (1979), Bakalem and Roman (in Crop, 1979) and France Aquaculture/Sepia (1980).

Continental hydrography descriptors

Data on the watershed, on superficial hydrography and estimates on fresh water inputs are found in the above mentioned works (Crop, France Aquaculture), as well as in Thomas et al. (1973), Guelorget et al. (1983), Semroud (1983). Very limited information is available on the geological nature of the watershed and land usage therein, including possible pollution sources.

Geomorphological descriptors

Bathymetric data were recorded and charted by France Aquaculture, 1980. Information on the channel is provided by Thomas et al. (1973), Guelorget et al. (1983) and Cataudella, 1982.

Physical descriptors

Data on water temperature in Lake Mellah, concerning both surface and bottom temperatures, in various sites and during various periods of the year, are reported in Crop (1979), Guelorget et al. (1983) and Semroud (1983). Data on turbidity are available in Guelorget et al. (1983) and in Semroud (1983). Reference on water circulation in the lagoon is made in Guelorget et al. (1983).

Chemical descriptors

Data on salinity variability and space distribution (including both surface and bottom measurements) are reported by Crop (1979), Chassany de Casabianca et al. (1981), Guelorget et al. (1983), and Semroud (1983) (obtained by either titrimetric or conductimetric determinations). Dissolved Oxygen Concentration was measured at various sites and in various periods (at both surface and bottom) by Guelorget et al. (1983) and Semroud (1983).

Biological descriptors

Phytoplankton biomass (as chlorophyll a) has been determined by Semroud (1983) and Guelorget et al. (1983). The latter paper contains cell counts on different taxa, identified down to the finest possible level. Further information on phytoplankton is contained in a thesis submitted at Annaba University (details not available to the Mission). No data are available on zooplankton, with the exception of a thesis, submitted at Annaba University, which was not made available to the Mission.

There are several data on benthic fauna, including information on species composition, abundance (both as counts and biomass assessments), distribution, community structural parameters and population dynamics of selected species at various sites of the Lagoon and in various periods. These data are found in Messili and Rebzani-Zamat (1980), Bakalem et al. (1981), Guelorget et al. (1983), Semroud (1983). The latter paper also includes a quantitative data treatment by a multidimensional technique.

No data are available on necton population size structure, but there are records on species composition of fish having commercial interest. Data on shore fishes (including fry and fingerling distribution) are given by Guelorget et al. (1983), who also provide information on migration patterns of marine fish. This work also includes data on the lake Mellah fishery. Further data on the same subjects can be obtained from Cataudella (1982).

Other descriptors (see Pilot Programme)

Data on sediment structure (lithology and granulometry) are given by Semroud (1983) and Guelorget et al. (1983) (lithology). Information on $CaCO_3$ and organic matter concentration is contained in Guelorget et al. (1983).

Thomas et al. (1973) give estimates on the hydraulic exchanges through the channel as well as on tidal patterns. Guelorget et al. also give the results of theoretical calculations for the improvement of the hydraulic performance of the channel.

Data on pollution are found in Guelorget et al. (1983) and in Aissi and Siblot (1981).

Present ecological monitoring in Lake Mellah

Regular monitoring is currently carried out on Lake Mellah by the El Kala ONDPA office which owns a small laboratory located at the Lake Ouberia farm. Parameters such as water temperature, salinity, dissolved oxygen and turbidity (Secchi disk) are recorded.

The technical staff is at present composed of 3 members and a biology engineer. Three more posts for technicians are foreseen for the near future.

The laboratory has the basic equipment for such measurements. Recently, equipment for the bacteriological monitoring of products was added. The installation of a meteorological station at Lake Mellah will be carried out shortly.

Ecological research is going to be enhanced through cooperation with the Biology Department of Annaba University whose students have already done occasional thesis work at Lake Mellah.

Conditions for the implementation of the Joint Project

The mission proposes Lake Mellah for the implementation of the Joint Project. From the information obtained it is clear that:

- The ONDPA office in El Kala is involved in regular monitoring and maintenance of the present ecological conditions in Lake Mellah. The basic environmental parameters are monitored in order to assess the global conditions in the lagoon and to produce information useful for lagoon management.

- Desirable integration and improvement of ecological monitoring can be expected through cooperation with the Biology Department of Annaba University.

- The basic equipment for hydrographic measurements is available at the small laboratory located at the Lake Ouberia farm. The requirements for bacteriological monitoring and monitoring of meteorological parameters will be satisfied in the near future.

- The cooperation climate is favourable and the staff members are well motivated.

- Expertise is potentially available in most of the fields to be covered by the Joint Project, including both physico-chemical and biological analyses. However, permanent assistance will be needed in the application of numerical techniques for the processing of ecological data.

General conclusions and recommendations

The coastal and inland aquatic resources of Algeria which comprise salt and freshwater lakes, lagoons and marine coves have good potential for aquaculture development. Within the general context of aquaculture development in Algeria, Lake Mellah is characterized by a number of appropriate aspects such as hydromorphological and ecological conditions, geographical position and other factors of fundamental importance. For the above reasons, this coastal lagoon has already been chosen (by MEDRAP) for the implementation of the first intervention, to be followed by a series of future initiatives on the coastal territory of Algeria. The mission is of the opinion that the Joint Programme can be easily integrated in the on-going Lake Mellah activities.

For a long-term plan, the Mission proposes to the Ministry of Agriculture and Fisheries the establishment of an integrated aquaculture project for more stable and permanent activities. This implies:

1. Identification and description of sites suitable for aquaculture development with particular reference to the lagoon formation of the area along the coastal belt.

2. Definition of hydrogeological resources available for aquaculture with particular regard to warm waters in the area under study, including spring water and heated effluents; their quality, quantity and temperature regime are most important.

3. Nature of existing aquaculture activities and techniques used (intensive, semi-intensive and/or extensive; ponds, raceways, cage production, shellfish culture, breeding techniques used etc.).

4. Evaluation of projects and studies in the planning or implementation phase.

5. Quality and quantity of the available seed sources (both hatchery produced or obtained from the natural habitat) and information on the area where it is caught. Suitable species include the grey mullet species, primarily Mugil cephalus, sea bass, Dicentrarchus labrax, sea bream Sparus aurata and eel Anguilla anguilla. As for freshwater species the candidates are common carp, Cyprinus carpio, Tilapia sp. Micropterus salmoides and Lucioperca sp.

6. Definition of other existing aquaculture activities or activities connected with aquaculture.

It is hoped that such an approach will lead to detailed studies essential for the design of productive management plans and comprehensive evaluation required for future aquaculture project development.

From the preliminary observations at the site the following short-term actions can be proposed:

1. Immediate completion of the sea bass pilot scale hatchery to include breeding, hatching and nursing facilities.

2. Establishment of a raceway culture system for commercial sea bass production.

3. Pre-feasibility study of Artemia culture as a complementary project to the sea bass hatchery production. The potential for mass production of Artemia cysts is important in view of the latter's high market price and great demand by the world's aquaculture industry. It is recommended to undertake:

   - an identification survey of possible sites in the salt lakes of the country;
   - the inoculation of the existing solar/salt with a strain suitable to the environmental conditions; the Tunisian strain could be introduced;
   - before the Artemia inoculation, phytoplankton may be grown with chemical fertilizers.

4. Integration of life support facilities and infrastructure for handling and marketing of the expected product.

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MISSION REPORT FOR PILOT OBJECT BIZERTE LAGOON (TUNISIA)

by

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Review of aquaculture development in the Bizerte lagoon

The lagoon of Bizerte covers 15,000 ha and is still an under-exploited site despite its potential for aquaculture. The principal cultured species are musssels, Mytilus galloprovincialis and oysters, both Ostrea edulis and Crosostrea gigas. Aquaculture activities were initiated by the ONP (Office National des Pêches) at Menzel Jemil in 1963. Production is carried out in 15 fixed parks of about 800 m2 each. It is estimated that at present production is carried out on less than 1 per cent of the total surface area.

Total shellfish production in the period 1977-1982 ranged from 100 to 150 tonnes (90% of which was mussels). Production increased in 1982 to 300 tonnes by importing oyster seed from France. However, because local markets were not developed and the existing trade channels for export were not exploited, the entire production could not be commercialized. The current production is estimated again at between 100 and 150 tonnes.

Some efforts have been made to grow clams, Tapes semidecussatus. The bottom culturing techniques were employed; good growth rates and negligible mortality were reported (Gimazane and Mehaioub, 1979).

More recently, an aquaculture development programme has been initiated (MEDRAP/FD/86/07). Within the framework of this programme, in addition to shellfish culture, a pilot-scale production of gilthead sea bream, Sparus aurata and sea bass, Dicentrarchus labrax is carried out in 4 net cages (50 m3 each) fixed on the shellfish installations. Fish culture will be expanded by employing 4 additional floating cages of about 100 m3 each. This production is based on both collecting wild fingerlings and obtaining them from a hatchery located in Ghaer El Melh (sea bass).

Studies have been conducted in order to evaluate the aquaculture potential of the Bizerte Lagoon. Some studies indicated that mollusc production could reach 10,000-15,000 tonnes year^{-1} (MEDRAP/FD/86/08) and even 20,000 tonnes year^{-1} (ADCP/MR/83/21).

Fisheries in the Lagoon

No precise statistical data exist on fisheries in the Bizerte lagoon. This could be because the fishermen of Menzel Jamil and Menzel Abd-Er-Rahmane fish both inside and outside the lagoon.

. However, a progressive increase of the total catch (mullet, sea bass, eels, gilthead sea bream, sole) has been recorded: from 30 tonnes in 1976 to 100 tonnes in 1981 (Zaouali and Baeten, date missing). The same authors reported a total catch in the Bizerte lagoon of about 400 tonnes $year^{-1}$ in the beginning of this century.

Review of available ecological data

In this chapter the available data on the Bizerte Lagoon regarding the descriptors retained in the Programme Proposal of the Joint Project are considered.

Meteorological descriptors

Data on air temperature (average of minima, average of maxima) are available on a monthly basis in Soussi (1981). Zaouali (1979) and Azouz (1966) indicate minimum, maximum and average air temperatures, Azouz giving only data for the years 1956-1960 and 1963-1964.

Data on wind (speed, frequency and direction) and rainfall are given in Soussi (1981), Zaouali (1979) and Azouz (1966). Azouz however obtained the data from the Meteorological Service of El Aouina airport (Tunis) and only for the period of 1944-1950, regarding wind and for the years 1956-1960 and 1963-1964 regarding rainfall.

A few data on total radiation time, evaporation and relative humidity can be found in Zaouali (1979).

Meteorological data given by Soussi (1981) are derived from the meteorological station of Bizerte for the period 1901-1970, except for wind (1951-1960 only); those mentioned by Zaouali (1979) are calculated from observations between 1901 and 1960.

Continental hydrography descriptors

The major source of information is Soussi (1981) who gives not only data on the hydrological regime of the tributaries of the Bizerte Lagoon but also on the geology of the whole region. However, data on soils are given by Kallal (1979) and Lemoalle (1983).

Geomorphological descriptors

Bathymetry can be taken from a map (scale 1:25,000) issued by the Hydrographical Service of the Marine, Paris, in 1897 and updated for the last time in 1984.

Data on the surface area of the Lagoon as well as on the length and width of the channel which connects the Lagoon with the open sea vary according to the author (Azouz 1966, Zaouali 1979, Soussi 1981, Frisoni et al., 1986, Gimazane, date missing).

Physical descriptors

Regarding water temperature, data can be obtained from the papers of Azouz (1966), Zaouali (1979), Gimazane (date missing), Belkhir et al. (1985), Frisoni et al. (1986), Frisoni et al. (1986a and b) and Soussi (1981).

Transparency of water has been measured by Belkhir et al. (1985) and Frisoni et al. (1986).

Chemical descriptors

Chemical descriptors such as salinity and O_2-saturation are reported by Azouz (1966), Zaouali (1979), Gimazane (date missing), Soussi (1981, salinity only), Balkhir et al. (1985), Frisoni et al. (1986) and Frisoni et al. (1986).

Biological descriptors

Regarding phytoplankton, Azouz (1966) gives results of cell counts as well as a floristic list. Biomass as Chlorophyll a is shown in Belkhir et al. 1985), Frisoni et al. (1986) and Frisoni et al. (1986).

Data on zooplakton are not available. Only one mostly qualitative study with some rough indications on the abundance of the most frequent species of copepods has been carried out by Azouz (1966).

Qualitative studies of the phytobenthic communities have been carried out by Azouz (1966) and Zaouali (1979), who also gives some abundance estimates. In Frisoni et al. (1986), only a few qualitative data on the distribution of the most important macrophytes can be found.

Regarding zoobenthos, qualitative data are obtained from Azouz (1966) and Soussi (1981). This last author, however, only refers to molluscs and foraminifers. Zaouali (1979) also provides quantitative information (number of individuals and biomass). The same type of data is found in Frisoni et al. (1986, both papers) but the data on abundance and biomass estimates only deal with the entire fauna.

So far, no data on necton biomass or necton population size structure are available.

Other descriptors

A very extensive study on sediments has been completed by Soussi (1981). Other qualitative (mainly lithological) data as well as data on the organic matter content of the sediment are found in Zaouali (1979) and Frisoni et al. (1986, both papers).

Present ecological research on the lagoon of Bizerte

At present, there is no regular research programme carried out by INSTOP in the Lagoon of Bizerte. Measurements are made, however, on a number of parameters, especially for the assessment of pollution levels.

Present activities deal with the following descriptors where values are determined mostly in sediments:

- hydrocarbons
- organic matter
- Hg, Cd, Cu, Cr
- pesticides in some organisms (oysters and mussels).

At the ONP station in Menzel Jemil regular recordings are taken on the lagoon level, rainfall, wind speed and direction (subjective estimates).

Evaluation of present ecological information

There are many studies on the Lagoon of Bizerte. These studies had different goals and achieved different results. The majority of these works is of a descriptive nature with a very poor data treatment if any at all. Their usefulness is therefore limited as they cannot form the basis for any advanced analysis. In general, the sampling design is suitable neither for the application of synthetic numerical descriptions, nor for hypotheses testing. This is largely due to a very poor observation density because of which one cannot assess the space variability of any descriptor. Thus cartographic representations of the distribution of certain descriptors are mere subjective interpolations and cannot be used as such, in planning aquaculture development. This applies to most of the zonal patterns identified so far and to related maps. The same holds for time series: Generally only month (or year) averages have been considered and this gives rather trivial results. No circadian or semi-diusual (e.g. along a tidal cycle) series have been established which hinders the assessment of the short time variability scales in the ecological processes of the lagoon.

There is very little also on the hydrodynamic behaviour of the basin: indirect and subjective determinations have been attempted, but they can only be considered as informal hypotheses on circulation patterns and are therefore of limited use.

As it is, present information only allows a premodelling exercise on the hydrodynamic patterns of the lagoon: sufficient data on bathymetry, tide and dominant winds are available. The results of such an exercise can be used as a reference to improve the performance of the Pilot Programme once it is cleared up.

Conditions for the implementation of the Joint Project

The INSTOP Laboratories in Salambo and La Goulette offer a full set of instruments for hydrochemistry and hydrobiology.

Among major items, the following can be mentioned:

- dual beam long light path spectrophotometer;
- gas chromatographer;
- atomic absorption spectrophotometer;
- set for hydrocarbon separation and determination.

The relevant equipment for sampling and measurement of other descriptors is also available.

Experience is available in all fields to be covered in the Joint Project, including both physico-chemical and biological analyses.

The cooperation climate is quite favourable and staff members are competent and well motivated. In particular, several of them showed great interest in the scientific approach used in the formulation of the Project, with special reference to numerical techniques for ecological data treatment.

The ecological programmes currently carried out at INSTOP also concern the lagoon of Bizerte. This is due to the will to define a rational plan for the development of aquaculture in an assessed environmental framework. No great efforts have however been made so far in research and monitoring of the lagoon. Such a situation implies that the Joint Project Proposal would promote integration and improvement, which would provide, in a relatively short time, preliminary guidelines for the development of aquaculture in the lagoon of Bizerte.

Conclusions and recommendations

From the above information, it is clear that very favourable conditions exist at INSTOP for setting up a Local Unit. The latter would implement not only the core programme but one or more Satellite Programmes as well. Concerning the Satellite Programmes, a number of possible subjects, which will be better defined during the Pilot Programme, have been discussed to some extent. The field of contamination (many sources have already been detected) and the field of aquaculture environmental impact, with special reference to fish cage culture have already been identified as holding major interest. In this context, some indications were given by the Mission with regard to the implementation and/or modification of the INSTOP short-term programmes, with special reference to sampling strategy and data treatment.

In the light of the above, the Mission is of the opinion that, in the case of the INSTOP Local Unit, the conditions exist for the utilization of the financial support foreseen in the Joint Project, so that the above mentioned Satellite Programmes, once they are agreed upon, can be implemented.

Mr. C. Rais has been indicated as Co-ordinator of the INSTOP Local Unit.

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6. PROPOSAL FOR A MEDITERRANEAN COOPERATIVE PROJECT

Definition of ecological criteria for the rational development and protection of aquaculture in the Mediterranean coastal zones.

Prepared jointly

by

FAO and PAP/RAC experts

Introduction

The potential of the Mediterranean coastal environments for the development of aquaculture has only recently been fully recognized. With this realization, almost all countries have implemented or are planning substantial aquaculture activities.

This process should be seen in the broader context of the "littoralization" which is affecting the entire area. Aquaculture, in fact, is but one of many productive activities exploiting more and more fully the natural resources of the coastal environments. Unfortunately, the development of aquaculture, especially in its more modern forms, has so far been seen primarily as a biotechnical problem, even though the objectives are generally spelled out in socio-economic terms. Potential interactions with other productive activities, particularly where those are accompanied by environmental impact, have been given little consideration.

The programme proposed herein is designed to help the governments of the Mediterranean to plan and carry out appropriate actions to ensure that in the course of promoting aquaculture, environmental and broad socio-economic considerations are adequately considered along with the more strictly economic and bio-technical issues.

Project description

Background of the project proposal

Aquaculture is one of the priority fields of the Priority Actions Programme (PAP). In the framework of the PAP workplan for the 1986-1987 biennium (UNEP/WG.129.5), the formulation of a joint project of PAP and the FAO/UNDP Mediterranean Regional Aquaculture Project (MEDRAP) was envisaged in order to study the environmental aspects of aquaculture management. This came about as a result of the cooperation between PAP and MEDRAP experts in the 1984-87 period, during which the need to define and test an effective procedure for the proper management of aquaculture in lagoon and coastal ecosystems was thoroughly investigated.

The aims of this preparatory phase were, among others, to identify and select the relevant environmental scenarios and production systems in a number of sites, to assess the level of information available for each site and to evaluate the local means and facilities which could be put at the disposal of the project.

The information obtained during the Preparatory Phase (1986-1987) made possible a realistic evaluation of the needs and constraints of both a scientific and technical nature for the implementation of the project. This led to the formulation of the present proposal.

Project objectives

While there is no doubt that an operation procedure, capable of producing sensible evaluations and forecasts, under different environmental and production scenarios, would represent a precious tool both for coastal zone planners and entrepreneurs, such a procedure does not exist at present.

It is in fact clear from the analysis of the studies that have been carried out in this field that only qualitative suggestions were possible within the descriptive and scientifically informal approaches that have been adopted.

This is due to conceptual, technical and economic constraints, some of which are specific to the field of aquaculture, especially in terms of equipment and manpower costs and time necessary for a more scientifically sound environmental analysis.

The long-term objectives of the project are therefore:

- to establish a conceptual and operational procedure of site evaluation and monitoring for the development and protection of aquaculture in Mediterranean coastal environments, with special reference to lagoons;

- to define a realistic and consistent set-up of operations necessary to calibrate and validate the procedure as a whole and its individual components.

It is however essential that the procedure to be developed be in line with the specific problems and needs of aquaculture, that it be of general applicability, simple and inexpensive in terms of field effort and capable of providing accurate estimates and predictions.

The immediate objectives (pilot phase) are:

- to obtain an evaluation of previous data
- to obtain supplementary data
- to prepare and run a preliminary model
- to prepare an Operational Handbook
- to provide preliminary indications for aquaculture development and protection
- to provide preliminary training of local staff in field operations.

To achieve these objectives, it is necessary to frame different production systems and their development in various environmental scenarios, to define the scenarios by means of efficient descriptors and to choose a sampling design for each descriptor according to its specific space and time scales. Also, a set of numerical techniques has to be defined that can treat the information obtained so as to produce the desired quantitative assessments and forecasts, as well as to assess the relative significance of the selected descriptors. Furthermore, the most appropriate numerical simulation models of the ecological events that are most relevant to aquaculture production systems have to be selected and validated.

Expected outputs

When such a procedure is constructed and validated, the following outputs illustrate the results expected in the field of aquaculture:

- guidelines for the selection of sites suitable for aquaculture development;

- guidelines to assess the compatibility of already existing or planned aquaculture activities with the development of other forms of natural resources exploitation (e.g. a prediction of the cumulative effects of organic enrichment from aquaculture and urban wastes);

- guidelines for the selection, within a given ecosystem, of the zones that are best suited for the various production systems (e.g. the prediction of the best combination of water movement types for the installation of fish culture cages);

- guidelines for the definition of how far a given type of production can be developed without exceeding the carrying capacity of an ecosystem (e.g. the prediction of achievable shellfish culture density vs. phytoplankton productivity;

- guidelines for the definition of the amount of exploitable resources (e.g. the accurate estimate of the biomass of prey for the commercially valuable species in semi-intensive cultures, such as enclosures);

- guidelines for the definition of the extent to which available resources can be developed by intervention (e.g. the prediction of the yield obtainable by fertilizing semi-intensive fish cultures).

These guidelines and their associated models will be designed in such a way as to be readily used by decision-makers and aquaculture professionals without specific training. As is implicit in simulation, they can be used to perform computer experiments utilizing various types of scenarios and production systems, prior to the real implementation of any aquaculture development.

Organization of the Project

In the light of the above considerations, the project has been organized in the following integrated parts:

i. Pilot Programme to integrate previous data and to collect supplementary data, to prepare pre-models and to start the operational calibration of the project, with particular reference to sampling design and related technical problems.

ii. Core Programme, to perform those basic research activities that are feasible at all sites; to implement Seminars and Advanced Training Missions.

iii. Parallel National Activities (so-called "Satellite Programmes") to be performed in individual institutions, depending on both their specific interests and experience/facilities; the Satelite Programmes will include complementary parts of the project that can be developed independently but consistently with the project itself; specific local problems may be taken into account.

iv. Training Component. The project will have a strong training component consisting of seminars, training missions and the preparation of a methodology manual and an Operations Handbook.

The Pilot Programme

The Pilot Programme will be carried out mostly by the Coordinating Group. It will be performed una tantum at the onset of the project, on all the previously selected sites. It will cover sampling and measurement of sediment descriptors, water levels and water flows. Furthermore, it will include sampling and measurement of all the descriptors listed in the Core Programme, except items a and b (see Technical Annex) for which no direct investigation is considered.

The Pilot Programme will establish:

a. the grid for spatial analyses to be used in the Core Programme for the benthos;

b. the time variability (high frequency) of physical and chemical descriptors of the water column, thus establishing the optimum sampling frequency to be adopted in the Core Programme;

c. the bathymetry of the basin if the one available is older than 50 years (or is not available at all);

d. the location and permanent marking of sampling sites to be adopted in the Core Programme.

The Pilot Programme also includes the preparation and running of the hydrodynamic model for each site, the results of which will form the basis for the definition of the space grid for pelagic sampling to be adopted in the Core Programme.

In addition, a methodology manual will be provided as an output of the Pilot Programme. This manual will provide "how to" assistance in all the practical steps of the procedure, including standard cards for data logging during the Core Programme.

The Core Programme

The Core Programme is designed to validate numerical models (see Annex) on the basis of a minimum number of descriptors which are easily obtained or measured. Some descriptors (e.g. incident radiation) can be calculated from known physical laws or used as variable-forcing functions (e.g. nutrients). Consequently, these descriptors are not included in the list that follows.

The expected result is a validated and calibrated model which will permit simulations by varying the level of the forcing functions and/or border conditions. For example, the model would predict the increase of BOD under a set of cages in a lagoon under different conditions of water exchanges with the sea.

The Core Programme will concern the following descriptors:

- Meteorological descriptors (25-year time series), such as temperature, relative humidity, sky cover, rainfall and wind. Data can be obtained locally or from the nearest Meteorological Office. Raw data are sufficient if no statistical analyses are available.

- Continental hydrography descriptors, such as watershed, soil data, main water inflow and runoff sources. Data can be obtained locally or from the various Regional/National Authorities.

- Geomorphological descriptors, like lagoon-bathymetry and length, width and depth of outlets.

- Physical descriptors, such as water temperature and transparency.

- Chemical descriptors, such as salinity and oxygen content.

- Biological descriptors, such as biomass of plankton, benthos and nekton.

The operational sampling design for the Core Programme will partly depend on the results obtained in the Pilot Programme. It should be considered that sampling, data analysis and modelling are performed interactively (eventually with blocks deriving from the Sattellite Programmes). For this reason, flexible sampling designs are proposed. The general strategy aims at obtaining the best coverage of the system. It can be briefly described as follows:

- meso-scale space grid for sediment and benthos sampling: the system will be divided into squares the size and number of which will depend on the size of the system; two sampling points will be included in each square; only one of the two samples will be studied while the remaining one will be part of a reserve to be used, if necessary, on the basis of a map of errors generated from space distribution analyses;

- micro-scale space grid for benthos sampling: the grid will have the fixed size of 100 x 100 m and will contain a number of squares in which two samplings will take place with the same criteria as those described above. The location of the micro-scale grid will depend on the results of the analysis of meso-scale spatial patterns;

- space scale for pelagic sampling: in general, space resolution will be kept rather low (4-5 sampling points);

- sampling time scale: basic frequency for time series generation of pelagos descriptors is 1/4 of a tidal cycle; sampling will be carried out in seasonal batches of 3 consecutive days (6 tidal cycles) centered on seasonal average meteorological conditions; sampling frequency for benthos will be once a year; fish fry migration studies will be performed once a month, with observations along two consecutive days.

Satellite programmes

The goal of the satellite programmes is to develop particular aspects of the dynamics of an aquatic ecosystem.

The choice depends on the specific problems generated by the unique aspects of different sites and of the different environmental scenarios in connection with the respective aquaculture activities and/or plans.

It will be up to local institutions to select a subject which best suits both the site's problems and laboratory facilities/expertise that can be devoted to these special studies. The only condition required will be consistency with the sampling and modelling strategies adopted in the Project (see Annex).

At this stage, one can only list examples of research that can be undertaken in the Satellite Programmes. These activities will be agreed upon with the staff of local Institutions after the completion of the Pilot Programme. Possible items are:

- Time variability in nutrients and primary producer biomass concentration (high frequency, e.g. weekly)
- Oxygen production and respiration by in situ experiments
- Primary production experiments
- Spatial distribution of size spectrum in selected benthic species
- Gut content analysis in fish of commercial interest (by age and time)
- Feeding and exertion rate experiments on selected species (e.g. Cerastoderma, Sparus aurata)
- Fish stock assessment through different experimental strategies (e.g. capture-recapture, etc.)
- Utilization of waste feeds from cage culture by "wild" stocks.

Training component

Four Project Seminars, spread over the whole duration of the Project, will provide an opportunity for discussion and planning among the Coordinating Group and the Local Units (see 2.6 below). They are designed as Plenary Assemblies of the Project, at the beginning and at the end of particular phases, where an active flow of ideas and experiences, as well as problem-solving, can be obtained. Seminars also represent the occasion for personal contacts and it is expected that they will promote self-identification in the Project of all its participants.

Two Advanced Training Missions are offered to Local Units. ATMs are meant to improve the knowledge of already experienced staff Members of Local Units in particular fields concerning the Project. Special reference is made to methodology in model building and managing, electronic data processing (EDP) and related topics.

An Operations Handbook will be an operative output of the whole Project. It will provide reminders to the users in the application of the procedure under different environmental scenarios and with different production models. The Handbook will condense the experience obtained in the Project in terms of problem solutions, data base and case history reports. It will also include user-friendly software, which will run on most of IBM PC compatibles and which will be designed to carry out Numerical Analysis and Simulations.

The Operative Structure

The Operative Structure consists of:

- A Coordinating Group, which will be a task team carrying out most of the work foreseen in the Pilot Programme, with some assistance from the Local Units (see below). The members of the CG will therefore not constitute a permanent unit with an established office during the whole duration of the Project, but will meet whenever needed in order to direct the activities.

In particular, the role of the CG is:

- to carry out the Pilot Programme
- to perform quality controls
- to plan and assist in Seminars and Workshops
- to perform data processing and modelling
- to prepare reports.

The members of the CG will be assisted by consultants during the Pilot Programme phase as needed. The CG will have at its disposal its own instrumentation in order to ensure the uniformity of the collected data as well as computer facilities for data processing.

- Local Units composed of up to seven staff members (juniors and students included) and a local Coordinator from relevant National Institutions. The role of a Local Unit is to carry out, in cooperation with the CG, the activities planned for the Core Programme and (eventually) for the Satellite Programmes, to cooperate with the CG and participants in the Pilot Programme, to provide laboratory facilities, field work facilities, instruments and whatever else is necessary for the implementation of the project.

Timing

Activities of the Project are scheduled as follows (times are computed from the operative clearance):

- Step 1: Pilot Programme. Seven field missions, one at each site, are included. Data analysis, pre-models, preparation of reports, methodology manual and Data Log. Duration: 10 months.

- Step 2: Core Programme Phase 1. Data collection and analysis, pre-validation of models, training, Parallel National Activities (Satellite Programmes). 2 Seminars, 2 quality control-assistance missions, 2 advanced training missions, 1 meeting of CG are included. Duration: 12 months.

- Step 3: Core Programme Phase 2. Data collection and analysis, validation of models, application, training, Parallel National Activities (Satellite Programmes). 2 Seminars, 2 quality control-assistance missions and 2 advanced training missions are included. Preparation of final reports and of an Operations Handbook. 1 CG meeting is included. Duration: 18 months.

Total duration from clearance: 40 months.

Expected achievements

The major practical achievements expected from the project will include a validated analytical tool for site evaluation and impact assessment with regard to the specific needs of aquaculture under different ecological and development scenarios. Hence, planning of production activities will become easier and more efficient. In particular, the project will provide a tool to manage and increase biological production of economic interest without imposing undue stress on the environment. A deeper insight into the information available so far will also be gained and additional valuable information on the ecological state of the investigated sites will be made available.

This set of achievements will be transferable at both national decision-maker and professional levels, thus improving rational planning of aquaculture in the framework of other production activities using the same environmental resources.

Another important expected achievement is the promotion of advanced education and specialized training enabling improvement of national capabilities for aquaculture development and protection through an efficient site selection and monitoring.

Finally, the role of the Project in promoting cooperation, communication and exchange of both scientific knowledge and practical experience in the field of applied ecology and aquaculture among Mediterranean countries should be underlined.

Financing

The tentative budget has been calculated on the basis of the following criteria:

- to provide the Coordinating Group with equipment and data processing facilities to meet the necessities of both the Pilot Programme and the Core Programme;

- to provide each Local Unit with a contribution to bring its equipment to the level required for the Core Programme;

- to provide each Local Unit with a contribution to the costs of field work and expendable materials.

No financial support is initially foreseen for the Satellite Programmes. However, it is definitely considered that those Local Units that are able to execute the Core Programme using their own means (equipment, manpower etc.) as required in this proposal may allocate the financial support to the development of one (or more) Satellite Programme(s).

This flexibility is designed to compensate for the fact that some Local Units have a level of equipment that already meets the requirements of the Core Programme, as well as expertise enabling the successful implementation of Satellite Programmes. It is expected that this will allow the improvement of the overall output level of the Project.

I. Pilot Programme

A. Coordinating Group

1. Equipment	96 000
2. Missions	45 800
3. Consultants (6 m/m)	29 400
4. Electronic Data Processing (EDP)	18 000
5. Reports	7 000
6. Meetings	7 200
Sub-total	203 400

B. Local Units

1. Equipment	140 000
Grand total:	343 400

II. Core Programme Phase 1

A. Coordinating Group

1. Missions	56 000
2. Electronic Data Processing (EDP)	36 000
3. Reports	14 000
Sub-total	106 000

B. Local Units

1. Contribution to field work	51 000
2. Expendable material	6 900
3. Seminars	93 000
4. Advanced Training Missions	23 100
Sub-total	174 000
Grand total:	280 000

III. Core Programme Phase 2

A. Coordinating Group

1. Missions	56 000
2. Electronic Data Processing (EDP)	36 000
3. Reports	14 000
Sub-total:	106 000

B. Local Units

1. Contribution to field work	51 000
2. Expendable material	6 900
3. Seminars	93 000
4. Advanced Training Missions	23 100
Sub-total:	174 000
Grand total:	280 000
Project total cost:	903 400

A P P E N D I X

7. METHODOLOGY

A. Data to be collected during the Pilot Programme

1. Sediment granulometry distribution (Wentworth or Doeglass classes), with special reference to clay smaller fractions (18f)

2. Sediment $CaCO_3$ content

3. Sediment TOM content

4. Water level (in selected places)

5. Water velocity (at the outlets)

B. Data to be collected during the Core Programme

a. Meteorological descriptors (25-year time series). Data can be obtained locally or from the nearest Meteorological Office. Raw data are sufficient if no statistical analyses are available. Measurements of descriptors a.1, a.3 and a.5 (direction and speed) will be made in each sampling operation. Other data (e.g. incident radiation, evaporation etc.) necessary for model implementation, will be calculated on the basis of known relationships with the descriptors measured.

a.1. Air temperature
a.2. Relative humidity
a.3. Sky cover
a.4. Rainfall
a.5. Wind direction frequency, speed and duration

b. Continental hydrography descriptors. Data can be obtained locally or should be available from various Regional/National Authorities.

b.1. Watershed (surface)
b.2. Soil permeability (average)
b.3. Type of soils
b.4. Main inflows (max. and min. flows)
b.5. Main runoff sources (max. and min. flows, type: industrial, domestic, equivalents etc.)

c. Geomorphological descriptors. Detailed maps (1:5-10,0000) are needed.

c.1. Bathymetry
c.2. Length, width and depth of outlets

d. Physical descriptors

d.1. Water temperature
d.2. Water transparency

e. Chemical descriptors

e.1. Salinity
e.2. O_2 saturation (%)

f. Biological descriptors

f.1. Phytoplankton biomass (as cell number of Diatoms, Dinoflagellates, Gymnodiniaceae, Small Flagellates, Chlorophytes)
f.2. Zooplankton Biomass (as number of Copepods, Cladocerans, Other Taxa)
f.3. Macrozoobenthos Biomass (as wet weight of Anellids, Molluscs, Crustaceans, Others)
f.4. Macrophytobenthos Biomass (as cover and wet weight)
f.5. Nekton biomass, including fry, of Sparids, Mugilids, Serranids, Eels
f.6. Nekton population size structure

C. Sampling and measurement techniques for the Core Programme

Methods and equipment to be used are as follows:

- Air temperature: mercury thermometer
- Sky cover: direct estimation
- Wind speed and direction: hand anemometer
- Salinity: refractometer
- Dissolved oxygen: polarographic electrode
- Temperature: mercury thermometer
- Transparency: Secchi disk
- Phytoplankton: Niskins bottles, Lugol fixation and Utermohl counting techniques; cell volume-based biomass estimates
- Zooplankton: bongo net, sample splitting and counting; biomass estimates according to Shmeleva's conversion formulae
- Benthos: Petersen grab, sieving onto 1mm mesh, weighing on technical balance
- Nekton (fry): visual catches with Italian fish fry net; samples with purse seins
- Nekton (sub-adults and adults): fisheries catches, measurements as usual.

8. ECOLOGICAL MODELLING

by

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Modelling Mediterranean lagoons

The term modelling is used here in its broadest sense of rational simplification and abstraction of the real world.

Ordination or cluster models have been used in several instances and mainly regarded zonal patterns of both abiotic and biotic characteristics. Most of them have suffered from inadequate sampling designs. Model time series are rarer and some also address the stability of spatial configurations. A few examples exist of path analysis (linear) and its predictive application. There have also been several exercises in modelling population dynamics of some species of economic interest.

Mechanistic models and simulations are very rare. Some of them deal with the Lagoon of Venice and Rhone Delta lagoons. There are a couple of applications in Sardinian lagoons. Several modelling exercises are now developing in a variety of sites (France, Italy, Tunisia). In general, the physical sub-system is the one which has attracted the major efforts. Simulations of bi-dimensional velocity fields as basis for the study of advective transport phenomena are the most interesting applications. Numerical approximations of Navier-Stokes equations were used and solved by either the finite difference or the finite element method. These models are inspired to Leendertse's solution which is particularly suited to shallow waters and proved to be rather satisfactory in both estuaries and closed bays.

Ecological (trophic) models have also been used. Solutions are 0-dimensional (the space component is not considered) and therefore numerical solutions deal with ordinary differential equations. There are a few applications (e.g. the Lagoon of Venice) the formulation of which is largely inspired by the classic Kremer and Nixons's Narragansett Bay model. Simulations of primary and secondary production in the pelagic compartment seem to offer the most interesting perspectives.

Elaboration of the procedure

The procedure results from a methodological amalgamation based on the convergent and integrated application of different approaches and techniques (or their adaptations) to the study of aquatic ecosystems. The procedure is scientifically formal in that it makes reference to inductive and deductive methods both in the planning of information collection and in data analysis. For these reasons, although it does not disregard inputs from purely descriptive and analogic readings, the procedure aims at the construction and testing of numerical models. Models are of a statistical and a mechanistic nature and are used interactively. Their major role is to produce at least sensible assessments and forecasts.

Due to the nature of the specific problems concerning aquaculture, the evaluation of conceptual, technical and mathematical constraints is done in the light of economic constraints, in terms of cost, time and manpower. The parametrization of the above items is expected to lead to an optimized operational scheme.

The procedure consists of the following steps:

Step A: construction of the mechanistic model. It implies (1) identification of the system of interest, (2) definition of the objectives of the model, (3) definitions of conceptual, physical and temporal boundaries, (4) identification of sub-systems, (5) identification of internal and external forcing functions, (6) selection of state variables (descriptors), (7) creation of the conceptual model, (8) collection and evaluation of available information, (9) specification of functional relationships, (10) translation into mathematics, (11) translation into a computer programme, (12) test for sensitivity and select coefficients, (13) simulations, (14) comparison with reality often based on sub-step 8.

Step B: based on the results of the model, establish a sampling design which should afford: (1) a validation scheme for the model as a whole by comparisons, (2) data for synthetic descriptions and factorizations, (3) a scheme for the statistical testing of some of the relevant hypotheses worked out in the previous step (e.g. correlations, causal paths, zonal patterns and anisotropies), (4) construction of statistical models in both space and time, (5) interpretation of facts. The sampling design does not necessarily imply a unique set of variables and is not restricted to passive observation. Some manipulative experiments are, in fact, recommended if not necessary. Finally, some of the variables are of interest only in a synchronic context: their spatial configurations may be used for indirect validations by analogy or correspondence. A list of variables to be measured during the Pilot and the Core Programmes as well as information on sampling and measurement techniques is given in the Appendix.

Step C: feed back onto the conceptual model and its mathematical formulation. At this point, the mechanistic model has a stochastic component.

Step D: iterations through Steps A and B up to the point where the results match with observed data.

Step E: applications.

It is worth noting that in many modelling exercises, Step B is either simplified or lacking. In this case, sub-step 14 may represent nothing else than a fitting exercise.

In both Steps A and B the selection of descriptors is crucial, since from this point on, the system will coincide with the list of its descriptors. There is no prescribed way of choosing these descriptors, besides consistency with formulated hypotheses and the consideration of a number of constraints. These are of a technical as well as of a mathematical nature in the sense that they must be readily measurable and their number manageable with limited computing facilities. Natural constraints, depending on the properties of the variables, should be carefully considered.

The procedure described above has never been applied as such. Its main advantage seems to consist in the interaction between mechanistic and statistic modelling, since it should solve problems connected with the fact that mechanistic models often lack data for validation and statistical models need large and expensive sampling efforts. In our case, the mechanistic model guides the sampling design for the statistical model, the results of which will serve for validation.

Modelling approach proposed for the project

The formulation of the mechanistic model is derived from:

- Leedertse approximation for the hydrodynamic and for the dispersion model. A finite difference solution and the elated NSMODEL programme, written in BASIC for a MS-DOS environment (PC-level hardware), is available for the hydrodynamic subsystem. A finite element solution is being developed which seems better adapted to manage the complex geometries of coastal lagoons. This will form the basis for a 2-dimensional dispersion and trophic model (at least for pelagic primary and secondary production). At present, the model also computes water exchanges at the opened boundary (e.g. lagoon-sea boundary). There are several applications to coastal lagoons and bays. Validation is mostly indirect (by analogy).

- Kremer and Nixon 0-dimensional ecological model, including a stochastic component for the forcing functions at the water-air boundary (meteorological events are defined at random within the 25-year statistical limits of the region). At present, spatial elements are identified on the basis of the results of the hydrodynamic model (persistent isokinetic fields and circulation patterns). The coupling with pelagic production to selected benthic elements (e.g. Molluscs) is being developed. Computer programmes are available under the same conditions as NSMODEL. This model will be later merged with NSMODEL in order to obtain two-dimensional biological reactors. Validation of physical exchanges has been performed.

- Evapo-transpiration model to simulate surface hydrography in the watershed.

As for the statistical models, several methods are available depending on the scopes, hypotheses and type of variables. A major role is taken by space configuration analysis especially of conservative or semi-conservative characteristics of the system. A variety of techniques is available for stochastic interpolative mapping (Kriging), regionalization by free and constrained clustering, fuzzy partitions, anisotropy and clump detections, clump size evaluation, coherence evaluation of physical and ecological spaces etc. for both uni- and multi-dimensional data sets. Several algorithms are available for the study of "resemblance" matrices, such as Multi-dimensional Scaling, Coordinate Analysis, Factor Analysis, Component Analysis, Correspondence Analysis (both simple and multiple) etc., which perform "ordinations" in two-way data sets.

Another important class of statistical models is represented by Casual Analysis. Canonical Correlations, Procuste's Analysis and Mantel's statistics are considered (and computer programmes available) for multiple data sets. Path-analysis is another relevant approach to detect direct and indirect causation models and derive linear (multi-regressive type) predictive equations.

Time series can be analysed (and models constructed) by a series of innovative techniques such as chronological clustering, auto-distance analysis, contingency periodograms, Markovian chains and related methods. More conventional methods (e.g. Spectrum Analysis, ARMA and ARIMA models etc.) are available depending on the quality and the amount of data.

Finally, population models, growth statistics, biometric evaluation methods, and more generally the classic tools of parametric statistics have their own typical applications in modelling exercices, whenever hypothesis testing is feasible.

A library of computer programmes developed for IBM compatible PC is available for the project. This library ensures an interactive use of the techniques available; a part of the library can be used for didactic purposes.

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