Thesis
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COASTAL AQUACULTURE AND RESOURCES MANAGEMENT IN THE MECOACAN ESTUARY, TABASCO, MEXICO

A thesis submitted to the University of Stirling for the degree of Doctor of Philosophy

By

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August 2002

02/03

DECLARATION

The candidate has composed this thesis in its entirety. Except where specifically acknowledged the work described in this thesis has been conducted independently and has not been submitted for any other degree.

Signature of candidate:

Date: 16 AUGUST 2002

To the Fisher of men

In loving memory of my father

To my Mother, Ruth, Mauricio, Keila Rebeca and Gonzalo Javier

ACKNOWLEDGEMENTS

I would like to thanks the Consejo Nacional de Ciencia y Tecnologia CONACYT for the support provided to carried out the PhD programme

My gratitude to my supervisors, Professor James F. Muir and Professor Lindsay G. Ross for their valuable guidance and advice to develop this study

Special thanks to all my dear friends; you made my time in Stirling the best time of my life. You will always be in my heart: Rodolfo, Monica, Norasma, Rohaiza, Khaled, Rudwan, Leticia Mar, Noe, Gabi, Sergio, Ivonne, Antonio, Mercedes, William, German Antonio, Conrado, Joaquin, Juan, Beatriz, Danitzia, Rafael, Emine, Oscar, Luis Matias, Matias, Jorge, Dio, Adrian, Alberto, Jose, Nicola, Leticia, Daniela, Julieta, Cuitlahuac, Sadiq and Genomar

ABSTRACT

By dealing with aspects of coastal aquaculture and resources management, an analysis is herein presented at the macro-scale using GIS techniques for the coastal zone of Tabasco state, and at the micro-scale with the description of the characteristics of a coastal community located in the Mecoacan estuary.

Transfer of appropriate aquaculture technologies and introduction of sustainable farming systems are major challenges. The total area identified for aquaculture development through the GIS modelling accounted for 23 462 ha, 80% of which were located in the Centla Biosphere Reserve (Centla and Macuspana). The suitable area identified through the multi-criteria evaluation provided a structure in which requirements for aquaculture development could be met.

An analysis of the farming systems in the Mecoacan estuary was carried out to understand local attitudes, capabilities and processes and evaluate whether the potential identified by the GIS modelling can be realised. The results from participatory assessments showed that conditions within Mecoacan cooperatives have deteriorated and increasing interest in restructuring the organisations is regarded as a means of integrating employment and income generation alternatives such as aquaculture practices, to support and improve current levels of fisheries production, and to achieve gains in market development.

The analysis of the economics of Mecoacan fishermen suggests that rural problems have not yet been engaged in progressive policies. It seems that previous forms of governance have been maintained to shore up power instead of laying the groundwork for viable rural production, as it is clear that some fishermen are competitive while others are not, regardless of whether or not they are associated in cooperatives.

The large-scale exploitation of resources, degradation of the environment and increased conflict over resources in coastal communities suggest the need of an integrated multi-sectoral approach. A strategy towards an integrated coastal management for Tabasco coastal zone is discussed, including those related to aquaculture development.

CONTENT

1. Coastal aquaculture and resources management

1.1 Coastal zone resources and management

Coastal zones are complex and productive ecosystems. A vast diversity of natural resources is contained in terrestrial and aquatic habitats due the interaction between land and sea. These ecosystems are closely inter-related to socio-economic activities and population size (Scura *et al.*, 1992; Caddy & Griffiths, *op cit.*), which can imply intensive resource use and demand.

The world population is expected to double in less than a century to 10 billion people and a suggested 75% of these may be expected to occupy the coastal zones of the continents. Increasing numbers of fishers are exploiting existing and new stocks in coastal areas of developing countries, and environment degradation and reduced resources are prominent results. Fisheries harvest has increased in the 1990s about 35% (OECD, 1993; Caddy & Griffiths, 1995; FAO, 1999).

The inappropriate implementation of policies results in the transfer of technologies that either do not respond to the needs of or that are not easily available to rural communities. By dealing with aspects of coastal aquaculture and resources management, an analysis is herein presented at the macro-scale based on geographical information systems modelling of Tabasco coastal zone, and at the micro-scale with the description of the characteristics and the interactions of a coastal community with institutions and organisations in a rural system where agriculture, fishing, aquaculture and coastal issues have important linkages regarding their management and development.

Fishing has been the major source of food, employment and economic benefits to those living beside aquatic resources. Other economic opportunities such as oil and timber extraction, agriculture, shipping and tourism are also alternative sources of commodities for coastal communities (Beatley *et al.*, 1995). Conflicts and competition for limited coastal resources and escalating environmental deterioration present a significant development challenge. Open access exploitation of fisheries resources leads to excess fishing capacity and dissipation of economic benefits from resource use. Failing open access fisheries throughout the world have been characterised by declining total yields, sharp decreases in the yield per unit of fishing effort, disappearance of the more highly valued species, cutthroat competition among fishermen and, in some cases, the economic collapse of the fishing industry (Ferrer, 1989).

The social and economic importance of estuarine fisheries is related in particular to artisanal fishing communities within which fishermen and their families seek employment and livelihood. Though they cannot necessarily access all exploitable aquatic stocks, artisanal fisheries can be highly efficient in terms of production per unit of energy input and capital investment and can produce quality protein at affordable prices, with a better cost-benefit ratio than large-scale fisheries (Ben-Yami & Anderson, 1985; Caddy & Griffiths, 1995).

However in changing conditions, since artisanal fishermen do not hold property rights due to the open access feature of most fisheries, they are not commonly compensated for any impact in their livelihood (Dubois, 1985; McManus, 1995). The need for participation of communities in formulating and implementing policies and management frameworks to sustain an appropriate life quality has been widely recognised (O'Sullivan, 1991; Yap, 1996).

Several significant consequences are acknowledged to result from the condition of common property. First, there is a tendency to waste the resource physically. A second consequence is economic waste, as in the absence of controls on capital and labour there is a tendency for too much effort to be spent on too few fish. Related consequences are that average incomes of small-scale fishermen in developing countries tend to be at the bottom of the scale, and conflict occurs in the form of congestion among fishermen using the same resource with the same technique or gear (Ferrer, 1989).

The common property condition is not the only cause, but is certainly an important contributory factor. There are other cultural, social and economic factors involved and the problems are complex and not readily understood. If the conditions were removed, and economic rents were produced, they could at least in theory be shared among the fishermen so as to increase average incomes. This, however, would require a means for sharing that might be difficult to impose and enforce (Christy, 1982).

As the coastal zone is characterized by ambiguities of resource ownership, and complex interactions between resources, ecosystems and resource users, the above represent major resources related issues in coastal zones. It has been widely recognized that to address these complexities and multi-use conditions, and also to promote sustainable development, select alternative income generating activities, establish appropriate technology, conduct environmentally friendly operations, and organize a regional operation network, a management tool such as integrated coastal zone management (ICM) may provide a framework for solving conflicts, support economic growth and expand social benefit (Vallejo 1991; GESAMP, 2001).

Regardless of the development options, given the particular renewable resources features of coastal zones, a range of social, institutional and political conditions influence planning and often involve critical social and political decisions. Thus, the approach depends on how effective and bureaucratic is the management as planned by governments, and the extent to which different aspects such as inputs from non-governmental organisations, government policies, legal obligations, and communities participation and traditions are considered (Gubbay, 1989; Johnston, 1992).

In terms of specific access to coastal natural resources, an emergent management tool is the allocation of territorial use rights in fisheries (TURFs), recognised as an important fisheries management approach, particularly in regard to efficiency goals and improvement of welfare in coastal communities (Christy, 1982; Ferrer, 1989). This concept was developed as a practical response to the problems consequent on open access conditions stated by 'the tragedy of commons' model. The evidence of TURFs under community management systems indicates that it may provide opportunities to improve community welfare and to enhance equity and self-regulation (McGoodwin, 1990; Bojos, 1991; Berkes, 1994).

However, care may need to be addressed in developing this kind of sea tenure, to avoid the creation of 'sea lords', which may worsen inequity where open access condition are removed. Thus, it has been recommended that the allocation of TURFs be granted to groups, rather than individuals and the use of extra-local authority would be paramount as it may otherwise become another source of disincentives and externalities in terms of the use of something in common with others, where the right not to be excluded from the use of something is wrapped by power, money and hegemony playing upon social structure (Christy, 1982; Vallejo, 1991; McCay & Jentoft, 1998).

Bureaucratic involvement in resource management may have a latent dislocating function, as vertical linkages between individuals and government take precedence over horizontal linkages such as those between users and within their local community and on the commons, inducing a lifting out of social relations in the local context of interaction with respect to responsibilities that were previously a concern of commons users. Therefore, in situations where the nature of the resources or existing resource management systems precludes more locally based initiatives, enhanced sectorial approaches may be the most appropriate (McCay & Jentoft, 1998; GESAMP, 2001).

McCay and Jentoft (1998) assert that arguments about problems with the commons in the modern era derive from attempts to understand the political economy of capitalism and more particularly the failures of capitalist markets from the perspective of liberal economics. Without well-defined and exclusive property rights, markets fail to do their jobs matching individual and social interests, as common property is a social institution rather than an attribute of nature where each individual acts essentially for his own good without regard for the good of others.

Proper planning for improving and maintaining coastal communities' livelihood must therefore take into account not only economic and environmental issues, as well as traditional management of coastal resources by communities in order to device an effective management and allocation of resources. These may allow the identification of development opportunities in appropriate areas where environmental conditions are optimal and conflicts may be reduced (Black, 1991; Black& Truscott 1994).

However, the lack of effective mechanisms for implementation has often been a weakness of such approaches, and requires particular attention in regard of traditional cooperative relation patterns, as the transformation into competitive and positional relationships may bring users into dependency in their relationship with government and at odds with each other. Thus, the conditions that are conducive to social action are eroded. When it occurs, Panayotou (1986) asserts that the tragedy of the commons is inevitable, as it may be the result of the rather appalling combination of market and community failure.

1.2 Resources management in Mexico

In December 1987 Mexico had embarked on a major programme of fiscal and monetary adjustments to be accompanied by profound structural reforms centred on a radical reshaping of the role of the state in the economy and a fundamental change in the nature of the country's international economic relations (Blejer & Del Castillo, 1998).

The Mexican macro-economic strategy for the 1990s was based on traditional budgetary and monetary discipline, including a series of social pacts between government, business and labour agreeing on a path for incomes, key prices and the exchange rate, for the reduction of trade and investment restrictions, stabilisation through the full liberalisation of the capital account, the financial sector and the re-privatisation of banks, and the conclusion of the North American Free Trade Association NAFTA. Even though economic transformations took place, democratic reforms have not occurred at the same pace and only large financial, commercial and industrial conglomerates are assumed to have profited from neoliberal policies (Davila-Aldas, 1997; Rosas, 1997).

Mexico's economy had experienced serious problems due to the 1994 devaluation. Under the new economic policies the currency was allowed to float and devaluation took place after the private sector portfolio had shifted in favour of the dollar indexed tesobonos, which accounted for over 50% of total government securities at end-November 1994. The increase of political and economic uncertainty caused the Peso to be devalued and the stock market tumbled, plunging the country into new economic stagnation, which proved difficult to revert. External financing was needed to ameliorate the weak financial situation in the short run, causing large increases in foreign indebtedness, falling real wages and widespread unemployment. Most of the shocks were domestic, relating to instability created by a series of political assassinations, the unrest in Chiapas state during an election year, together with international changes in interest rates particularly in the United States (Rosas, 1997; Blejer & Del Castillo, 1998).

The neoliberal agrarian reforms resulted in scarce and expensive credit and the removal of subsidies. The social unrest consequent on these economic and political conditions has caused a major break up of social organisations and increased conflicts among rural communities. Each of these factors adversely affected the livelihood of rural producers (McDonald, 1997).

Regarding the exploitation of coastal and marine resources, management had been done in a sector-by-sector basis, without any attempt of integrating the governance and management of the coastal zone and its resources. However, since 1995 the management of the coastal zone has become part of National Development Plans, in view of its potential for urban and industrial development, and in order to promote economic growth and the better management of coastal resource uses (NOAA, 2000; Rivera-Arriaga & Villalobos, 2001).

The type of approach to ICM followed by this program has been broad and regulatory for land ordinance planning, and tries to foster capacity building through education of government officials and the public. In 1996 the Agreement of Coordination for the Use of Beaches, the Federal Land-Maritime Zone, and Claimed Lands Plan was developed, which entered into force in 1997 and operates through a state Committee for the Sustainable Use of the Federal Land-Marine Zone (SEMARNAP, 1999). This program followed the recommendations made by the OECD Council and adopted the provisions of the Agenda 21 concerning ICM (NOAA, 2000).

1.3 Community management

From the characteristics of fishing culture, such as self-reliance, freedom from regimentation and certain level of indifference to community affairs, and the common marginalisation to which fishermen are subject from development and modernisation, the allocation of property rights or use rights over certain area of operation is a difficult task. It is often stated that collective property right regimes are less stable than private property regimes because the underlying 'prisoners dilemma', as each individual, anticipating the resource usage of others, tends to overuse jointly owned resources and quickly deplete resources. It is therefore assumed that individuals will destroy any social benefits that a fishery could produce, but in terms of practical understanding fishermen posses a vast knowledge of the particular environment and resources they use, and it has been recognised that informal property rights exist among fishers under informal and formal cooperative organisation (Charles, 1988; McGoodwin, 1990).

Alcala and Vande-Vusse (1994) assert that government must recognise fishing people as the real day-to-day fisheries resources managers to make proper management decisions and equitable allocation of resources. This makes participation of local people in coastal resources development planning, implementation and monitoring an important means to avoid or mitigate to some extent problems associated with open access conditions.

The rich and complex case studies in the literature on the arrangements developed by local communities to deal with commons issues are frequently interpreted simplistically to support the conclusion that when left to their own devices people will reach viable solutions to their collective dilemmas leading to a successful commons' management due its small-scale and self-governance character (Ferrer, 1989; McCay & Jentoft, 1998).

On the other hand, cooperation may denote competition, as communities are not static and are often characterised by social fissures. Limiting or reducing the access to a particular resource may have a direct effect on job availability due to the intimate relationship between amount of employment and fishing effort, although the average income may be higher as the fishing rate is lower. Hence, conflicts between maximising employment and improvement of individual income may develop, as some present users of the resources may be excluded (Christy, 1982; Troadec, 1983).

Efforts to integrate aquaculture into coastal management can contribute to improvements in selection, protection and allocation of sites and other resources for existing and future aquaculture developments. As no simple, effective, and widely applicable models have been identified, less comprehensive approaches may be the only realistic option in some situations, but might also be seen as a starting point to a more comprehensive integrated coastal management (Newkirk, 1996).

The most appropriate approach will depend upon a wide range of local factors, including available skills and resources, the urgency of the problems or opportunities, and the nature of existing planning and development frameworks. The justification for more integrated approaches to aquaculture development is significant, as coastal aquaculture has brought economic and employment benefits to both national economies and coastal people throughout the world (Hugues-dit-ciles, 2000; GESAMP, 2001).

1.4 Coastal aquaculture

According to FAO definitions, organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture, while organisms which are exploited by the public as a common property resource, with or without appropriate licenses, are the harvest of fisheries. Many authors have suggested aquaculture as an efficient use of water surface for managing estuarine areas and to have beneficial influences on jobs and income (Kapetsky *et al.*, 1987; Schug, 1996; Ridler, 1997). The Bangkok Declaration and Strategy for Aquaculture Development (NACA/FAO, 2001) addresses the role of aquaculture in improving livelihoods and food security, maintaining the integrity of natural and biological resources, alleviating rural poverty and the sustainability of the environment by involving governments, the private sector and social organisations.

To the extent that it can generate additional output and economic surplus from existing aquatic resources, aquaculture has great potential for the production of food, alleviation of poverty and generation of wealth for people living in coastal areas, many of who are among the poorest in the world. Coastal aquaculture is dominated by the production of aquatic plants (seaweeds) and molluscs. However, a wide range of coastal aquaculture systems has been developed in Asia, Europe, and the Americas, operating at different intensities and scales of production. Aquaculture production is growing at more than 10% per year, compared with 3% for terrestrial livestock and 1.5 % for capture fisheries (Srinath *et al.*, 2000; GESAMP, 2001).

It has not been anticipated that substantial increases in supply can be obtained from oceanic fisheries. Therefore, any future growth in fish protein supply will have to come from aquaculture and the enhancement of wild fisheries. Aquaculture has been considered in developing countries as an alternative to support fisheries production, a way for improving average income through the creation of employment opportunities outside the fishery sector, and as a mean of reducing fishing effort, which may allow the consolidation of resources use through vertical or horizontal integration (Pollnac, 1992; Pomeroy, 1992; EIFAC, 1998).

The great diversity of the sector encompasses very small to very large-scale enterprises, implying that aquaculture can contribute significantly to a wide range of development needs. However, significant problems can be associated with coastal aquaculture development. These include unsuccessful development, where potential is not realized, especially among the poorer sectors of society; its vulnerability to poor water quality and aquatic pollution, caused by industrial, domestic, agricultural and aquacultural wastes; and adverse impacts of overlooked and unplanned development, where the undoubted successes of the sector have been tainted by environmental and resource use issues, social problems, disease, and in some cases, marketing problems. Though, current knowledge is sufficient for technical interventions to mitigate continuing damage by other users or to rehabilitate impacted systems, resolving the problem is still complex (EIFAC, 1998; Boyd & Schmittou, 1999; GESAMP, 2001).

The growing scarcity of water resources has lead to increasing competition amongst various resource users, including aquaculture. It has been concluded that planners and administrators must participate in promoting awareness and knowledge of the social, economic and environmental importance of water and living aquatic resources management. This may help to limit the potential damage resulting from the recognized impacts on the part of aquaculture by the introduction of exotic species and quality of its discharges (EIFAC, 1998).

Governments have responded mainly with specific regulations relating to farm operation such as effluent limits, design standards, best management practices, and codes of conduct. In some cases they have responded with more rigorous requirements for social and environmental impact assessment. However, the promotion of environmental assessment in particular has often failed to address the problem of rapid and unplanned development of aquaculture. For example, problems associated with shrimp farm development have arisen mainly when it has developed rapidly and uncontrollably in developing countries. The impacts associated with aquaculture are often insignificant for individual farms and assessments of this significance have been highly subjective and inconsistent, in the absence of any environmental quality standards (Tibbetts, 1996; GESAMP, 2001).

The rapid growth of aquaculture in recent years has been a feature of a range of sub-sectors, particularly through commercially targeted production of high valued species. Given the problems listed above, it is clear that this growth has great relevance in terms of sustainability, as current international development frameworks are in pursuit of ecosystem maintenance, proper distribution of benefits amongst participants in the local and global economy; enhanced socio-cultural welfare of communities and the endurance of appropriate institutional structures (Charles & Herrera, 1994; Newkirk, 1996; Mohamed & Dodson, 1998; Ashley & Carney, 1999).

Factors affecting the success of attempts to introduce collectively managed aquaculture include the existence of past successful collective activity in fisheries. Local leadership, management ability and the strength of local services are important in the context of cooperatively managed aquaculture. Communal management practices are regularly debated. Success or failure of group approaches to aquaculture arises from the motivations inducing groups to form. Problems invariably arise when formal groups are created primarily in expectation of assistance such as loans or grants, or because of disputes over rights to the harvest (Martinez & Pedini, 1997).

Better organisation and representation of the sector is also a precondition for better and more effective planning. Crucial elements in a more planned approach include: improvements in siting, design, technology, and management at the farm level; better location and spatial distribution of the sector as a whole; better water supply for the sector as a whole; better fish health management including disease and stock control at individual farm and sector levels; improved communication and information exchange; improved access to markets and trade opportunities; more equitable distribution of the benefits derived from coastal aquaculture development. In practice many of these are unlikely to be achieved without effective integration with planning and management of other sectors (EIFAC, 1998; GESAMP, 2001). There are many examples of more integrated coastal zone management initiatives, some of which have encompassed aquaculture. Aquaculture may represent a potential source of development where open access conditions exist, in particular regarding property rights and resources management. Therefore, efforts to integrate aquaculture into coastal management may contribute to improvements in selection, protection and allocation of sites and other resources for existing and future aquaculture developments (Dale, 1989; Johnston, 1992).

In these circumstances it has been suggested that where coastal aquaculture is in the early stages of development, institutions for resource management are un-developed but appropriate legal and institutional frameworks are in place and scientific and technical capacity can be developed rapidly. A locally focused and comprehensive integrated coastal management initiative would be an ideal starting point and this may lead to the identification of specific needs in terms of greater vertical integration (GESAMP, 2001).

Such initiatives may also consider the use of territorial use rights in fisheries (TURFs) as these can be attached to culture sites for sedentary species such as molluscs and to systems such as rafts or fish cages, even though common property conditions may remain with regard to the flow of nutrients and pollution. The territory governed by a TURF can relate to the surface, the bottom, or the entire water column within a specific area. The size of the territory will vary with use, the resources being harvested and geographical characteristics. It should be sufficient in size however, so that use outside of the territory does not significantly diminish the value of use within. The territory should be readily defensible and protected by laws and institutions of the country. The boundaries of the territory should, therefore, be clearly demarcated and identifiable (Christy, 1982; Ferrer 1989).

Once a TURF has been demarcated and easily identifiable, it may allow the owner to capture a satisfactory return on any capital investment. This would be done through appropriate laws and governance in terms of area protection. A proper legal regime must be developed, as control of access is a politically complex issue. Thus, government has to be disposed to take the steps required to distribute the resources (Ben-Yami & Anderson, 1985; Bailly & Paquotte, 1996). The major and fundamental problem is that the establishment of localised TURFs may require re-distribution of wealth. The provision of exclusive rights means that some present users of the territory are likely to be excluded (Christy, 1982). Although this may be socially and economically desirably it may be politically difficult.

In view of the prominent benefits, the development of property regimes may influence the nature of aquaculture practices, which are directly influenced by community attitudes and productive activities (Newkirk, 1992; Pomeroy, 1992; Ridler, 1997).

1.5 Geographical Information Systems (GIS) in coastal resources management

A range of more comprehensive approaches to coastal resources management have been proposed as frameworks for addressing the wider issues of sustainable coastal resource use, the minimisation of conflict, and the optimal allocation of resources. There have been two main types; the first has used GIS and remote sensing as the basis for defining suitable locations or zones for aquaculture. The second has focused on estimates of environmental capacity in order to define appropriate scale and location for sustainable aquaculture development. Both offer a useful practical focus for more integrated planning initiatives (GESAMP, 2001).

The expansion of aquaculture related activities and the increased concern regarding its suitability have promoted the use of GIS for decision-making in aquaculture development. Decisions may require considerations of social, economic and environmental segments; thus through the development of GIS models it is often possible to address different issues using the same database to conduct time-series analyses as changes occur at many spatial and temporal scales, and to forecast scenarios through the weighting of relevant factors. However, verification is essential in terms of the quality of the data sources and the modelling approach (Martin & Bracken, 1993; Ren, 1997; Skidmore *et al.*, 1997; Nath *et al.*, 2000).

Whilst the use of the technology as a tool for land-based resource management and planning is well established, GIS applications in coastal and aquatic environments are beginning to expand for the creation and improvement of databases to be used in the delivery of sustainable ICM frameworks. GIS applications for ICM initiatives have been adopted to outline opportunities and constraints and as a decision making tool to improve control over resources (Kam *et al.*, 1992; Mumby *et al.*, 1995; Jones *et al.*, 1999; Sherin *et al.*, 1999).

Among the multiple objectives for management in coastal areas, the production of coastal maps and monitoring aquaculture development are of particular concern (Mumby & Edwards, 2000). GIS-based modelling has been carried out for coastal aquaculture development in order to promote better resources management practices. The extent of GIS application for aquaculture development includes site selection, land use conflict analysis, environmental impact assessment and coastal zone management (Kam & Loo, 1992; El-Gayar, 1997).

The scale of investigation also varies. At the local level studies have been conducted on site selection for targeted species such as salmon and oyster based upon system and environmental issues (Ali *et al.*, 1991; Ross *et al.*, 1993; Habbane *et al.*, 1997; Arnold *et al.*, 2000; Scott, 2001), modelling the dispersal of solid wastes from cage culture sites (Perez, 1997) and relating microbiological data from shellfish monitoring to the type and size of sewage discharges (Lee & Glover, 1998).

Based on a wide range of data on environment, socio-economics, resource availability and infrastructure, national or state level investigations have been carried out (Kapetsky *et al.*, 1987; Kapetsky *et al.*, 1990; Bhan *et al.*, 1993; Aguilar & Ross, 1995; Mumby *et al.*, 1995; Salam, 2000). Regional investigations have been made particularly for Africa and Latin America (Kapetsky & Nath, 1997; Aguilar & Nath, 1998).

Aguilar (1992) and Gutierrez (1995) developed assessment studies for the state of Tabasco, Mexico, based on environmental, social and economic parameters. The approach used was system orientated (pond and cage culture). GIS modelling suggested that 86% of the state had potential for pond culture, but the most suitable areas according to the environmental and socio-economic parameters considered were located in the west and near the capital of the state.

1.6 Tabasco coastal zone: The case of the Mecoacan estuary.

This study considers the status and trends of fisheries management and aquaculture development in the Mecoacan estuary. The physical characteristics of the estuary, including the seaward portion are such that property rights have never been distributed amongst users, and thus these areas have remained open-access resources. The Mecoacan estuary is under pressure from several natural processes and human activities (oil extraction, artisanal fisheries). An important facility of Petroleos Mexicanos PEMEX[1] is located at Dos Bocas, where the oil extracted in the Campeche area is processed. Galaviz-Solis *et al.* (1987) have described the physical characteristics of the Mecoacan estuary.

The southern Mexican states on the coast of the Gulf of Mexico produce approximately 85% of the total national oil production. Extraction is mainly carried out in the states of Tabasco and Campeche in the marine and terrestrial areas with important impacts on the coastal zone (e.g. coastal erosion, accidental spills, deforestation by drilling and exploration activities) due to the lack of government legislative controls and mismanagement of the industry (Gold-Bouchot *et al.*,

[1] National Oil Industry

1999). The region has also attracted attention due its important economic influence in terms of fisheries, aquaculture and agriculture, and for its ecosystem diversity. These diverse resources and their use have led to conflicts among different users (Negrete-Salas, 1984; Gold-Bouchot *et al.*, 1995).

Coastal zones have been focal points of social conflicts and environmental problems in the last 25 years in Tabasco. Most of these have also resulted from the hasty shift in regional economic development from a predominantly agrarian production to a high technology oil industry (Allub, 1983; Garcia, 1984). The cumulative conflicts arising from this heterogeneous regional development had led to an increased lack of coastal resources management, an unregulated oil industry, increased population, reduction of stocks of valuable species due to over-fishing and environmental deterioration, together presenting a significant development challenge (Moguel, 1994; Perez, 1998).

The ecological impacts of oil in the area are better understood, as many biological effects have been measured and some toxicological patterns have become apparent. Spills have low or negligible impacts on fish populations but can taint fish and invertebrates, although there is little or no evidence from such events. It is generally acknowledged that prevention is the best way of reducing the known impacts of oil on the marine environment and its resources (GESAMP, 1993).

Fishery sector development in Tabasco has been one of the most severely affected by oil industry impacts and unmanaged estuary ecosystems. Since 1985 a constant reduction in fishery production has been recorded, particularly for oyster, which is the most important fishery of Tabasco representing 33.4% of national production in 1997. The exploitation of the oyster fishery in the Mecoacan estuary is based on two systems of production: the exploitation and management of natural banks and the use of semi-intensive aquaculture systems. They have been established since the 1940's and are managed by four local fishing co-operatives (Moguel, 1994; SEMARNAP, 1997).

The first fishing cooperatives in the Mecoacan estuary were organised to provide local fishermen with institutional resources and develop the management of estuary fisheries. "Andres Garcia" was established in 1941 and was granted a fish, oyster, and shrimp fishing permit. This is the largest cooperative, with 229 members. The second cooperative "Chiltepec" was established in 1944, but due to conflicts among its members regarding financial and management issues the membership decided in 1990 to reorganise the cooperative into two new organisations "Puente de Ostion" with 54 members and "Boca de los Angeles" with 90 members. The last cooperative to be established was "Mecoacan" in 1969 and has a membership of 117.

In order to operate, each cooperative member contributes a fee of approximately Pesos$ 350.00 (US Dollar$ 37.63) twice a year toward fishing permits, paper work and travel expenses of administrators to Fisheries Ministry offices in the municipality and state capitals. While they prefer to operate as independent producers, they have neither the capital nor the access to credit that would help them modernise. Lack of access to credit is also related to the perception of fishermen not using their own capital assets as collateral to secure a loan, as they are used to not being considered financially responsible if projects or initiatives fail. Credit is available through government rural development programmes operated by the Banco de Mexico such as Fideicomisos Instituidos en Relación a la Agricultura FIRA and the Fondo Nacional de Empresas en Solidaridad FONAES.

Mecoacan fishing co-operatives have played an important role in the development of management and control over the estuary resources. In 1992, after an important reduction of production, 70-80% mortality in natural areas and culture systems, the four fishing co-operatives of Mecoacan, represented by 538 members, and supported by the co-operatives established in the Carmen-Pajonal-Machona estuary denounced Pemex activities and asked for government intervention (Moguel, 1994).

After the preventive and corrective actions instructed by PROFEPA (Environmental Protection Agency) were not applied, a second social mobilisation was promoted by Mecoacan co-operatives in 1993 and agreements between fishing communities and Pemex supported by government agencies were signed. Operational enhancement of wastewater treatment plants, reallocation of oil facilities, mangrove reforestation, pollution source assessment, aquaculture technical assistance and culture implementation were some of the issues. However, most of these have developed slowly due to political constraints (Santo Tomas, 1996).

National and state government has recognised the dependence of economic development on the effective management of natural resources and the maintenance of sustainable yields from ecosystems with the participation of local communities. Policies and regulations to exert control over resources management through fishing licenses and resources reallocation are the most direct action. The ICM strategies for the state are those under the Convenio de Coordinacion para el Uso de Playas. This programme has been operating through licensing for exploitation and use of the federal coastal zone, and is regulated by the Federal Tax Bureau (SHCP) together with coastal state governments (NOAA, 2000). However, Tabasco state ICM programmes are not yet extended to fisheries and aquaculture.

Fisheries has been described as an open access resources; though in the case of small-scale and inland fisheries around the world, traditional or modern, restriction of access to common property systems exists (Christy, 1982; ICLARM, 1992). In the case of Tabasco coastal fisheries the mechanisms used to manage this 'common property' are poorly understood and the management and development of coastal aquaculture, practised since the 1960's to support and to enhance oyster production remain stagnant and poorly documented.

1.7 Rationale

The first approach to analysis of the status of coastal aquaculture in the Mecoacan estuary was the identification of the mechanisms for managing common resources. Therefore, the hypothesis to be tested was if the allocation of TURFs might promote voluntarily cooperation among fishing communities and how they could restrict access to outside competitors, protect the resources from external threats such as water pollution from external sources and participate in policies and regulations decision-making. The fieldwork comprised two phases. The first part of the fieldwork was intended to explore through structured questionnaires a broad range of issues as follows:

- Development of oyster fishery and farming, fishing cooperatives and resources management. It involved the description of natural resource attributes, resource boundaries and exploitation technology.
- Identification of the factors influencing resources management within cooperative organisations.
- Appraisal of the magnitude of potential losses and gains within current marketing activities.
- Assessment of socio-economic and environmental factors using Geographic Information Systems (GIS) techniques.

The first part of the work involved seven months of field work carried out in collaboration with Santo Tomas Ecological Association, a Tabasco's local non-governmental organisation working with Mecoacan fishing cooperatives since 1992. The fieldwork covered several important aspects of data collection and interaction with fishing cooperatives and households, governmental officers and non-governmental organisation agents involved in aquaculture.

In general terms the preliminary results showed that in the fishing communities of Mecoacan marginalisation from regional development and indifference to community's affairs have increased. This condition has made the allocation of management frameworks a difficult task. Although programmes have been developed, participation of communities and co-operatives in the formulation and implementation of management frameworks and policies has often been reduced to merely bureaucratic functions, affected by political agendas. These programmes have not fully achieved their objectives and have not solved or at least proposed alternatives for reducing the accelerated degradation of coastal resources or production and marketing improvement.

Given the introduction of aquaculture in coastal areas in Tabasco, the particular features of aquaculture as a means of increasing production, improving job opportunities and enhancement of fisheries management has been overlooked escalating open access conditions of most fisheries with an important impact on local communities. Although, different aquaculture systems (oyster, shrimp and tilapia) have been introduced, natural conditions are convenient and infrastructure is available, adoption of aquaculture has been low and practices are decreasing in the area due the combination of diverse factors, affecting in turn the livelihood security of local people. This posed whether aquaculture may be an appropriate means for the development of Mecoacan communities.

Hence, in order to have a comprehensive analysis of people choices and external factors (i.e. economy changes) impact on aquaculture related activities, in the second part of the fieldwork the approach was re-orientated to explore, instead of property rights, if aquaculture benefits can be available to coastal communities by extending the productivity of existing systems and to identify the factors promoting management frameworks for coastal resources. The data collection was organised through semi-structured questionnaires and interviews using preference ranking, focus groups and key informants in order to get more detailed information related to:

- Local informal and formal politics relevant to fishing organisations' membership such as public services, commercialisation of resources, rules and norms governing resource uses, opportunities for peace building, extent of membership, technology transfer access and organisational relationships.

- Links between local organisations, perspectives on relevant institutions, quality of service agencies, social relations.
- Services and facilities such as schools/education, access results from location and/or social status, type of information considered valuable, kin, income and occupational homogeneity, degree of decision making participation and interest of becoming member of particular groups.
- Capacities of fishermen to participate in development activities, their perspectives on this kind of activity, dependency upon resources, effects of change over resources availability and area of power and patronage.

1.8 Aims of the study

The aim of this study is to evaluate the potential implementation of an integrated coastal management framework for Tabasco with a particular focus on aquaculture development. A general description of the characteristics of the coastal zone of the State and the Mecoacan estuary is presented (Chapter 2), followed by a general description of the methodologies used in this study (Chapter 3).

The study has two components: a) A general analysis of factors affecting coastal aquaculture development at the State level based on GIS modelling techniques for site identification and conflict solution amongst competing resource users (Chapter 4), and b) a particular assessment of the social, economic and institutional status for the development of sustainable aquaculture in the Mecoacan estuary. This component includes two subcomponents:

i. An analysis of the socio-economics and livelihoods indicators of coastal communities in the Mecoacan area (Chapter 5)

ii. A cost-benefit and financial analysis of current aquaculture production in the Mecoacan estuary (Chapter 6)

In the final discussion (Chapter 7) the results from these analyses are presented together to gauge coastal management needs in Tabasco. Suggestions are included on potential mechanisms to improve current approaches for allocation of resources. This was done addressing the development of property regimes to support and/or enhance aquaculture as a potential source of development for employment opportunities and production alternatives within fishery sector.

2. Tabasco coastal zone: Mecoacan estuary study case

2.1 The coastal and marine sector

2.1.1 The Gulf of Mexico production

The relative contribution of coastal resources to economic and social development in a particular coastal area depends on the socio-political aspects, current development goals and endowment of resources (Scura *et al.*, 1992, Pedini, 2000). The coastal areas of southern Mexico are well endowed with economically important renewable and non-renewable resources. The direct contribution of primary fisheries is very low compared to other resource-dependent sectors such as tourism and oil industry, which are quite significant in terms of gross domestic product, export earning and employment in the southeast states of Mexico (Table 38).

Table 1. Production structure in Gulf of Mexico states by sector

Coast and state	*Total GDP Pesos$'000*	*Share (%)*	*GDP Pesos$'000*					
			Fisheries	*Regional/ Total Share (%)*	*Industry share*	*Regional/ Total Share (%)*	*Services share*	*Regional/ Total Share (%)*
National	2,737,548,126	100	9,892,688	100/0.4	2,223,927,356	100/81.2	503,728,082	100/18.4
Tamaulipas	71,643,026	2.6	584,987	5.9/0.81	57,381,668	2.6/80.09	13,676,371	2.7/19.09
Tabasco	88,227,546	3.2	459,886	4.6/0.52	80,631,425	3.6/91.39	7,136,235	1.4/8.09
Veracruz	129,243,708	4.7	449,130	4.5/0.34	111,396,396	5.0/86.19	17,398,182	3.4/13.46
Campeche	57,133,939	2.1	595,049	6.0/1.04	54,492,571	2.5/95.37	2,046,319	0.4/3.58
Yucatan	26,571,680	0.9	694,373	7.0/2.61	18,604,687	0.8/70.02	7,272,620	1.4/3.76

INEGI (1999)

Fishery production in Tabasco represents a relatively important part of the production on the Gulf of Mexico region. Table 39 shows capture volume at regional and state levels. The total share of Tabasco in national production in 1999 was 4.89% with a total value of Pesos $ 459 million (US Dollar $ 49.3 million).

Table 2. National fishery production landed weight 1999

Coast and state	*Volume*	*Share (%)*	*Value*	*Share (%)*
National	1,144,263	100	9,892,688	100
Gulf of Mexico	319,020	27.88	3,368,412	34.04
Veracruz	135,745	11.86	584,987	5.9
Tabasco	55,997	4.89	459,886	4.6
Campeche	43,325	3.77	449,130	4.5
Tamaulipas	44,623	3.90	595,049	6.0
Yucatan	35,409	3.09	694,373	7.0

Source: SEMARNAP (2000). Volume (tonnes) and value (thousand of pesos)

2.1.2 Tabasco fisheries production

Tabasco holds an important share of Southeast Mexico's fisheries, particularly for oyster production, which contributes 30% of the state fisheries production, based on one species, the American oyster *Crassostrea virginica,* which is fished and cultured in 9.3% of Tabasco's estuary area by twelve Cooperatives, four in the Mecoacan estuary and eight in the Carmen-Pajonal-Machona estuary system (Arriaga & Rangel 1988; Contreras 1993; Moguel 1994; SEMARNAP 1998). Despite the fact that Tabasco has a coastline of 190 km and excellent climatic conditions, the fishing grounds distributed along its coast are not large and the demersal stocks are regarded as underused. The total fish production, according to official statistics for 1999 was 55 997 t, representing 4.9% of national total. Table 40 shows the total production per species (INEGI, 2000).

Table 3. Tabasco fisheries total capture volume by principal species 1999

Production per specie	*Tonnes*	*% respect to National production*	*National place*
National	1,144,263	100	
State	55,997	4.89	6
Oyster *Crassostrea virginica*	20,726	49.70	1
Snapper *Lutjanus* spp, *Eugerres* spp	9,870	14.00	2
Atlantic cutlassfish *Trichiurus lepturus*	5,265	78.30	1
Atlantic mackerel *Scomberomorus sp*	3,545	52.10	1
Spanish mackerel *Scomberomorus maculatus*	1,575	11.50	4
Shrimp *Penaeus* spp	1,415	33.70	2
Crab *Callinectes* spp	1,301	6.80	6
Robalo *Centropomus undecimalis*	1,143	21.20	2
King mackerel *Scomberomorus cavalla*	910	18.30	2
Other species	10,247	N/A	N/A

INEGI (2000), N/A= No applicable.

Fish culture is limited to small-scale tilapia *Oreochromis* spp and oyster *Crassotrea virginica* farming with a total production of 29 537 t/yr representing 52.7% of the total fishery production in the state, with a total value of Pesos $ 101.9 million (USDollar $10.9 million), and an average of Pesos $ 3450.00 per tonne (USDollar $370.00) (Table 41).

Table 4. Aquaculture share in the National fishery 1999

Coast and state	Total fishery capture	Aquaculture volume	*Share (%)*
National	*1,286,107*	*166,336*	1.2
Gulf of Mexico and	*333,154*	*72,943*	5.67
Veracruz	136,328	35,755	2.78
Tabasco	55,997	29,537	2.30
Tamaulipas	46,846	5,165	0.40
Campeche	50,930	1,476	0.11
Yucatan	38,170	1,013	0.08

The municipalities with registered fish farms are Paraiso, Jonuta, Centla, Centro, Nacajuca and Macuspana. Approximately 12,700 registered artisanal fishermen depend on Tabasco water resources to support their livelihoods. They represent only the 1.9% of the economically active population (people 15 to 60 years old capable of working) compared to the 17% (117,701) and 54% (367,376) of those working in the industrial and services sector, respectively (INEGI, 2002). The total number of fishing organisations in Tabasco is 405, of which the most representative are the cooperative organisations and fishermen unions (SEMARNAP, 1999).

Nevertheless, conflicts and competition for coastal resources are escalating between the expanding oil industry, and the cooperative and independent fishermen (free riders), particularly in the Mecoacan area (Moguel, 1994). These may have severe environmental degradation consequences, as there are no territorial or use rights established on the available resources.

The National Fisheries Law entitles exclusively those Mexicans citizens associated in fishing co-operatives to fish oyster, shrimp, lobster, scallop and abalone from national inland and coastal waters (Cano 1986). But this does not necessarily apply for coastal communities, as the population has increased and more people who do not necessarily belong to cooperative associations find a livelihood in fishing practices.

2.2 General features of Tabasco state

The state of Tabasco is located at the Southeast of Mexico, between latitude 18º90'00'' - 19º21'00'' North and longitude 90º50'22'' – 94º07'49'' West (Fig. 1). Mexico's territory covers an approximate area of 2 million km^2 of which 24,661 km^2 are located in the state of Tabasco within four regions: Chontalpa, Centro, Rios and Sierra (Table 1). The principal cities are Villahermosa the state's capital, Comalcalco and Cardenas where the major commerce centres are located, and Paraiso where the most important seaport and petrochemical plant are located.

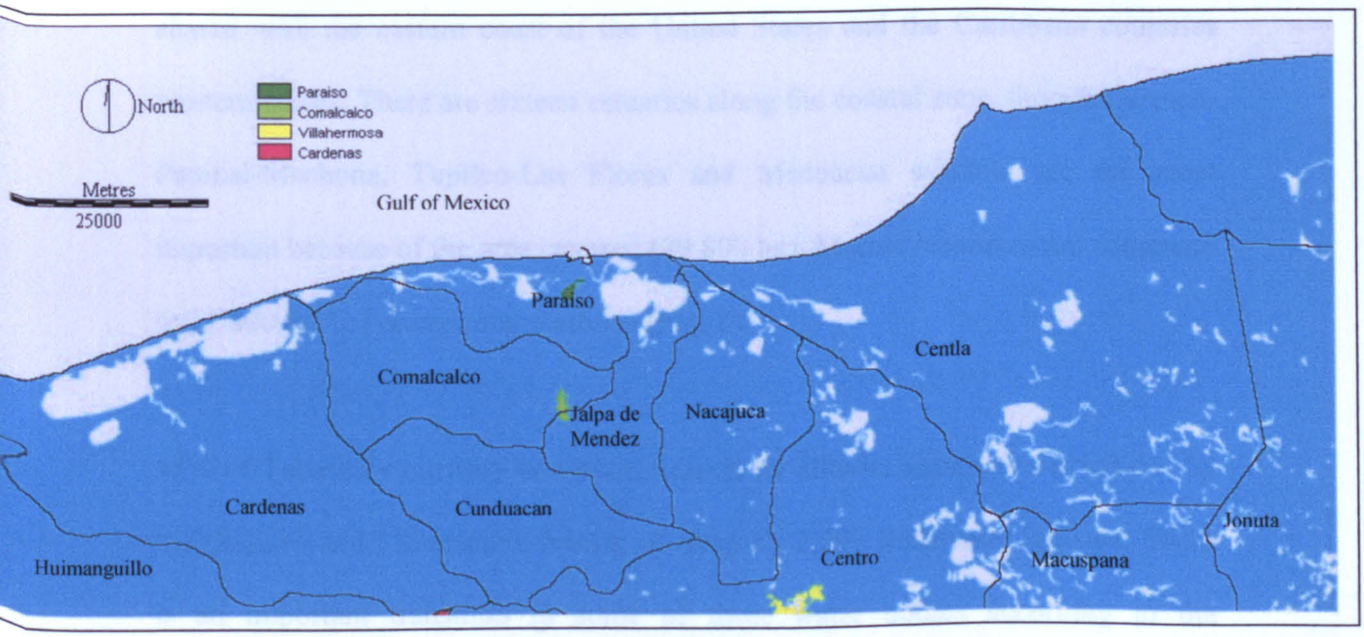

Figure 1. Tabasco coastal area

Table 5. Physiographic and economic regions of Tabasco

Region	*Surface km^2*	*Percentage represented*	*Municipalities*
Chontalpa	8,408	34%	Huimanguillo, Cardenas, Paraiso, Comalcalco, Cunduacan, Jalpa, Nacajuca
Centro	2,284	9%	Centro, Jalapa
Sierra	3,542	15%	Macuspana, Teapa, Tacotalpa
Ríos	10,427	42%	Centla, Jonuta, Emiliano Zapata, Balancan, Tenosique
Total	24,661		

Source: Velazquez (1994)

2.2.1 Water resources

The most important rivers of Mexico flow through Tabasco's territory, the Grijalva and Usumacinta rivers representing 33% of national water resources. These rivers form together a catchment area of 84,000 km^2 with an average water delivery of 115,715 million m^3. The basin formed by the system Grijalva-Usumacinta cover an area of 130,853 km^2, of which 14,319 km^2 are in Tabasco. This basin covers several physiographic provinces with diverse soil composition and topographic characteristics supporting a variety of agro-ecological conditions (Macias & Serrat, 1986; Velazquez, 1994).

Tabasco's coastline extends 191 km and is part of the basin of the Gulf of Mexico shared with the eastern coast of the United States and the Caribbean countries western coasts. There are sixteen estuaries along the coastal zone, though Carmen-Pajonal-Machona, Tupilco-Las Flores and Mecoacan systems are the most important because of the area covered (29 800 ha). Marine resources are contained in 11 800 km^2 of continental platform (Fig. 2).

95% of Tabasco's territory is a plain formed by alluvial materials carried out by the Grijalva and Usumacinta basins, covered by 2,097 freshwater lagoons. There is an important transition in some of these water bodies according to the occurrence and duration of rainy and dry seasons. The total area estimated for permanent lagoons is evaluated to cover 50,903 ha and temporal water bodies 18,301 ha (Lopez & Ezcurra 1985; Rodriguez & Benitez, 1994).

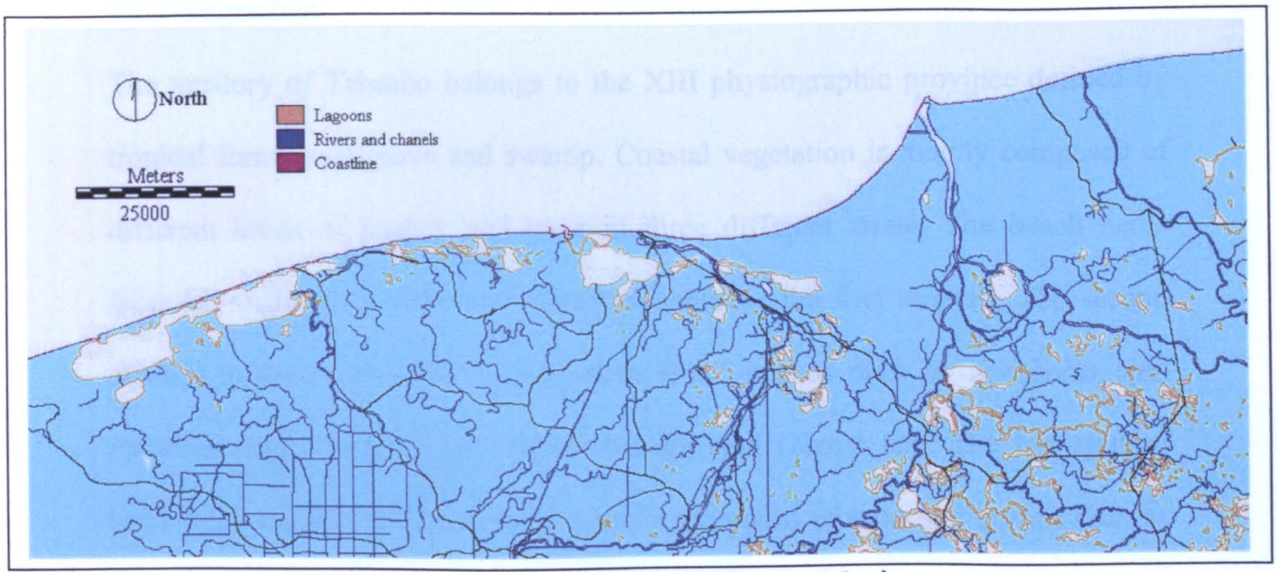

Figure 2. Water resources of Tabasco, Mexico

The average annual precipitation in the boundaries of estuaries is about 1690 mm, (INEGI, 1997). The mean monthly rainfall for the coastal zone of Tabasco is 240 mm. However, the rainy season is highly variable through the year as rainfall can extend for long periods, overloading the carrying capacity of basins. The dry season is also variable and long periods may occur causing important reduction of water supplies for agriculture and livestock production (CNA, 1998).

Despite the fact that the potential Tabasco's ground water resources has not been exhaustively quantified they can be considered good for domestic use, agriculture (including aquaculture), and industrial activities. Aquifer potential is greater in the western part of the state particularly in Huimanguillo municipality, where flows up to 100 l/sec are found. Central and eastern zones provide medium to low flow, though water quality from deep wells is poor (high levels of hardness, alkalinity and bicarbonates). The southern flow rates are low but the aquifers provide good quality water. The mean water temperature is 26ºC (Velazquez, 1994).

2.2.2 Vegetation

The territory of Tabasco belongs to the XIII physiographic province defined by tropical forest, mangrove and swamp. Coastal vegetation is mainly composed of different kinds of bushes and trees in three different strata. The beach herbs *Ipomoea stolonifera* and *Batis maritima* compose the first stratum. The second stratum is dense grassland mixed with small bushes such as *Serobolus* spp, *Paspalum* spp, *Cyperus* spp, *Amarantus* spp and *Okenia* spp. The last stratum located around and on the dunes is mainly composed of trees and bushes such as *Hibiscus tiliaceus*, *Coccoloba uvifera* and *Psychotria cuspidata*. Mangrove is located following the third stratum and it comprises three species, red mangrove *Ryzophora mangle*, white mangrove *Laguncularia racemosa* and black mangrove *Avicennia germinans* (Lopez *et al.*, 1997).

2.2.3 Soils

Soil assessment is of particular interest in term of coastal uses for aquaculture, as soil characteristics have a key influence on pond siting and construction (e. g. soil texture and permeability) (Coche & Laughlin, 1985; Aguilar, 1992). The soils covering Tabasco are from alluvial origin due to deposits from river and marine systems; the most common types are gleysol, regosol and solonchak representing 62% of the total surface. The coastal zone is composed of fine and coarse texture soils (gleysol, solonchak and cambisol) covering 75% of the total area (Fig. 3) with a high content of sodium, magnesium, calcium and high water saturation rate (INEGI, 1986).

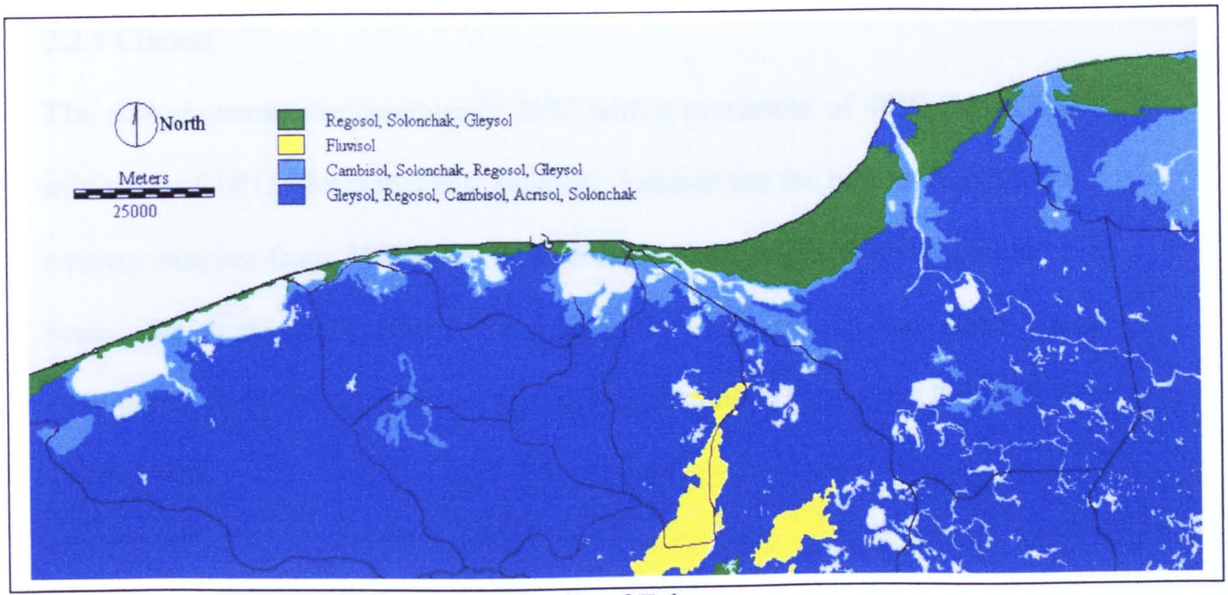

Figure 3. Soils of Tabasco

2.2.4 Topography

The territory of Tabasco is in its vast majority a plain formed by the influence of river and marine sediment deposits. Due to this characteristic the state has consequently been classified as the coastal plains of Tabasco forming a fringe 100 km wide from the coast up to the border with Chiapas state and Guatemala (Macias & Serrat, 1986). Elevation varies from 1 to 30 m above sea level in the coastal zone (Fig. 4) (USGS EROS, 2001).

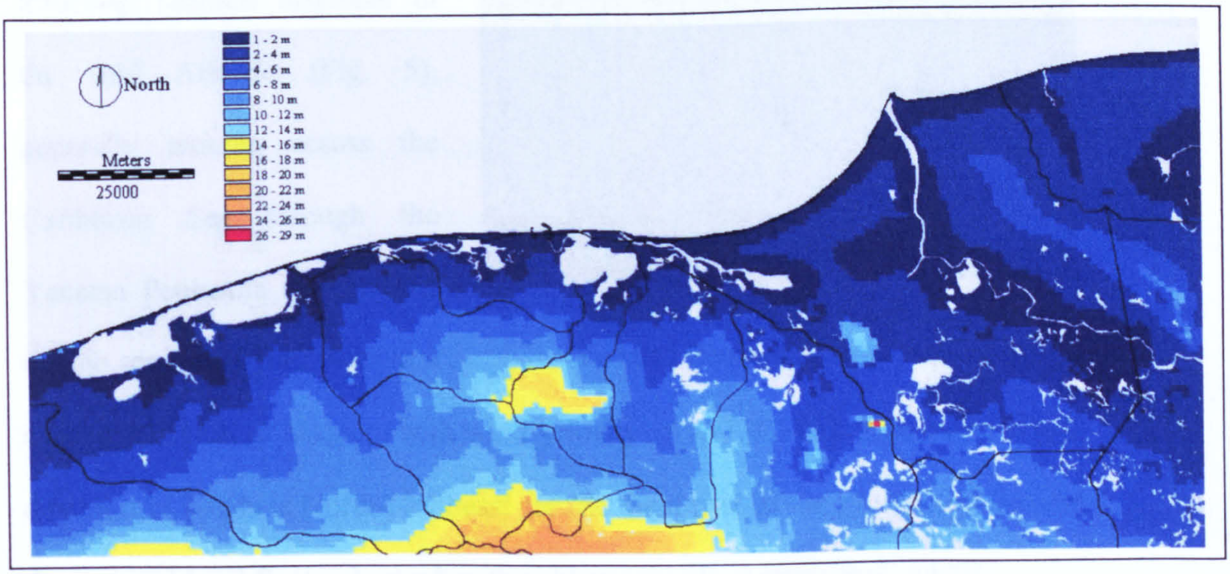

Figure 4. Tabasco coastal zone elevation map

2.2.5 Climate

The annual average temperature is 26°C with a maximum of 40°C (May) and a minimum of 16°C (December and January). Tabasco has the highest rainfall of the country ranging from 2000-4000 mm. Evaporation ranges from 921-1880 mm across the state. High values are mostly found in the coastal zone. These conditions favour the presence of a warm humid climate Am (f) w (INEGI, 1996; CNA, 1998).

The geographical location of Tabasco is influenced by climatic seasonal events such as tropical storms, hurricanes and cold fronts that produce heavy rainfall from October to March, causing important flooding problems. The major effects of these events on fisheries are the reduction in the number of days for fishing, which vary between days and weeks. In the case of aquaculture, flooding of ponds by heavy rainfall and removal of cages by strong winds are the major impacts.

Hurricanes occasionally affecting Tabasco originate in the mid Atlantic (Fig. 5), generally moving across the Caribbean Sea through the Yucatan Peninsula and parallel to the coast of the Mexican coast of the Gulf of Mexico, with wind velocity up to 120 km/h. The predominant direction of winds is North-Northeast for the most part of the year except for the dry season (April-September) when they blow easterly (Lopez *et al.*, 1997).

Figure 5. Hurricane Keith on the Yucatan Peninsula (Yahoo, 2000)

2.2.6 Infrastructure

Tabasco has one of the best levels of communication of the states of Mexico due to development promoted by the oil industry, and numerous land and sea communication networks. Tabasco links the Southeast with the rest of the country through 300 km of railroads, 7,821 km of roads (1,845 km of gravel roads and 5976 km paved roads) and two seaports located in Paraiso and Centla municipalities (Fig. 6). Recent additions to highway networks have expanded the connection between Mexico and Central America through Tabasco and linking state highways to the Pan-American Highway.

Figure 6. Tabasco coastal zone infrastructure

Telecommunications are well established, providing basic services to the general population. Microwave and satellite services are also available. Higher education and research centres are on hand through public and private institutions. Welfare and health services operate on a state and regional level as speciality hospitals have been set up in the last decade (INEGI, 1997; Gob. Edo., 1999).

2.2.7 Population

According to the preliminary results of the XII census, the total population of Tabasco was estimated to be 1,889,367, representing 1.9% of the national population with an average density of 77 people per km^2 (Fig. 7). There are a total of 2,597 population settlements of which 96.9% have less than 2,500 inhabitants. The municipalities where 68.7% of the population concentrates are Centro, Cardenas, Comalcalco, Huimanguillo, Macuspana and Cunduacan. The trends on the distribution according to age group show that 60% is within 0-24 years group (INEGI, 1997, 2000).

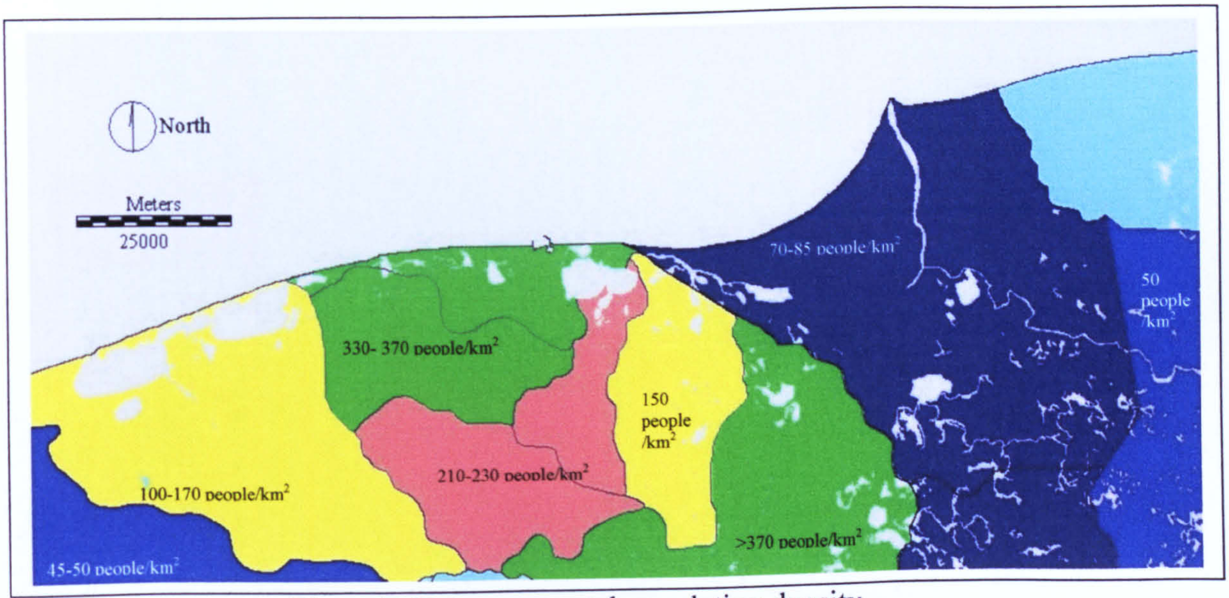

Figure 7. Tabasco coastal population density

2.2.8 Industries and Commerce

The geology of Tabasco has determined its natural significance in terms of oil deposits, though other mineral resources are negligible. There are over 7,000 oil wells, three petrochemical plants and 175 primary processing facilities in the state, which have resulted in extensive pollution (Macias & Serrat, 1986; Hamann & Ankersen, 1996).

Most of the industrial settlements in Tabasco are related to oil extraction and petrochemical processing. These are located in 13 out of the 17 municipalities, where 19% of national oil and 39% of natural gas are produced. Processing plants for agriculture and livestock products are mainly located in Centro and Cardenas municipalities. The labour force employed in this sector is 1.52% of the economically active population (INEGI, 1997; Gob. Edo., 1999). Commerce and service activities (hotels, restaurants and specialised) are regionally located. 60% of these activities are enclosed in the central region (Villahermosa) and in the Chontalpa region (Cardenas and Comalcalco) providing employment for 40% of the economically active population (INEGI, 1997).

2.2.9 Agriculture

In Tabasco the main agriculture production are perennial crops of cocoa, banana, coconut, rubber and sugar. Approximately 35% of agricultural land is mechanised, though, 98.8% is rain-fed agriculture (Fig. 8). The other 65% remains as traditional backyard production. A total of 87,357 production units occupy a total area of 1,099,689 ha, with an average of 12 ha per unit (INEGI, 1997).

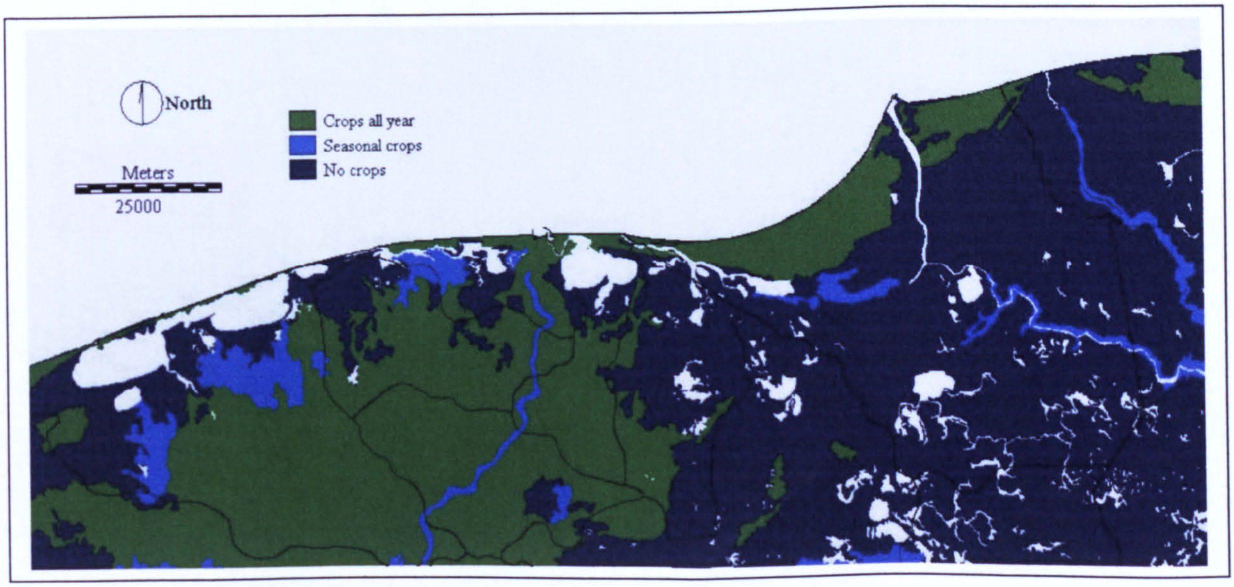

Figure 8. Distribution of agriculture area

Livestock

Livestock represents half of the primary sector of the state with a share of 2% in the national production. Most production is concentrated in the central and eastern regions with a total area of 1,654,514 ha (Fig. 9). The main rearing practices are focused on cattle, pig, goat and chicken (Gob. Edo., 1999).

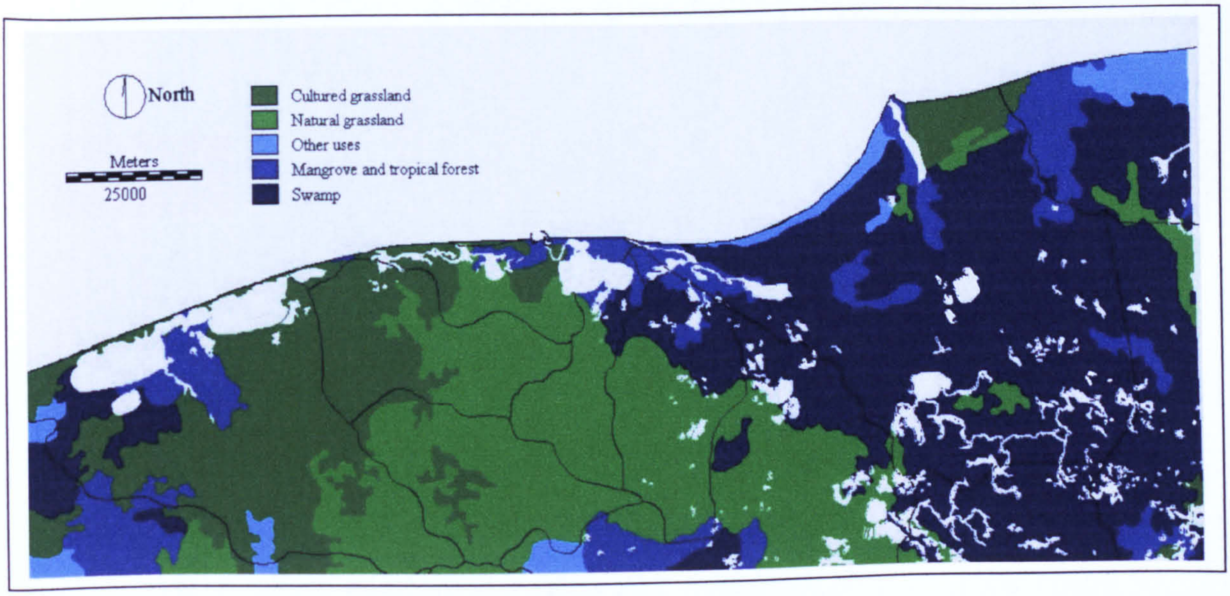

Figure 9. Livestock rearing areas

Forestry

Forestry occupies a total area of 1,209,446 ha of which 276,618 ha is covered by tropical forest, though it is an undeveloped sector affected by cattle ranching and uncontrolled exploitation, which have left 410,001 ha of disturbed areas (Fig. 10). The area with most significant reduction is mangrove, previously covering 34% of the total surface and reduced to only 4.3% (SEMARNAP, 2000).

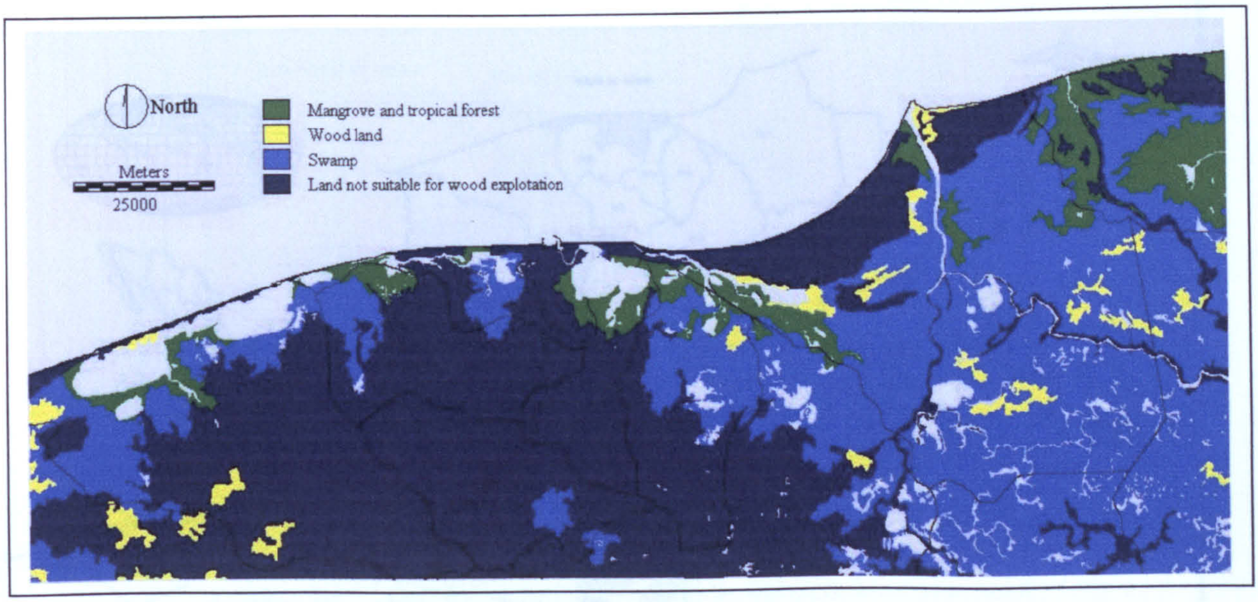

Figure 10. Forestry in Tabasco

2.3 Mecoacan estuary characteristics and fisheries

2.3.1 Characteristics of the estuary

Mecoacan estuary is located at the North of the state between latitude 18°15' – 18°26' and longitude 93°01' – 93°15'. It is shallow with an average depth of 1.50 metre and a total area of 5 160 ha. The system has permanent communication with the sea through the Dos Bocas natural mouth in its northern extreme, which stretches to the sea trough a narrow bar of 400 m (Fig. 11).

The seaward side of the estuary is formed by a chain of small islands with the largest (3 km in length) located in the middle of the mouth. Along with its tributaries Seco, Escarbado, Cucuchapa, Cunduacan and Arrastradero rivers, the Mecoacan area is considered the second most important coastal lagoon system of Tabasco, with extensive oyster banks at its bottom and bordered by mangrove areas which have been reduced due to timber exploitation (Dominguez-Dominguez, 1991; Valdes, 1998).

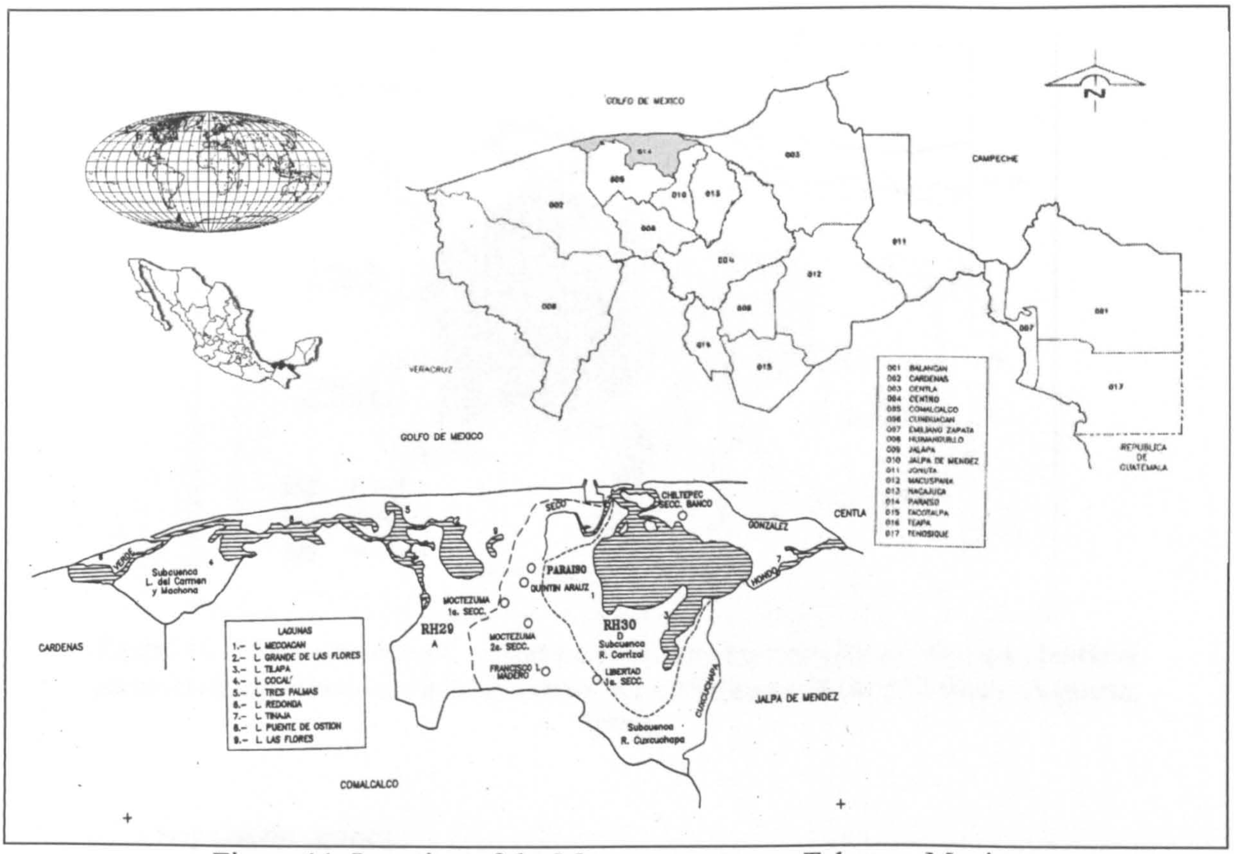

Figure 11. Location of the Mecoacan estuary, Tabasco, Mexico

To define the main physico-chemical parameters, the average water temperature is 24-30.2ºC, dissolved oxygen is about 3.0-4.5 mg/l and salinity 1.3-14 ppt, precipitation averages about 1,800 mm/yr, evaporation is 1,600 mm/yr and estimated runoff is 300 mm/yr (Arredondo *et al.*, 1993; Rodriguez, 1998; Valdes, *op cit.*). The major physical changes in the estuary have been the reduction in depth by sedimentation from the rivers and the reduction of seawater inflows due to the installation of the Dos Bocas seaport and petrochemical plant breakwaters (Cervantes-Castro, 1984). As a result three major physico-chemical regions can be described, as shown in Figure 12. Group A and C correspond to zones where brackish water conditions are present. Water parameters in Group B are closely related to freshwater environments (Alvarado-Azpeitia, 1996).

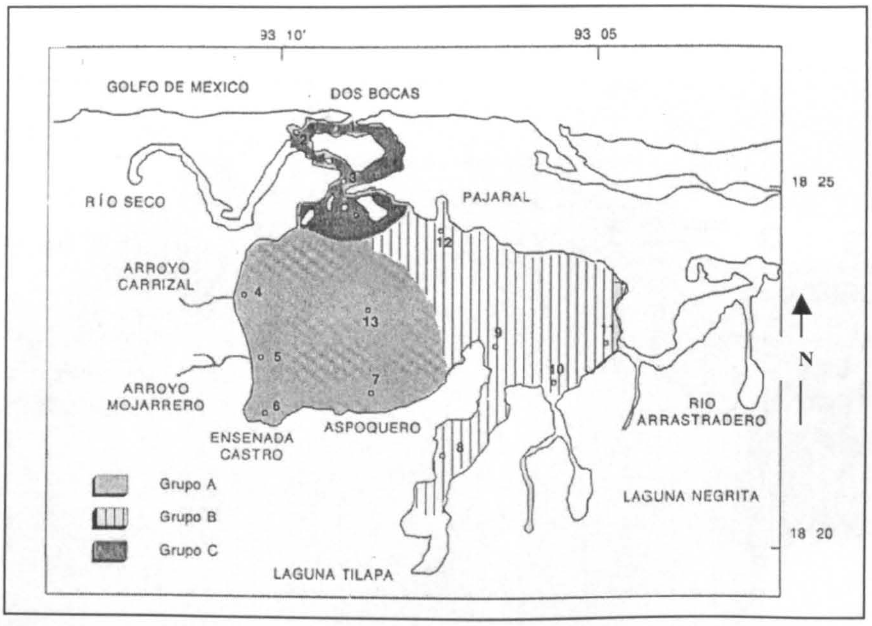

Figure 12. Mecoacan estuary environmental zones according to physico-chemical parameters distribution. Numbers show the sampling stations (Alvarado-Azpeitia, 1996)

2.3.2 Population centres

This study is focused on the four co-operatives located in Mecoacan estuary, which represent about 2016 people in the Municipality of Paraiso. According to the political division of the Municipality they are located in the boundaries of the estuary area in the following towns: Rancheria Jose Maria Morelos (Andres Garcia Island and Bellote), Ejido Chiltepec (Banco and Tanque section), Puerto de Chiltepec, Ejido Libertad (El Chivero section), Ejido Carrizal, Puerto Ceiba (Villa and Carrizal section), Colonia Nuevo Torno Largo and Colonia Miguel de la Madrid (Fig. 13).

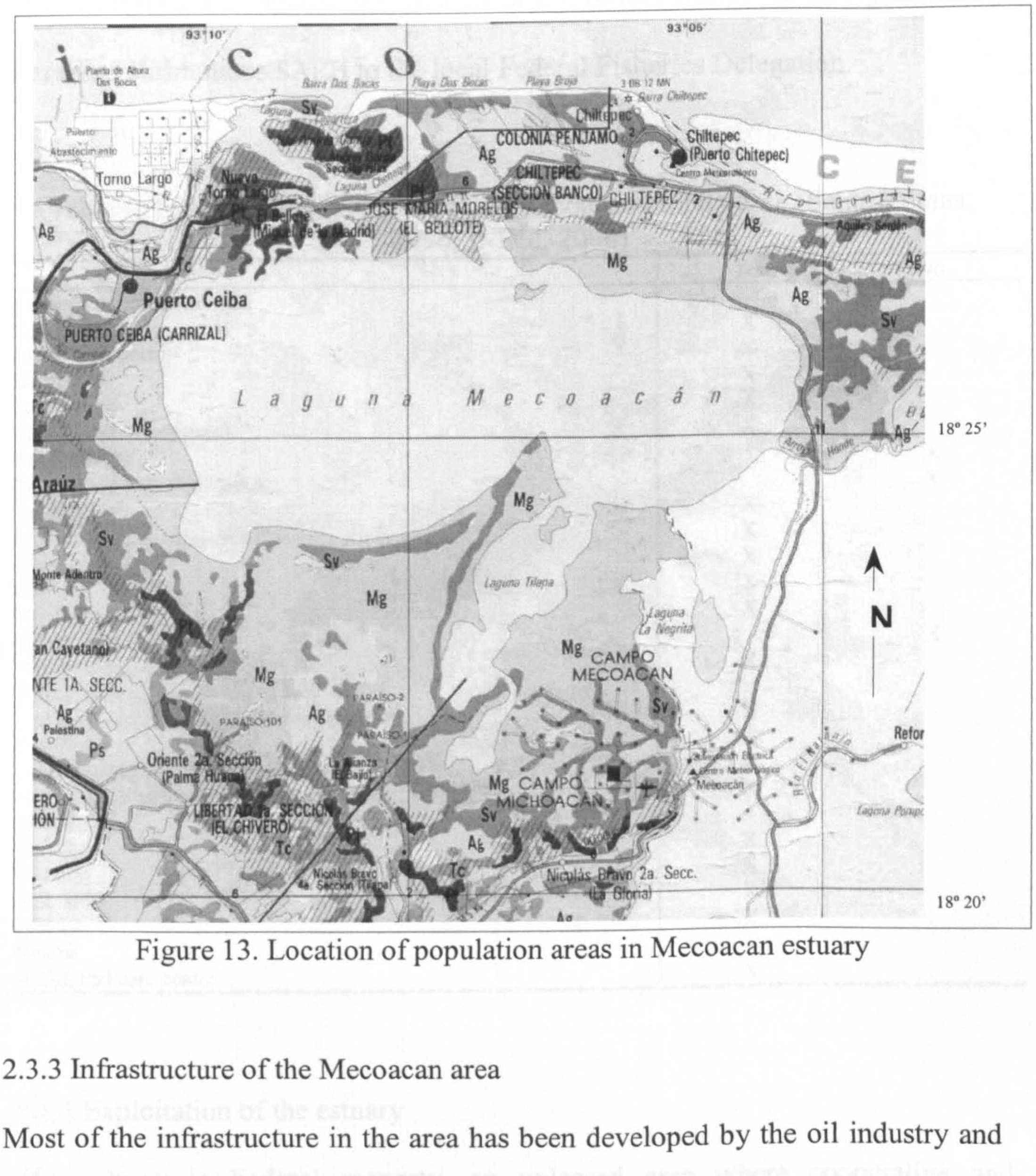

Figure 13. Location of population areas in Mecoacan estuary

2.3.3 Infrastructure of the Mecoacan area

Most of the infrastructure in the area has been developed by the oil industry and state urbanisation programmes, as summarised in Table 6. Although government or cooperative owned production facilities are available to process fishery products, some are not in operation.

The government aquaculture station located in the northwest of the estuary has reduced operations due to budget shortages. This was established to support coastal fisheries management and coordinate oyster farming and restocking programmes. It was named as the Centre of Tropical Aquaculture in 1977 after the reallocation of the Aquaculture District of the former Secretaria de Agricultura y Recursos Hidraulicos SARH to the local Federal Fisheries Delegation.

Table 6. Infrastructure and services in Mecoacan estuary area (Santo Tomas, 1996; INEGI, 2000)

	Yes	*No*
Urban development		
Road access	X	
Urban transport	X	
Electricity	X	
Street lights	X	
Rural telephone network	X	
Potable water		X
Drainage and sewage system		X
Paved streets	X	
Postal and telegraphic services	X	
Gravel roads	X	
Parks	X	
Security services	X	
Cleaning services		X
Market place	X	
Fishery sector		
Fish farm and Fisheries Ministry Office	X	
Ice factory	X	
Catch landing registration office	X	
Processing buildings for fisheries produce	X	
Education		
Nursery	X	
Primary	X	
Secondary	X	
Library	X	
Health		
Health and care centre	X	

2.3.4 Exploitation of the estuary

The estuary is Federal property, an unleased area where cooperative and independent fishermen (free riders) operate indiscriminately using different fishing gear, mainly with cast and gill nets and oyster grabs. Fish and shellfish are captured year through and selected mainly by size and market value. Table 7 shows the species captured according to fishing ground.

Table 7. Species captured in the Mecoacan area[1]

Estuary species	*Sea species*
Robalo *Centropomus undecimalis*	Sierra *Scomberomorus maculatus*
Mojarra *Eugerres* spp	Cazon *Sphyrna tiburo*
Ronco *Conodon nobilis*	Pargo *Lutjanus sp*
Camaron *Penaeus setiferus, P. Aztecus, P. dorarum*	Bandera *Scomberomorus sp*
Ostion *Crassostrea virginica*	Peto *Scomberomorus cavalla*
Liseta *Mugil curema*	Mojarra blanca *Eugerres* spp
Robalito *Centropomus parallelus*	Cintilla *Trichiurus lepturus*
Jaiba *Callinectes similes, C. sapidus, C. rathbunae*	Barrilete *Auxis thazard*
	Jurel *Caranx hippos*
	Bonito *Sarda sarda*
	Curvina *Eugerres mexicanus*
	Sargo *Archosargus probatocephalus*
	Trucha *Cynoscion nebulosus*

[1] Data from field surveys done by the author

There are not reliable data regarding the fish yield of the estuary. The independent fishermen do not report total catches as most of their activities are related to the smuggling of high value species regardless of fishing seasons and quotas. Fishing cooperatives have to report their total catches to the local fisheries office. The duty in practice is 15 percent on the gross value of the catch; however these are not heavy taxes, cooperatives register less than actual catches due to:

a) Most of members' catches lock on by middlemen

b) Out-of-season catches of species which are under Fisheries Ministry management programmes (e.g. shrimp and oyster)

2.3.5 Legal issues

In general, the legal aspects governing the estuary are the subjects of the Federal Ministries regulating natural and rural resources. Under the last restructuring of the former Secretaria del Medio Ambiente, Recursos Naturales y Pesca SEMARNAP[2], the Secretaria de Pesca (Fisheries and Aquaculture) was reallocated to the new Secretaria de Agricultura. Ganaderia, Desarrorllo Rural, Pesca y Alimentacion Agriculture SAGARPA[3], formerly know as SARH.

Environmental issues related to fisheries management are governed by the Procuraduria Federal de Proteccion al Ambiente PROFEPA[4], which is the law enforcement branch of the new Secretaria del Medio Ambiente y Rescursos Naturales SEMARNAT[5].

Specific laws regulating fisheries and aquaculture are include in The Fisheries Law, General Law for Environmental Equilibrium and Protection, the Cooperative Associations General Law, Administrative Procedures Law and the National Act. For Tabasco there is only one legal framework that includes aquaculture activities, the Mexican Official Norm (NOM) 015 for the exploitation of Oyster, NOM-015-PESC-1994. In general, fisheries NOMs vary according to the species and there is a total of 18 NOMs (PROFEPA, 1998).

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[2] Environment, Natural Resources and Fisheries Ministry
[3] Livestock, Rural Development, Fisheries and Food Ministry
[4] Federal Environmental Protection Agency
[5] Environment and Natural Resources Ministry

3. Materials and methods

3.1 Background

The potential for aquaculture and other sectors to come into conflict over natural resources exists because the rights to use some of these resources are not well defined or enforced. Therefore, information is required to determine appropriate locations for aquaculture operations and set the conditions for integrated coastal management. State and site-specific data were collected and analysed using different techniques.

3.2 Geographical Information Systems (GIS) modelling

3.2.1 Introduction

The fragile nature of many coastal environments, the extended demand on coastal resources and the restricted geographical zone point out that successful coastal management strategies to adopt an integrated approach of rational and sustainable interventions requires access to a diverse range of spatially referenced data on the biophysical and socio-economic processes operating on coastal zones. There is an expanding interest in the use of GIS as a decision support tool in ICM programmes and it appears to be an attractive tool to facilitate the decision-making process and execution of ICM activities due to its capability to integrate large databases (Ross *et al.*, 1993; Jones *et al.*, 1999; Scott, 2001).

3.2.2 Development of thematic maps

Although the study is focused in Mecoacan area, the information required to develop the socio-economic and environmental GIS-based models was limited at the micro-scale by the absence of suitable data. Therefore, the modelling was developed for the entire coastal zone of the State in order to establish the status of Mecoacan estuary in the context of macro-scale systems and processes.

The modelling was carried out using a raster based software Idrisi version I32.1 and a spatial data builder Cartalinx version 1.2 both developed by Clark Labs, USA. A CalComp Drawing Board III and Paint Shop Pro version 5.01 were used to digitise vector layers and for image editing. The software operated in a Dell Dimension XPS D333, 128Mb, 8+13Gb hard disk and display was on a Dell 21" colour monitor.

A diverse range of data was extracted from land use, soil, rivers and other topographical maps and tabulated information published by the Budget and Programming Secretariat (SPP) and the National Institute of Statistics, Geography and Informatics (INEGI) on a 1:250,000 scale. Tabular data collected from field surveys were also used to develop population thematic maps. The grid chosen for this study was 6000 columns by 2667 rows, a total of 16,002,000 pixels and at resolution of 30x30 m per cell.

The reference system used was Plane as the input reference was unknown. Maps with no scale were scanned and digitised with Cartalinx and then geo-referenced using eight control points to establish a grid reference system of the maps digitised on the CalComp Drawing Board. Some inaccuracies can occur in this process, as the control points might not match after digitising due to inaccuracy of the data implicit in the source map (Jones 1997). Thematic layers were created as follows:

a. Maps were digitised on the CalComp board or scanned and edited using Cartalinx

b. Tabular data were transformed into vector and classified using Cartalinx
c. Vector layers were rasterised, reclassified and interpolated with Idrisi32

3.2.3 Classification of primary data

All factors were reclassified for use in model development either by reclassifying distances range (proximity) or reclassifying the original data according to its features (Eastman *et al.*, 1993). Reclassification and scoring of certain factors varied according to the criteria of layer integration used for each sub-model as many of them were used for both socio-economic and environmental models.

3.2.4 Classification of secondary data

Given the spatial component of coastal aquaculture pertaining to its interdependency with other users and trade-offs that may be established, the data generated in the previous section were integrated to produce models based on weighting verification using data gathered from the questionnaire applied to governmental officers, non-governmental organisations and fishermen, to evaluate their attitude towards aquaculture and resources management (see section 3.3.3).

3.3 Livelihood characteristics of coastal communities in the Mecoacan estuary

Coastal development and management requires an understanding of the social and economic structures governing communities. In order to structure the scope of enquiry, the approach used in the Mecoacan area was sectoral, focusing on fishery production, and the constraints and opportunities regarding the development of coastal aquaculture, at two different levels in the communities, households and fishermen groups.

3.3.1 Sampling design

In order to assess the characteristics of Mecoacan estuary resources use the study was focused on the associated and independent fishermen (free riders) and their families in the Mecoacan estuary areas. The fishermen from the four fishing co-operatives of Mecoacan were selected as they are entitled by law to extract oyster species from the wild, to manage culture sites, and to participate directly in the management of estuary resources. They were also selected since they have accumulated a great deal of experience in managing the oyster fishery (Arriaga & Rangel, 1988; Arredondo *et al.*, 1993; Rodriguez, 1998). Independent fishermen (free riders) were selected for the study as they represent the strongest competition to associated fishermen in terms of economic benefit of resources use. This approach allowed a comprehensive analysis of the interactions among fishermen.

Sampling was carried out to identify respondents based on the sample size calculated during the experimental design phase of the study, in order to collect a statistically representative sample assuming that the population size had to be large enough to represent the population. The sample sized calculated for the socio-economic survey was N equal to 440 households and for ranking and attitudes towards resource management analysis the n was equal to 22 individuals per group of resource users (Zar, 1996; Salkid, 2000). Sources of variability in the data were related to the position of fishermen within organisations and their relationship with middlemen and extensionist.

Random and non-random sampling across the Mecoacan estuary was used as a method to make subgroup samples representative. Associated fishermen were interviewed based on an address list provided by the President of each association before the interviewing process took place. The snowballing method was carried out to survey the independent fishermen (free riders), that is based on the contact of one or two potential respondents at the beginning of the survey to lead in turn to other similarly oriented people (Watts & Halliwell 1996). Even though confidentiality was stressed to involve independent fishermen in the survey, only a sample of 21 persons was collected. The total number of fishermen interviewed in Mecoacan estuary was 442 complying with the sample size calculated.

3.3.2 Data collection design and analysis

It has been argued that in order to remain practical and to reduce the inherent risk of undesirable outcomes from community assessments, sustainability should be considered by sector, and simple approaches are most recommendable (Garcia & Staples, 2000; Garcia *et al.*, 2000; Howlett *et al.*, 2000; Rigby et al., 2000). The collection of data was based on rapid rural appraisal (RRA) approach using questionnaires (households and fishermen groups data) and interviews (cooperatives' administrative committees and government officers) (McCrossan, 1984; McArthur, 1994; Townsley, 1996). All questionnaires were pre-tested using a sub-group of 30 individuals in order to rephrase sentences according to local expressions. The information was classified according to the group from which data were collected.

Focus groups were selected after preliminary general meetings with the fishing cooperatives to carry out stakeholder and seasonal calendar analysis. Although it was difficult to set a time and place, as the fishing season was at the top and fishermen were engaged in several fishing and community related activities, individuals from different social groups participated in these meetings. Questions and discussion points were modified according to the local way of speaking to make information accessible to the respondents. The parametric analysis used assumed that the variances of each group were homogeneous or similar.

3.3.3 Specific methodologies to analyse the livelihood system of Mecoacan

Livelihood characteristics

A socio-economic survey was devised based on the available literature on household socio-economics (Ahmed *et al.*, 1993; Legaspi, 1994; Hishamunda, 1998) to gather basic information of fishing households according to the following issues: family structure, employment, fishing activities, food, housing, health, resources and environment (Appendix A). The data from this structured questionnaire were entered in spreadsheets according to pre-coded response categories on the questionnaires to produce cross-tabulated statistics using SPSS v10.

Effects of co-operative membership on resources access

It was intended to use a questionnaire to determine the attitude towards resource management and to current and proposed aquaculture initiatives. Due to limitations of time and resources relative to the size of the population, a representative sample approach was employed. The assessment involved a sample of 154 individuals, involving fishermen from each of the four cooperative organisations established in the Mecoacan estuary, independent fishermen (free riders), fisheries officers and members of Santo Tomas non-governmental organisation.

A questionnaire with a set of 15 closed-ended questions was given to each participant (Appendix B). Individual comments and ideas were also encouraged while answering the questionnaire during both the pre-test and the survey. Statistical tests were applied to measure differences in the ranking of variables and the level of agreement between the different groups. Theses questions also allowed the assessment of the different levels of group awareness of the potential benefits and impacts of aquaculture.

Livelihood indicators

Seasonal calendars were used to identify stakeholders' access and power over capitals as appropriate in relation to social and environmental impacts on accessibility, benefits, costs, and technical requirements. The stakeholder composition in Mecoacan area was recorded in a tabular format (Howlett *et al.*, 2000) through the classification of the different levels of participation, and the impact on and access to resources.

In order to assess success of production systems two sets of indicators were selected to identify the groups and organisations (key stakeholders). This allowed comparability across different groups, to understand the use of resources, the livelihood status of fishing communities, and define criteria of successful aquaculture and other farming practices (Fig. 14). The perception of success and failure was determined through participatory meetings and semi-structured interviews with the different groups and with key informants.

In order to define the impact of past and current aquaculture development programmes on the livelihood of Mecoacan communities, an assessment of selected environmental and socio-economic indicators was carried out through a ranking survey. A number of indicator scores based on value judgements were displayed in this way to avoid having to aggregate across different scales (Garcia and Staples, 2000; Garcia *et al.*, 2000).

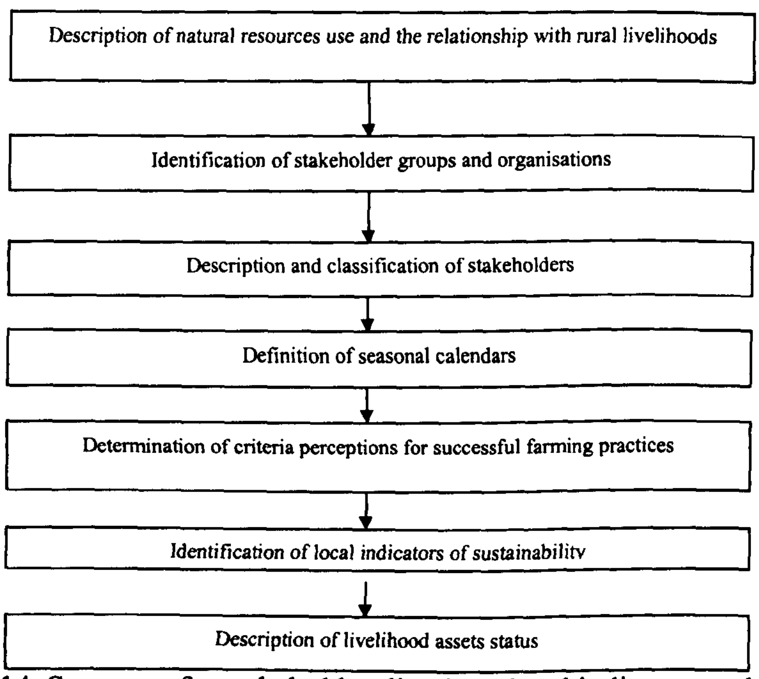


Figure 14. Sequence for stakeholder, livelihood and indicator analysis

The author subjectively defined the threshold levels (Text box 1) and weighting values used for all the indicators are based on the quantitative data obtained from the ranking survey. The set of criteria for the value judgments used with the quantitative

Text box 1. Threshold levels to assess

Good	10 – 8
Fairly good	8 – 6
Moderate good	6 – 4
Poor	4 – 2
Very poor	2 – 0

methods were tested for correlation using Kendall's W coefficient of concordance (Appendix C).

3.4 Fisheries and aquaculture economics issues in Mecoacan estuary

3.4.1 Evaluation of fishermen income and costs

From an economic perspective the open-access problem in fisheries is a pervasive externality, where all individuals do the same, racing to catch as much as possible before someone else does, imposes an externality on other fishers. This is despite the quotas allocated for each fishing cooperative, which in the case of oyster are as follows: 22 t for Mecoacan, 15 t for Puente de Ostion and 36 t for Andres Garcia. The sustainability of fishery production on economic criteria may be defined by using financial indicators to separate out a range of variables that determine profitability and vulnerability to shocks (Hundloe, 2000).

The costs considered in the analysis included those of purchasing/maintaining boat and gear, and operating costs such as crew payments, fees, fuel and other costs. A regression model was run to analyse the variability of total costs (fishing equipment and gear maintenance, gasoline and equipment rent) and gross income (total amount pay per capture volume) on a monthly basis.

The variables used to define cost variability include the type of propulsion, ownership of the fishing equipment, fishing ground, number of fishing days, storing and type of fishing gear. The variables to define the income variability were selected according to the fishery capture volume, market price, type of processing, processing labour input, grading of produce and market channel for fish, shrimp, oyster and crab. A dummy variable controlling for the association of fishermen were used in both analysis.

3.4.2 Assessment of aquaculture integration

A major constraint in the financial evaluation of aquaculture practices in Mecoacan is the absence of historical cost and returns data. Aquaculture has been singled out as the alternative to the fishery for food production, and one that could capture coastal productivity. The importance of aquaculture in development terms has been noted earlier, and it is clear that sectors such as aquaculture are widely sought. Hence, in terms of aquaculture potential for economic development cost-benefit analysis of individual projects can be estimated in a local context (Shang, 1981; Newkirk, 1996).

Economic development planning is concerned with resource allocation, infrastructure and human resource development, and the benefits to be derived, thus it is useful to consider the potential role and impact of aquaculture in this context (Muir, 1998). A financial analysis and a cost-benefit analysis (CBA) of an oyster farm ran by a group of members from the largest fishing organisation in Mecoacan was therefore conducted, based on the data provided by the fisheries group of the local environmental NGO, in order to assess the potential for development arising from the implementation of aquaculture activities.

3.5 Control methods

Triangulation was carried out to corroborate and compensate RRA data limitations through a series of participatory meetings with the management committees of each cooperative and through plenary sessions with the members (Appendix D). The meetings were recorded on audio-tapes, then transferred to a document file in order to apply a qualitative analysis regarding behaviour, structure, causes, processes, consequences and the strategies fishing households face. Another triangulation method used was secondary data, with qualitative analysis gathered from government agencies, non-governmental organisations and from academic transcripts.

4. GIS models for coastal aquaculture development in Tabasco

4.1 Introduction

In recent years Geographical Information Systems (GIS) have increasingly developed, as the need to place information in a geographical context has become paramount for management and resource allocation decisions. GIS capability for modelling a wide range of factors allows a comprehensive assessment process for planning and management of natural resources and it is particularly suited to store, analyse, manipulate and display spatially referenced data. This has resulted in the widespread application of GIS due its ability to draw together complex and multiple factors and to assist resolution of potential conflicts of space or resources use (Aguilar & Ross, 1995; Isaak & Hubert, 1997; Jones, 1997).

The aim of this chapter is to assess the production functions influencing aquaculture development in the coastal zone of Tabasco and the correlation among socio-economical and environmental factors given the spatial component of coastal aquaculture pertaining to its interdependency with different resource users. The type of system considered for modelling was primarily land-based, as information required to develop environmental models for water-based systems was limited by the absence of suitable data.

4.2 Classification and integration of primary criteria

Geographical matters entail fundamental problems on food production whatever the level of analysis (world, national, regional or local) as any human activity is influenced and controlled by different and changing factors (Jones & Hollier, 1997).

The diverse range of factors and the complexity of the interactions between land and water present a very difficult decision-making task in achieving site selection, as matching land and water resource requirements for food production is limited to the space available among competitive production activities (Meaden & Kapetsky, 1991). A comprehensive identification of these factors, called production functions by Meaden and Kapetsky (*op cit.*) is required for location decision. The criteria for the selection of production functions were based on the relevance of variables affecting the development of coastal aquaculture. The integration of criteria for the selection of variables is shown in Figure 15. The general model was developed based on previous models developed by Aguilar (1992, 1996), Gutierrez (1995) and Aguilar and Nath (1998) consisted of four sub-models (social, production, market and environment) generated from environmental and socio-economic data (Figure 16).

The layer representing each production function was reclassified on an 8-point scale (Text box 2), which displayed an appropriate level of detail. The scale was adjusted in each case to show level of suitability of the variable in terms of aquaculture production systems appropriate for the region. Boolean maps were developed for each constraint to classify areas of environmental concern (e. g. water bodies) and for those representing land use restrictions and potential pollution problems.

Text box 2. Criterion used for classification of factors

Score	Suitability
1	None
2	Limited
3	Marginal
4	Moderate
5	Some
6	Fair
7	Good
8	Very good

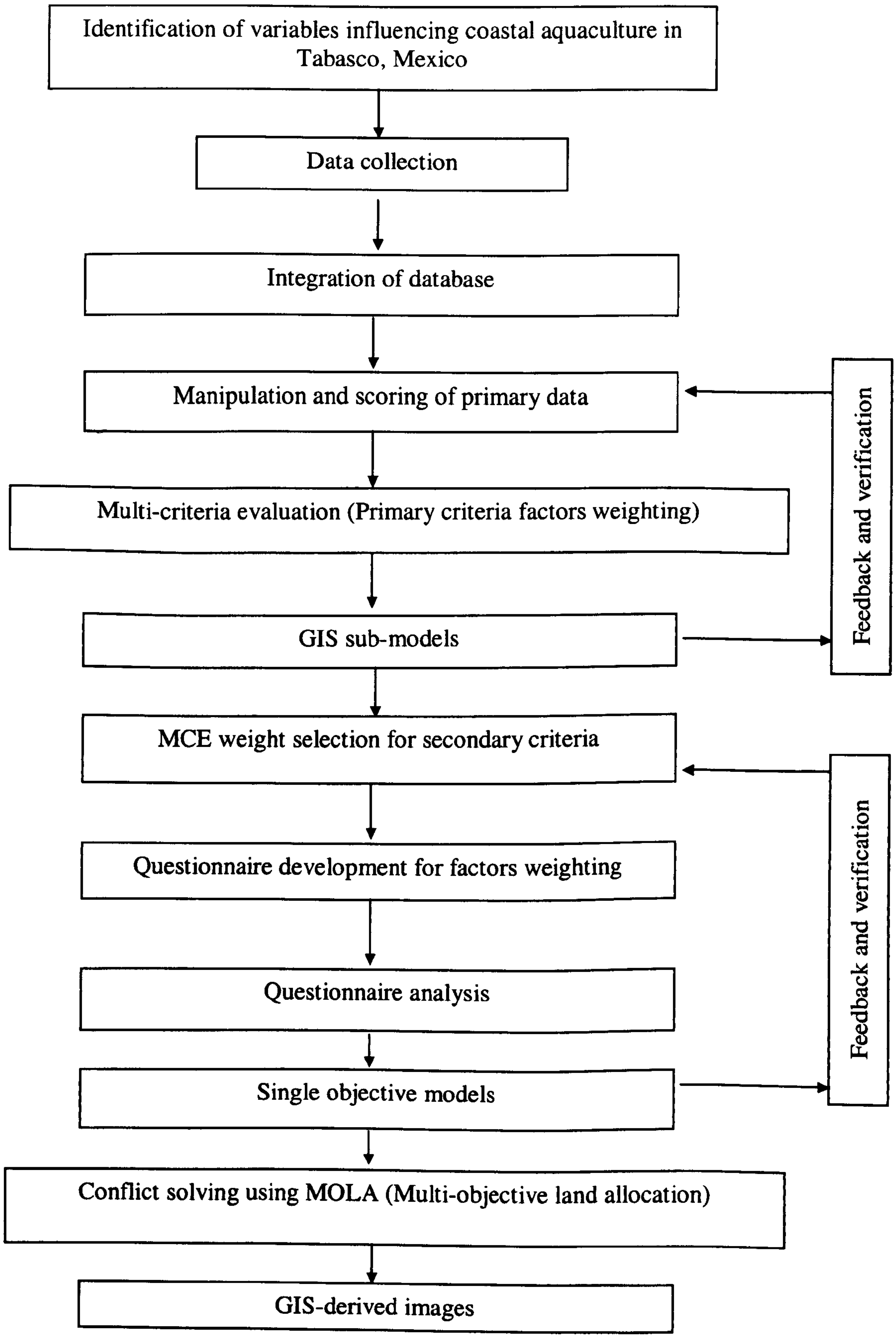


Figure 15. Integration of the criteria for coastal aquaculture in Tabasco, Mexico

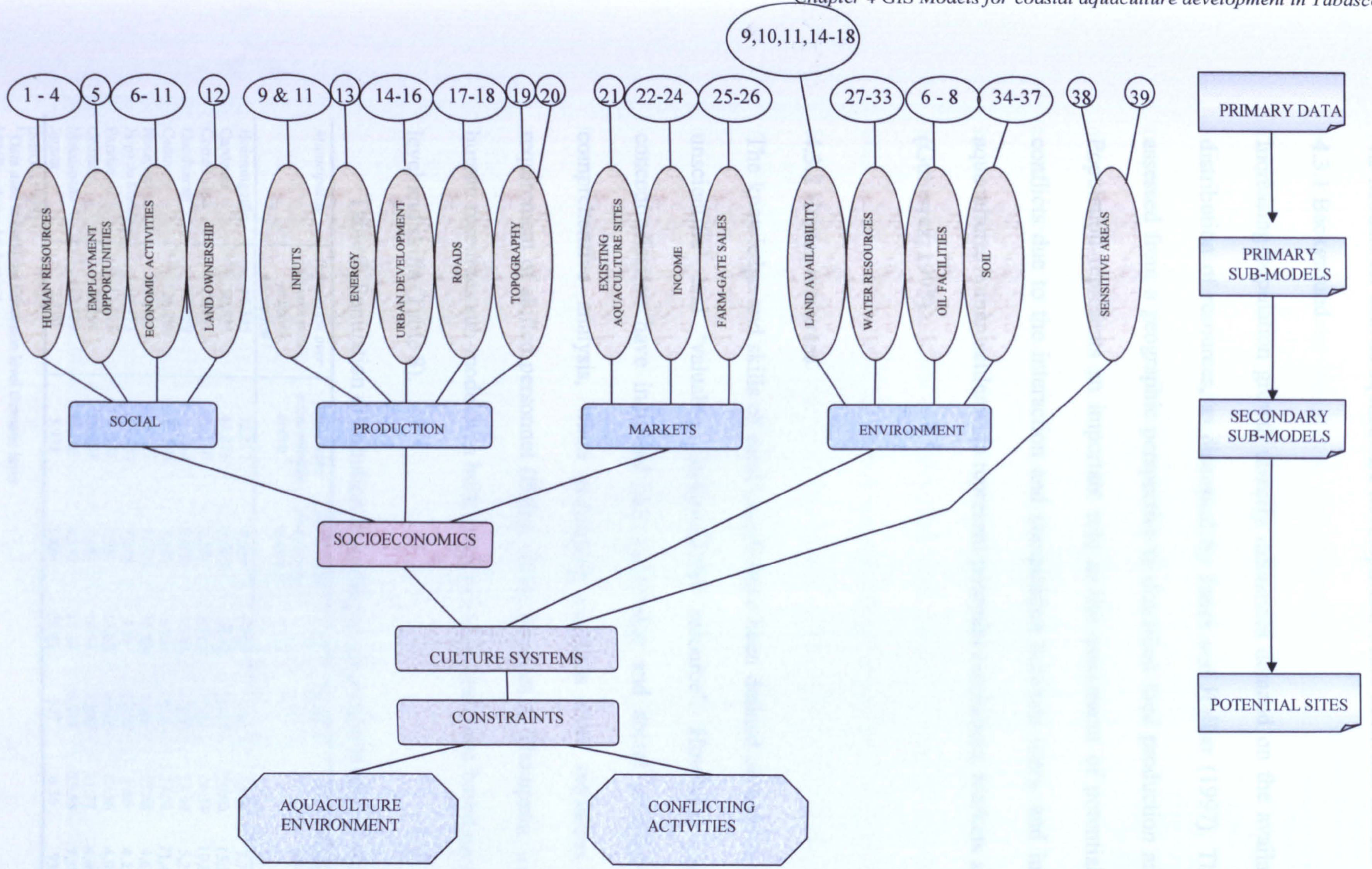


Figure 16. GIS decision diagram for coastal aquaculture and resources management in Tabasco, Mexico. 1=Age group, 2=Employed population in the Agriculture and Fishery sectors, 3=Employed population in the Industry sector, 4=Employed population in the Services sector, 5=Economic active population without a job, 6=Oil industry buildings, 7=Oil wells, 8=Pipelines, 9=Agriculture, 10=Forestry, 11=Livestock, 12=Parish communities, 13=Energy infrastructure, 14=Cities, 15=Towns, 16=Villages, 17=Gravel roads, 18=Paved roads, 19= Elevation, 20 = Slope, 21 = Current oyster farming sites, 22=Disposable income (1 minimum wage), 23=Disposable income (2 minimum wage), 24=Disposable income (>5 minimum wage), 25=Population density, 26=Population growth, 27=Precipitation, 28=Evaporation, 29=Seepage, 30=Lagoons, 31=Rivers, 32=Groundwater, 33=Seawater (coastline), 34=Texture, 35 = Structure, 36 = permeability, 37 = Plasticity, 38 = Flooding areas, 39 = Mangrove

4.3 Models for coastal aquaculture development: Socio-economic factors

4.3.1 Background

Increasing population growth directly influences demand on the availability and distribution of resources, as discussed by Jones and Hollier (1997). This can be assessed from a geographic perspective to described food production and supply. Population represents an important role in the assessment of potential resource conflicts due to the interaction and competition between users, and in terms of aquaculture, human settlements represent potential consumers, markets and labour (Gutierrez, 1995).

4.3.2 Human resources

The knowledge and skills of rural people have been defined as both 'a primitive, unscientific' and 'valuable, under-utilised resource'. However, changes in conceptualisation have indicated that knowledge and social interfaces require comprehensive analysis, when estimating conflicts over resources and the requirement of skilled personnel (Pillay, 1994; Scoones & Thompson, 1994). The human resources sub-model was built using two thematic maps based on education level and skills (Table 8).

Table 8. Population distribution according to education level and skills

Municipality	*Population over 15 with post-primary education* [1]	*Population economically active* [2]	*Agriculture and fishery sector*	*%*	*Industry sector*	*%*	*Services sector*	*%*
Huimanguillo	16,345	32,117	8,658	26.96	5,022	15.64	7,793	24.26
Cardenas	30,533	42,875	7,800	18.19	8,608	20.08	15,206	35.47
Comalcalco	22,911	32,558	6,555	20.13	7,892	24.24	10,831	33.27
Cunduacan	13,259	21,103	6,605	31.30	3,309	15.68	5,291	25.07
Centro	126,286	121,226	7,586	6.26	28,624	23.61	71,485	58.97
Nacajuca	10,115	12,327	1,876	15.22	3,166	25.68	4,632	37.58
Jalpa de Mendez	10,473	112,839	3,626	3.21	2,547	2.26	4,226	3.75
Paraiso	11,873	14,373	1,957	13.62	4,005	27.86	4,990	34.72
Centla	12,254	16,089	2,981	18.53	1,893	11.77	4,899	30.45
Macuspana	18,739	23,663	4,102	17.34	6,047	25.55	7,383	31.20
Jonuta	2,190	5,931	1,484	25.02	377	6.36	936	15.78

INEGI (1998)
[1] Data used to build the Education level thematic layer
[2] Skills sub-model data set

The criterion for the reclassification of the education level was based on the frequency distribution of the population over 15 years old with post-primary education. It is not herein proposed that people with this or higher levels of education are the subjects to be targeted for aquaculture development. The assumption comprises the facilitation of technology transfer in communities where people are able to read and write. In order to include people with no education, the skills layer was develop to take in account people with practical/traditional abilities in the modelling based on the sector they have found employment. The thresholds are shown in Text box 3. The image in Figure 17 shows that Centro municipality was found to have very good suitability (>100 000 people). Areas of fair suitability (30 000-40 000 people) were found in Centla, Macuspana, Cunduacan, Comalcalco, Paraiso, Cardenas and Huimanguillo municipalities.

Text box 3. Reclassification threshold of Population Education level

Score	Frequency distribution (Number of people/municipality)
1	< 2,500
2	2,500 – 3,000
3	3,000 – 10,000
4	10,000 – 20,000
5	20,000 – 30,000
6	30,000 – 40,000
7	40,000 – 100,000
8	>100,000

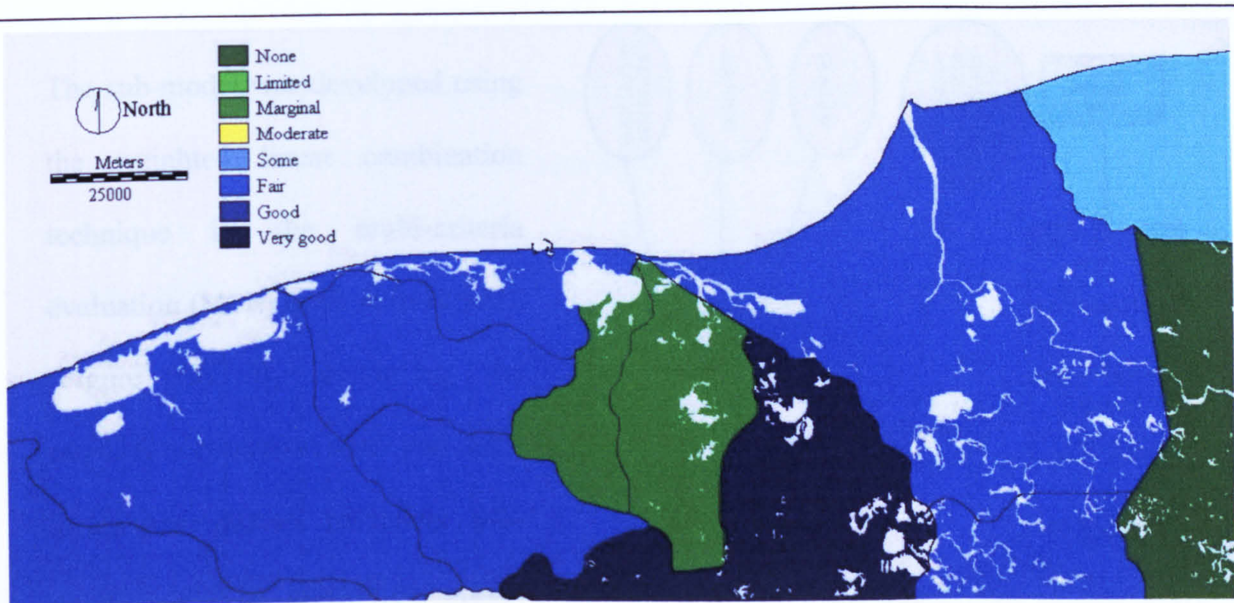


Figure 17. Reclassified image of population distribution according to education level

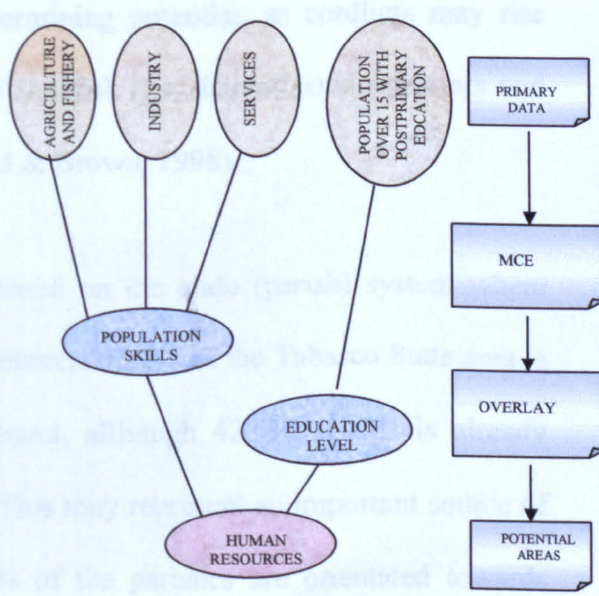
The population skills (Fig. 18) thematic map was reclassified using the percentage of the economically active population by economic sector: agriculture and fishery, industry and services as an indicator of knowledge and skills acquisition using tabulated data from INEGI (1996). Threshold and sub-model are shown in Text box 4.

Text box 4. Population skills sub-model threshold

Score	Population distribution (%/municipality)
1	0 – 10
2	10 – 20
3	20 – 30
4	30 – 40
5	40 – 50
6	50 – 60
7	60 – 80
8	> 80

Figure 18. Population distribution according to skills

The sub-model was developed using the weighted linear combination technique in the multi-criteria evaluation (MCE) module in Idrisi32 (Figure 19). By overlaying the population education level and skills layers the human resources sub-model could be assembled. About 40% of the area was found to have a



Mathematical expression
PPOPSKILLS= (agrisector x 0.64)+(indusector x 0.11)+(servsector x 0.26)
Scalar x 15+yearagegroup agegroup 3 2
Overlay x 3 agegroup popskills humanresu

Figure 19. Human resources sub-model

moderate suitability. Areas of very good suitability were located in the Centro municipality and areas with good suitability were found in Huimanguillo, Comalcalco and Cunduacan municipalities (Fig. 20).

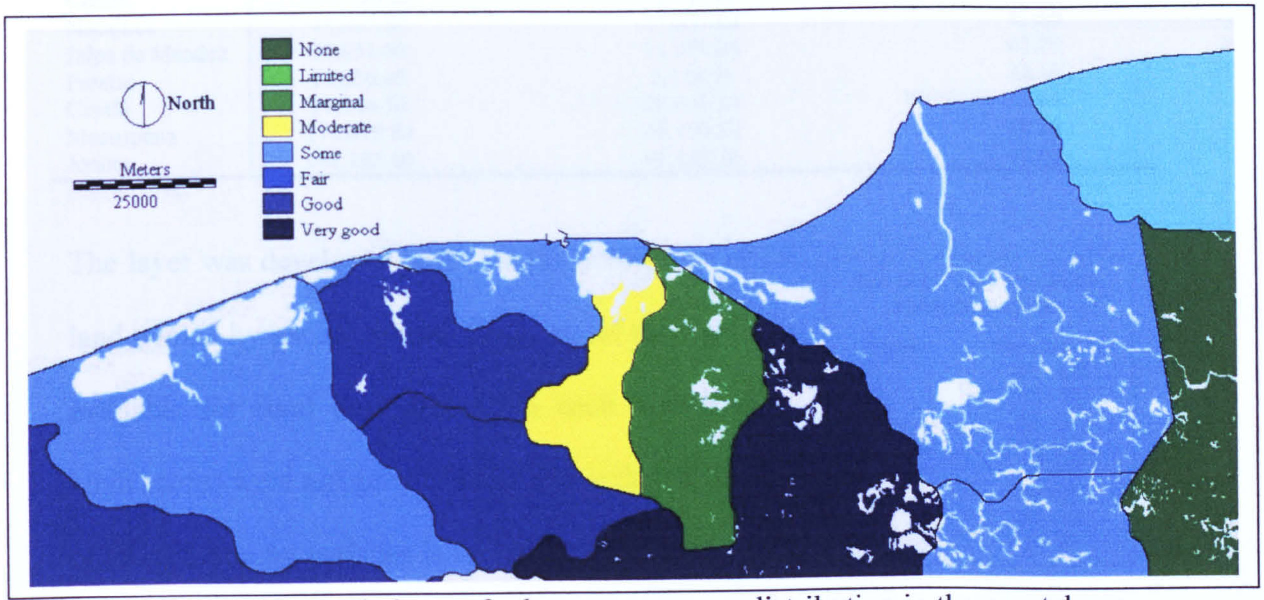


Figure 20. Multi-criteria image for human resources distribution in the coastal zone of Tabasco

4.3.3 Land ownership

Use and access to land are subject to development policies and laws on private and public property. Aquaculture takes up land as do many other economic activities, and these issues may be critical in determining potential, as conflicts may rise because the interactions between shrimp and fish (i.e. tilapia) pond operators and other resource users (Nash, 1995; Holland & Brown, 1998).

In Mexico, rural production is mainly based on the ejido (parish) system where organised groups possess and exploit resources. 53.2% of the Tabasco State area is subject to this land ownership arrangement, although 42.5% of this is already subject to individual land use (Table 9). This may represent an important source of conflict for accessing resources, as 96% of the parishes are orientated towards livestock and agriculture production (INEGI, 1993, 1997, 1998).

Table 9. Percentage of land owned by parish communities

Municipality	*Total area (ha)*	*Total land owned by parish communities*	*%*
Huimanguillo	310,479.70	141,268.26	45.50
Cardenas	121,088.60	90,211.00	74.50
Comalcalco	46,710.30	20,692.66	44.30
Cunduacan	45,635.00	18,801.62	41.20
Centro	123,330.40	39,342.39	31.90
Nacajuca	43,067.50	17,657.68	41.60
Jalpa de Mendez	28,054.00	11,979.06	42.70
Paraiso	17,626.40	5,834.34	33.10
Centla	91,746.50	28,991.89	31.60
Macuspana	174,619.80	45,750.39	26.20
Jonuta	101,165.40	47,143.08	46.60

INEGI (1998)

Text box 5. Land allocated to parish communities

Score	Threshold %
1	87 – 100
2	75 – 87
3	62 – 75
4	50 – 62
5	37 –50
6	25 – 37
7	12 – 25
8	0 – 12

The layer was developed based on the percentage of the land owned by parish communities, out of the total area available for rural development in each municipality. High scores were assigned to areas where the percentage of land owned by parishes is low in order to identify the areas where conflict for land use may be reduced, as shown in Text box 5. Fair suitability areas were found in Paraiso, Centro, Centla, and Macuspana municipalities, where land ownership by parishes' communities accounted for only the 37% of the total area (Fig. 21).

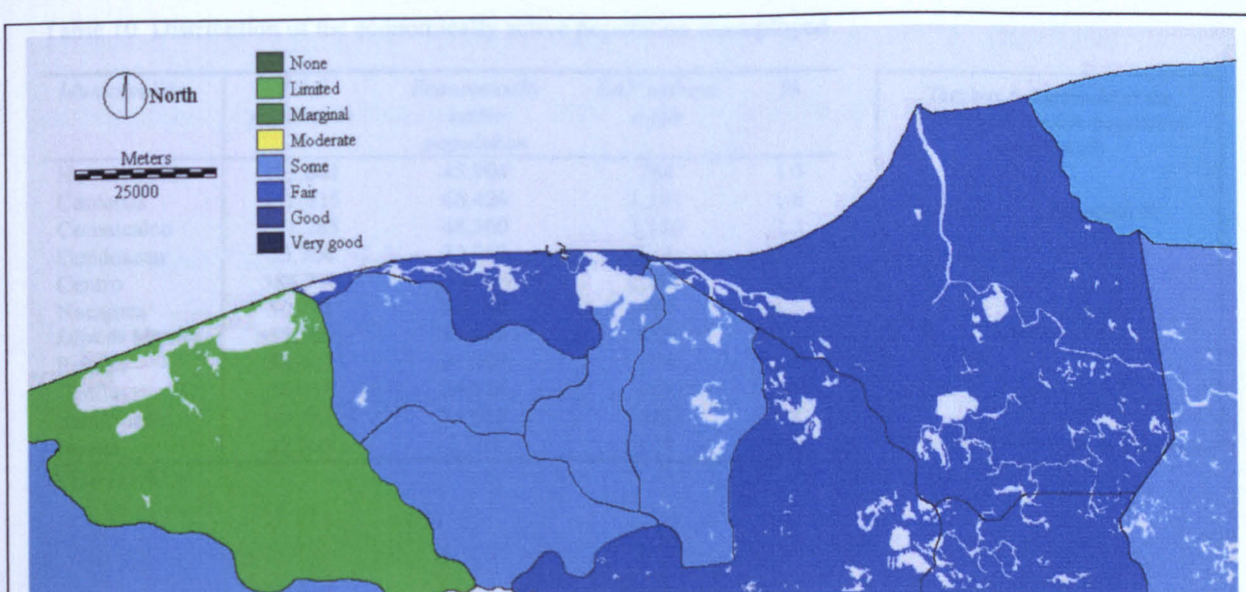


Figure 21. Land ownership distribution in the coastal zone of Tabasco

4.3.4 Employment opportunities

Limiting or reducing access to a particular resource may have a direct effect on job availability, due to the intimate relationship between the amount of employment and fishing effort (Christy, 1982; Troadec, 1983). Aquaculture has been defined as an alternative source of income and employment for the rural poor while improving nutritional and economic status of the population and promoting regional economies development (Hishamunda & Jolly, 1998; DFID, 1999).

The population parameter considered to reclassify the layer was the percentage of economically active population currently unemployed by municipality based on data from INEGI (1998), as this section of the population represents the potential work force available (Table 10). The threshold selected is shown in the Text box 6. All municipalities had an unemployed population rate between 1-2.5% indicating a marginal suitability for employment (Fig. 22).

Table 10. Distribution of the economically active population unemployed

Municipality	*Total population*	*Economically active population*	*EAP without a job*	*%*
Huimanguillo	135,641	45,904	784	1.6
Cardenas	172,635	66,426	1,141	1.6
Comalcalco	141,285	48,360	1,180	2.3
Cunduacan	85,704	32,062	643	1.9
Centro	386,776	196,669	2,988	1.4
Nacajuca	50,791	26,548	443	1.6
Jalpa de Mendez	57,250	19,898	455	2.2
Paraiso	58,403	21,309	554	2.5
Centla	70,053	24,125	489	1.9
Macuspana	105,063	35,652	488	1.3
Jonuta	22,000	8,723	174	1.9

INEGI (1998)

Text box 6. Threshold of the economically active population without a job

Score	Threshold %
1	0-0.5
2	0.5-1
3	1-2.5
4	2.5-4
5	4-5.5
6	5.5-7
7	7-8.5
8	>8.5

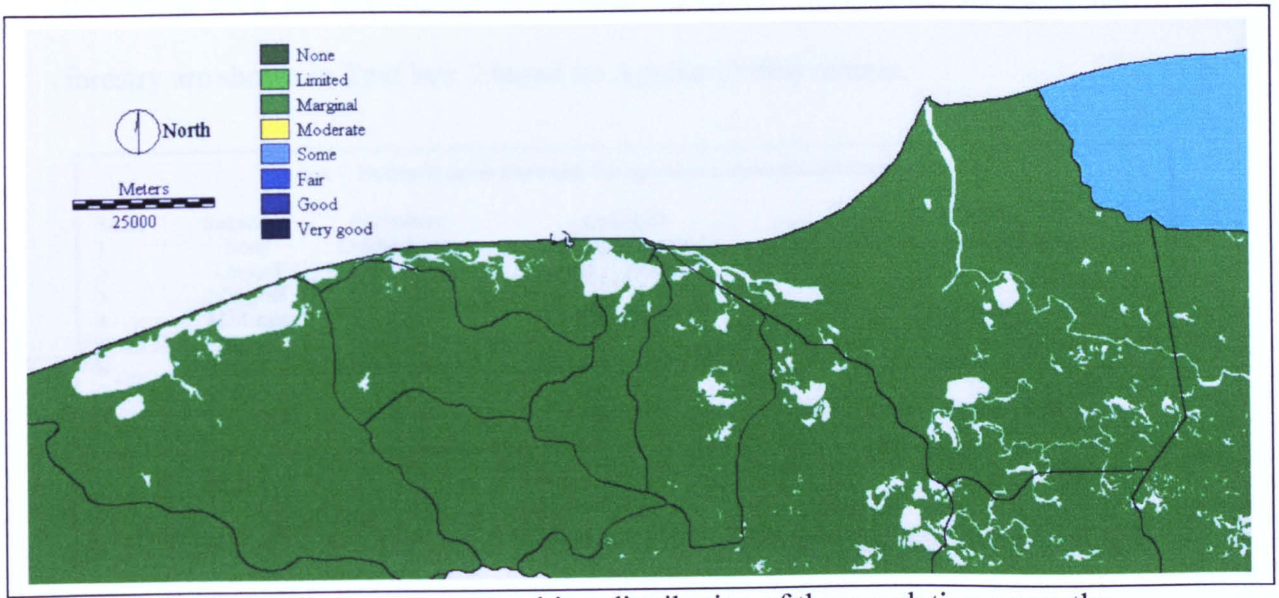


Figure 22. Employment opportunities: distribution of the population currently unemployed in the coastal zone of Tabasco

4.3.5 Economic activities

Fishery activities have been a major source of food, employment and economic benefits to those living beside aquatic resources. Other economic opportunities such as oil and timber extraction, agriculture, shipping and tourism are also important for coastal communities. Conflicts and competition for limited coastal resources, and escalating environmental deterioration present a significant development challenge (Beatley *et al.*, 1995; Aguilar & Ross, 1995).

On the other hand, there is some scope for all these activities to be integrated, to improve or complement each other, by identifying the areas where most opportunities for development can be achieved. Aquaculture may also be incorporated into these activities to minimise conflicts between user groups (Meaden & Kapetsky, 1991; Arnold *et al.*, 2000). In Tabasco State, activities in conflict for land and water resources are the oil industry, agriculture, livestock and forestry. The layers used for this sub-model are shown in Figures 25-28. The thresholds used for developing the thematic maps for agriculture, livestock and forestry are shown in Text box 7 based on Aguilar (1996) criteria.

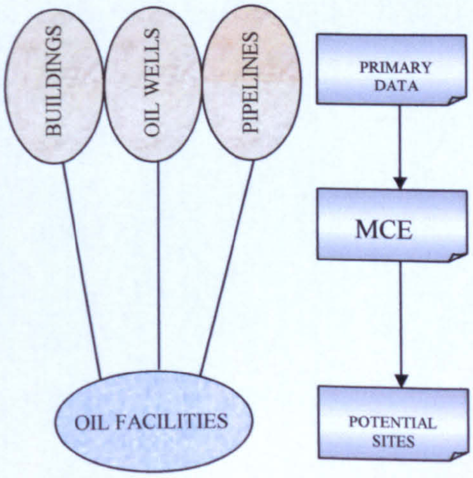
Text box 7. Reclassification thresholds for agriculture, livestock and forestry land use.

Score	Suitability	Agriculture	Livestock	Forestry
1	None	Crops all year	Cultured grassland	Mangrove and tropical forest
2	Limited		Natural grassland	
3	Marginal			
4	Moderate		Other uses	Wood land
5	Some			
6	Fair	Seasonal crops	Mangrove and tropical forest	Swamp
7	Good			
8	Very good	No crops	Swamp	Land not suitable for wood exploitation

An oil facilities sub-model was developed by weighting pipelines, oil wells and buildings (processing plants and loading stations) according to the safety distances (proximity suitability) established in the National Programme for Urban Development (Text box 8). Areas close to oil facilities were considered as high-risk areas as the exploitation of petroleum has the potential to cause significant direct environmental impact through construction activities, spills and the discharge of pollutants (SEDESOL, 1999). Weights were assigned by the author to develop the sub-model according to the layout shown in Figure 24.

Text box 8. Threshold for oil facilities land use

Score	Description	Distance Km
1	High risk	
	Buildings	3 - 4
	Oil wells	1 - 2
	Pipelines	50 m – 500 m
3	Possible risk	
	Buildings	4 – 6
	Oil wells	2 – 4
	Pipelines	500 m – 1
6	Moderate risk	
	Buildings	6 – 12
	Oil wells	4 – 8
	Pipelines	1 –2
8	Low risk	
	Buildings	> 14
	Oil wells	> 10
	Pipelines	> 3



Mathematical expression

OILFACIL = (buildingsx0.50)+(oilwellsx0.20)+(pipelinesx0.30)

Figure 24. Oil facilities sub-model.

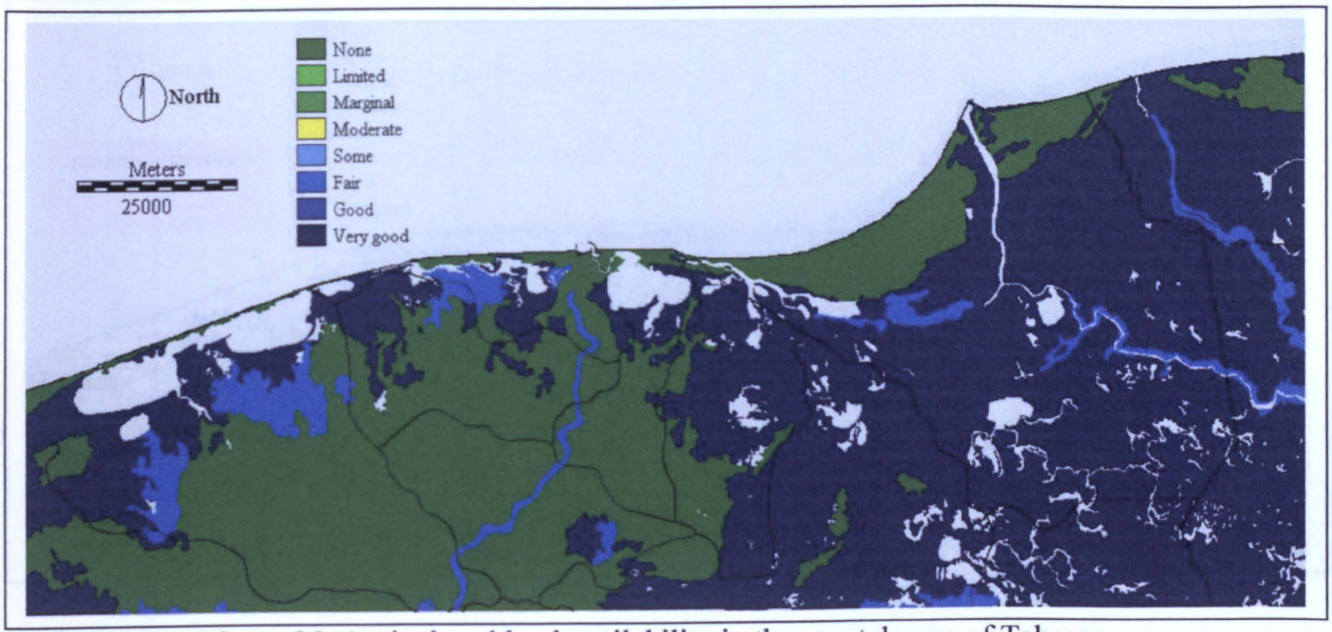


Figure 25. Agricultural land availability in the coastal zone of Tabasco

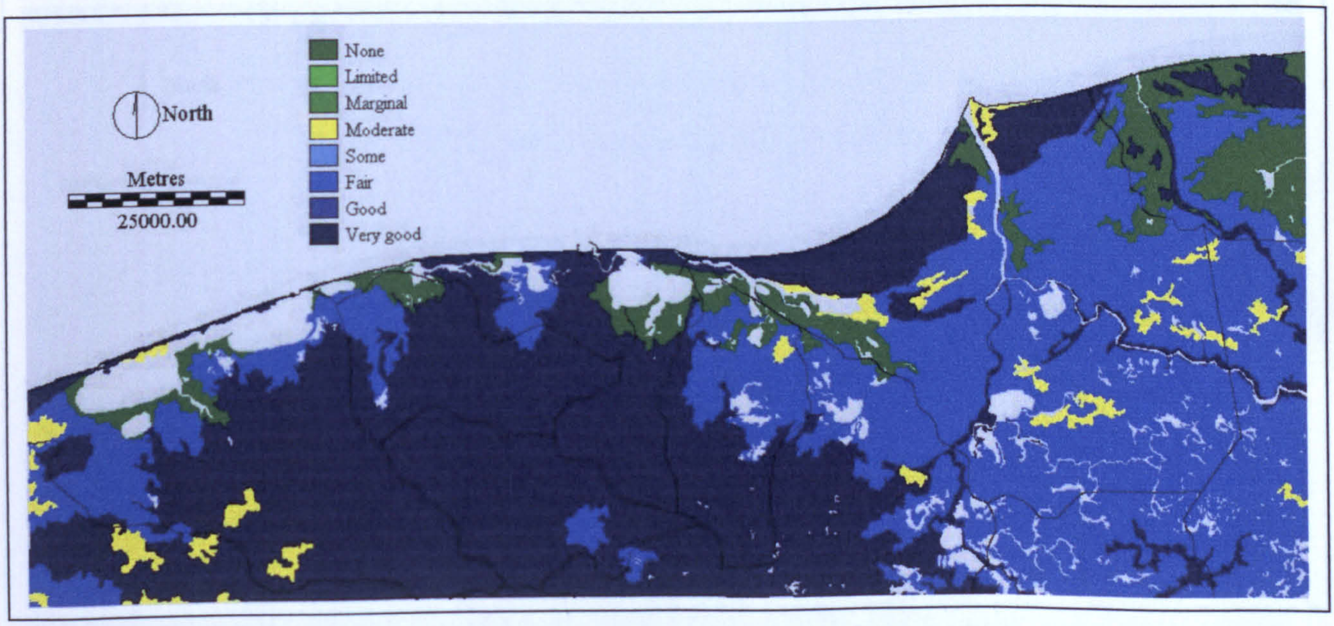


Figure 26. Forestry land availability in the coastal zone of Tabasco

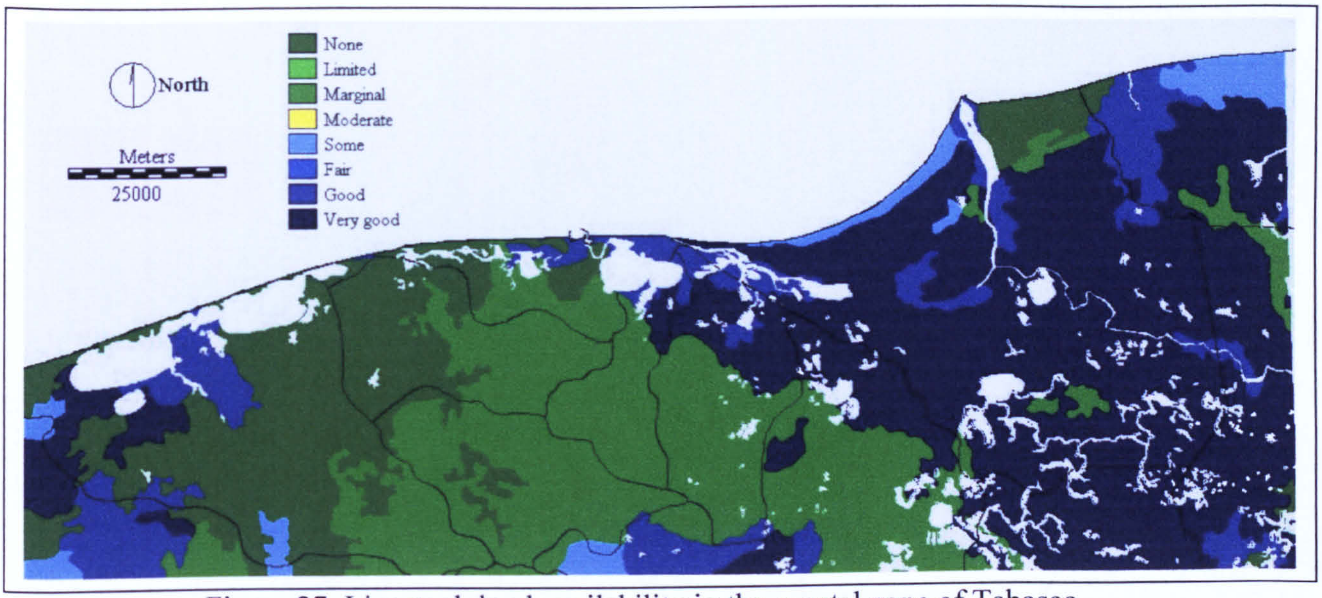


Figure 27. Livestock land availability in the coastal zone of Tabasco

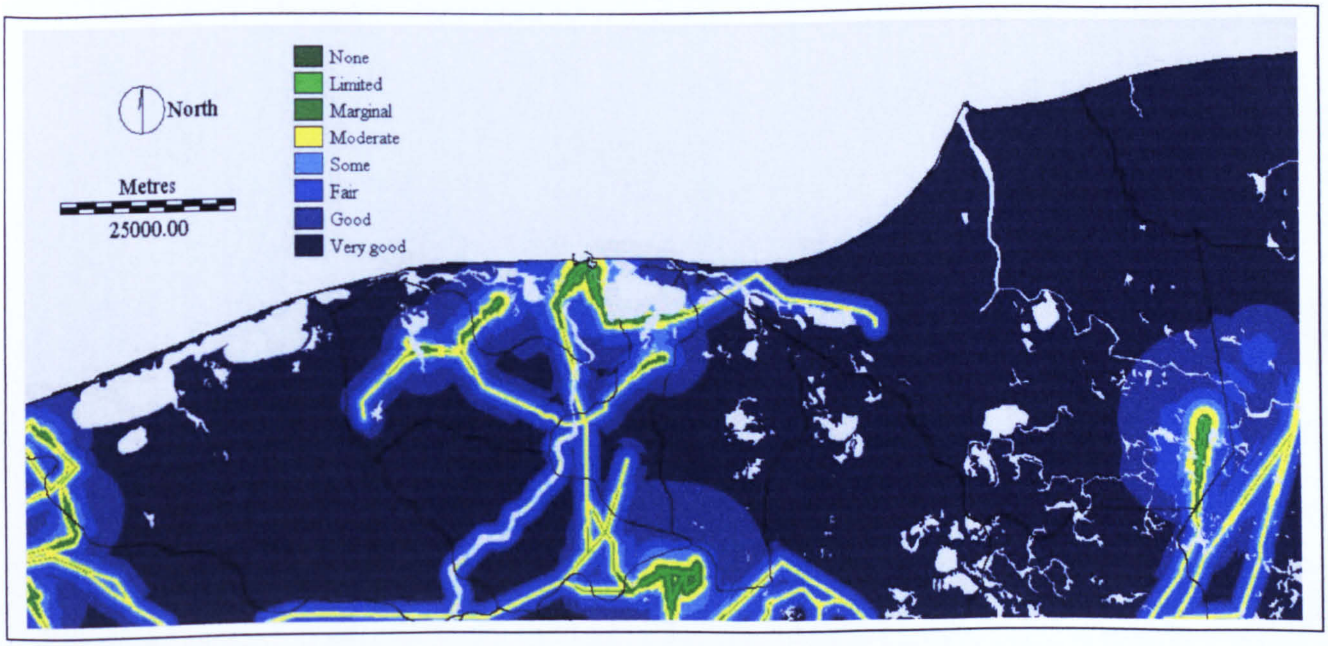
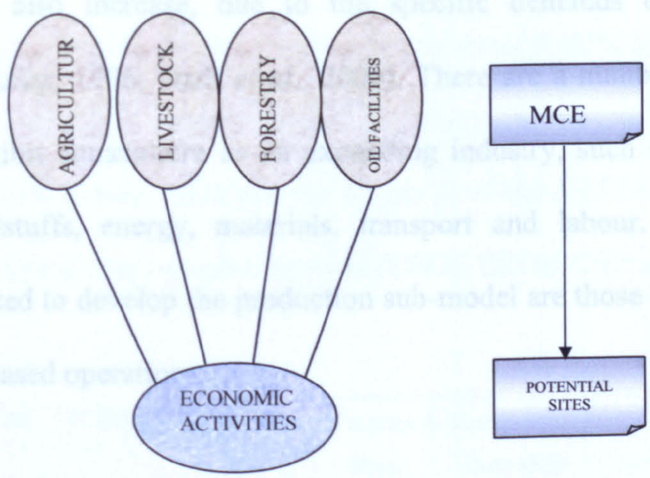


Figure 28. Oil facilities: land distribution according to distance from risk zones

The factors were reclassified and then integrated into a MCE sub-model to identify areas of potential risk. All factors were weighted according to their economic importance in the State by developing a pairwise matrix through the MCE module in Idrisi32 (Figure 29). The resulting image is shown in Figure 30. Areas of good and very good suitability were found covering approximately 31% of the total area.



Mathematical expression
ECOACTI = (oilfacil x 0.58) + (livestocklanuse x 0.22) + (agriculanduse x 0.13) + (forestuse x 0.08)

Figure 29. Economic activities sub-model diagram

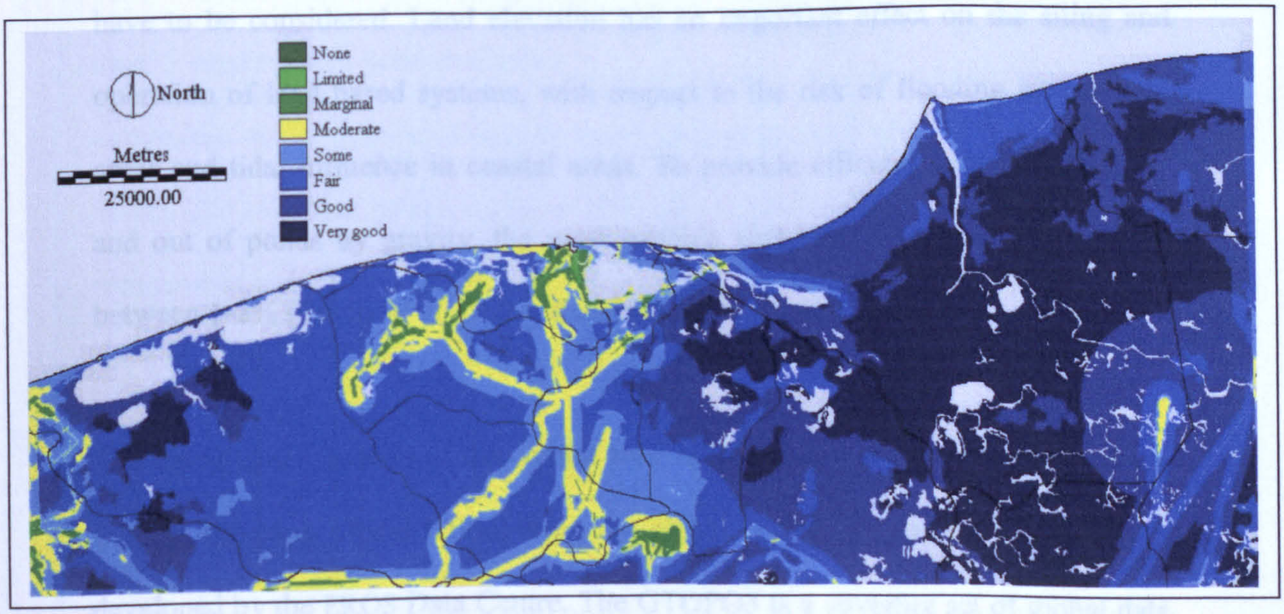


Figure 30. Multi-criteria image of the main economic activities in the coastal zone of Tabasco

4.4 Production sub-model

4.4.1 Introduction

It has been estimated that the inability of the fishery to supply animal protein will continue and aquaculture production would have to increase in greatly (Pillay, 1994). However, competition with urban development, agriculture and industrial activities may also increase, due to the specific demands on resources for operations (Aguilar, 1996; Nath *et al.*, 2000). There are a number of factors that promote or inhibit aquaculture as an expanding industry, such as availability of fertilisers, feedstuffs, energy, materials, transport and labour. The production modifiers selected to develop the production sub-model are those based on suitable areas for land-based operations.

4.4.2 Topography

In order to identify areas suitable for pond construction two topographic features have to be considered. Land elevation has an important effect on the siting and operation of land based systems, with respect to the risk of flooding in low land areas and tidal influence in coastal areas. To provide efficient water exchange in and out of ponds by gravity, the most suitable slope has been determined to be between 1-2% (Coche *et al.*, 1992; Kapetsky, 1994; Aguilar, 1996).

The topographic features of the coastal zone of Tabasco were acquired through the Digital Elevation Model (DEM) from the global digital elevation model GTOPO3 developed by the EROS Data Centre. The GTOPO3 is a covering set of global data with a horizontal grid spacing of 30-arc seconds and a co-ordinate system in decimal degrees of latitude and longitude referenced to WGS84 geodetic datum.

The vertical units are in meters above mean sea level. The DEM image represents ocean areas masked with assigned values of –9999 m and lowland coastal areas with an elevation of at least 1 m, which allows the reassignment of values while maintaining the land boundary. The data set for Mexico was developed from Digital Terrain Elevation Data (DTED) provided by INEGI. The vertical accuracy varies by location and data source, for DTED accuracy it has been estimated to have a root mean square (RMSE) of ±18 meters linear error at 90% of confidence. The horizontal grid spacing equates about 1 kilometre; the grid spacing may compromise the resolution, however, the 30-arc from the DTED is appropriate for resolving the important topographic features (USGS EROS, 2001).

Text box 6. Threshold for the topography sub-model

Score	Suitability	Elevation m	Slope %
1	None	>1	>30
2	Limited		20 – 10
3	Marginal	1 – 2	10 – 8
4	Moderate		8 – 5
5	Some		5 – 4
6	Fair	2 – 3	4 – 3
7	Good		3 – 2
8	Very good	>3	2 – 1

The image was reclassified for elevation and slope using the thresholds shown in Text box 6. Areas where elevation is higher than 3 meters have been described as suitable, as flooding is unlikely to occur in these areas (Velazquez, 1994; Salam, 2000). The elevation image is shown in Figure 31. The SURFACE module in Idrisi was used to convert the DEM into a slope image. Areas with a slope between 1-2% were considered as suitable to minimise pond construction costs and where water exchange by gravity is available (Figure 33).

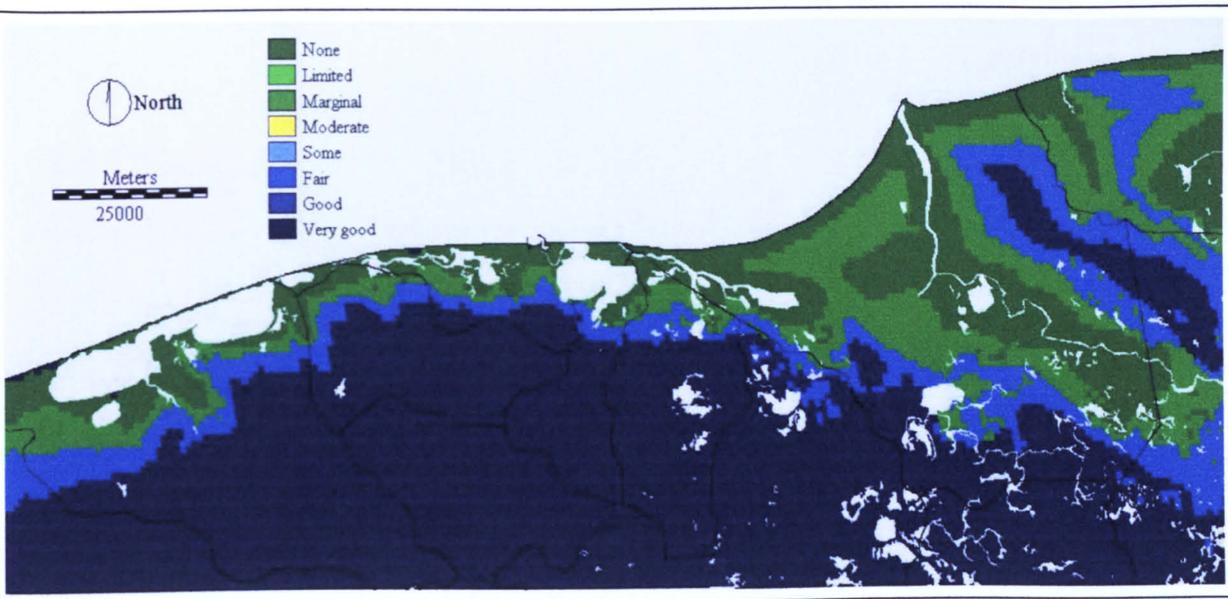
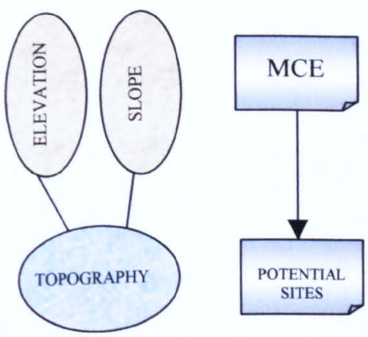


Figure 31. Elevation image, reclassified for aquaculture development in the coastal zone of Tabasco

The reclassified image from the DEM showed that areas with very good score were identified covering 95% (elevation) and 99% (slope) of the total area. Although there are some areas with elevation above 10 m, slope is not steep. This allowed the combination of both reclassified images into an MCE sub-model, which identified areas suitable by giving equal weights to both elevation and slope (Fig. 32). The final image is shown in Figure 34.



Mathematical expression:
TOPOGRAPHY = (elevation x 0.50) + (slope x 0.50)

Figure 32. Topography sub-model

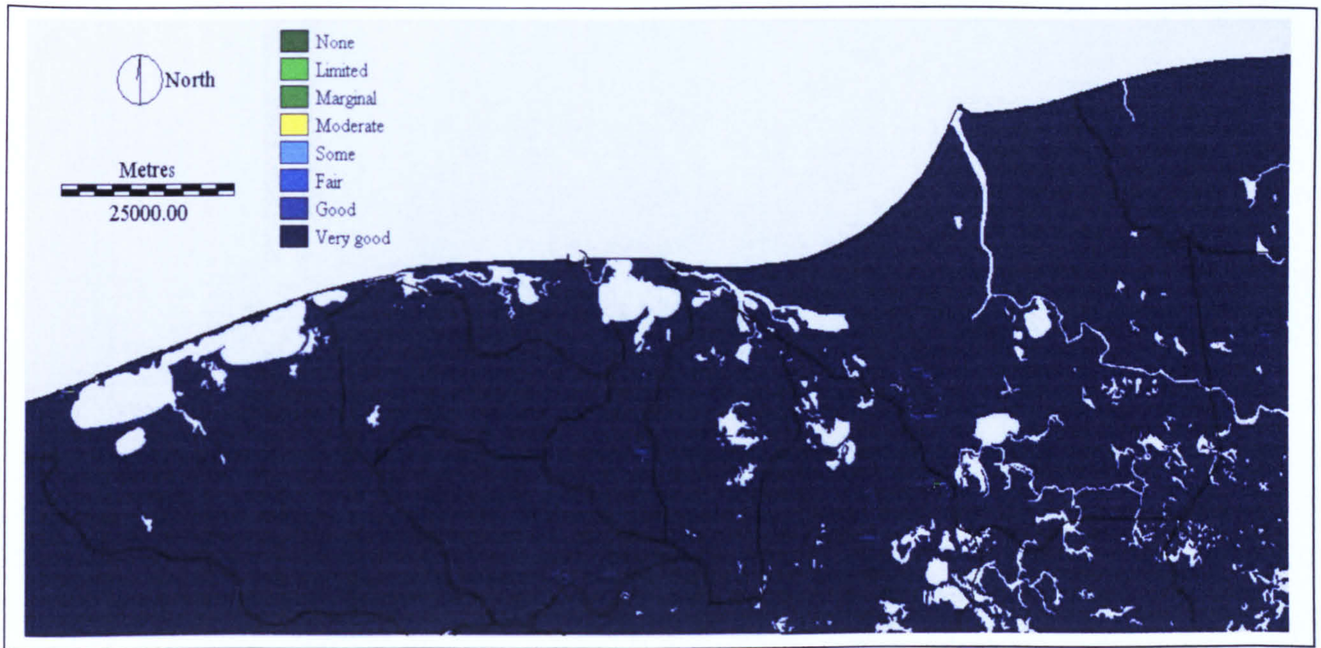


Figure 33. Reclassified image of slope suitability for the coastal zones of Tabasco

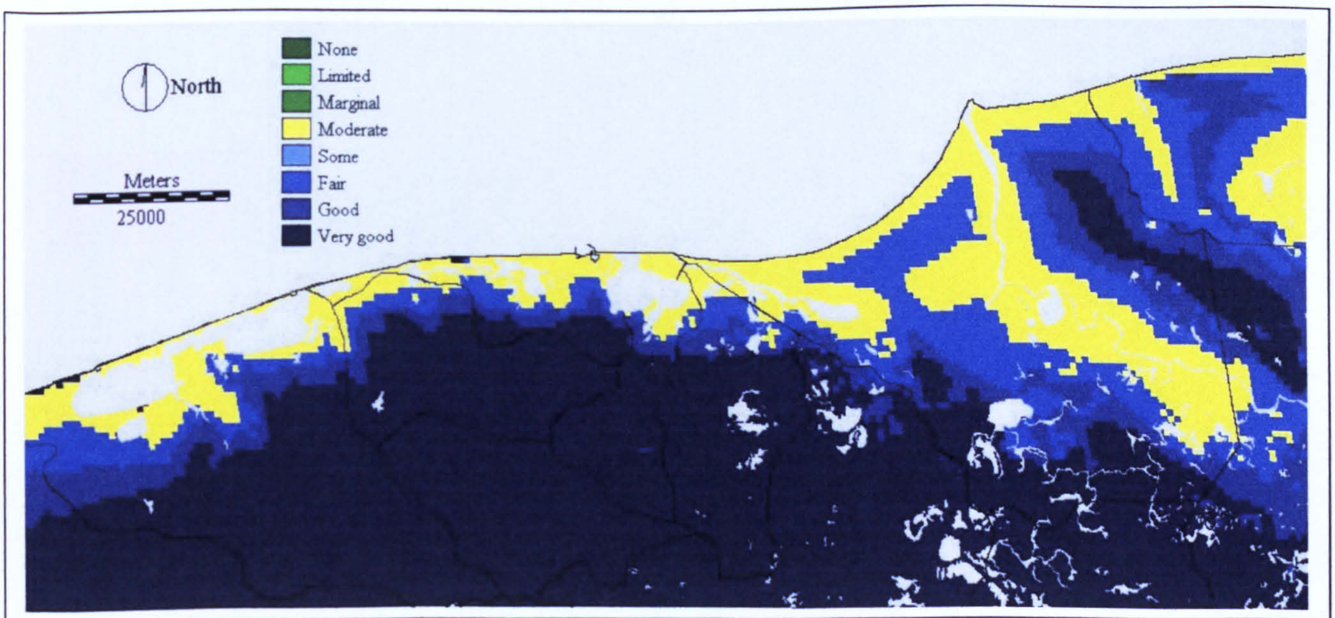


Figure 34. Topographic suitability image of the coastal zone of Tabasco

4.4.3 Land ownership

The land ownership layer was reclassified from tabulated data of INEGI (1998) considering that the parish organisation represents an alternative for management of resources, as basic community needs can be easily identified due to the low number of people involved. The threshold for this layer is shown in Text box 10. Very good suitability areas were found in the Cardenas municipality (Fig. 35).

Text box 10. Land owned by parish communities

Score	Threshold %
1	0 – 12
2	12 – 25
3	25 – 37
4	37 – 50
5	50 – 62
6	62 – 75
7	75 – 87
8	87 – 100

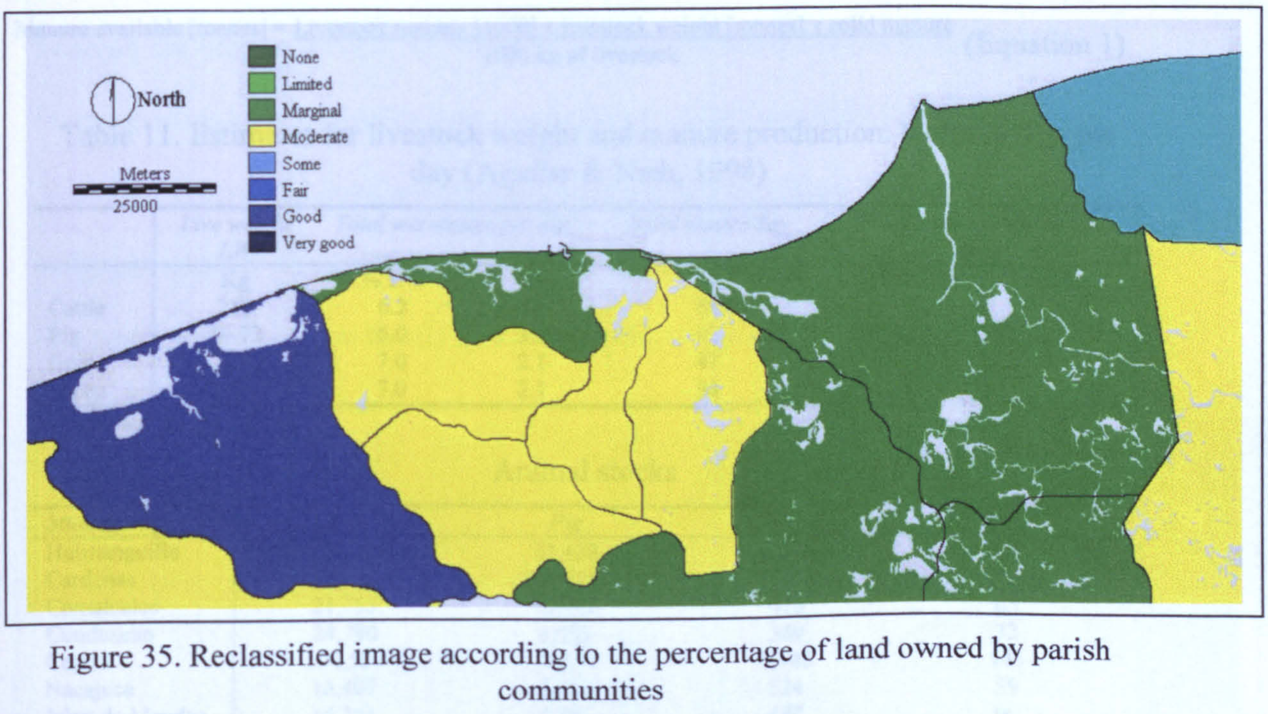


Figure 35. Reclassified image according to the percentage of land owned by parish communities

4.4.4 Inputs

The intensity of aquaculture depends on the local availability of inputs. Wastes from animal production and agriculture by-products are considered an inexpensive and advantageous source of fertilisers when they are easily available with little or no transport. This represents an alternative when considering the integration of aquaculture with other economic activities (e. g. pig and fish, rice-pig-fish) into rural communities, as the production system type influences the amount of fertiliser required particularly for pond culture (Meaden & Kapetsky, 1991; Bardach, 1997a).

The layer for manure availability was constructed based on the formula used (Equation 1) by Aguilar and Nath (1998). The authors use livestock numbers as a surrogate measure of manure availability due to the lack of data on manure. The calculation of livestock weight and manure production was based on INEGI (1996) tabulated data as shown in Table 11:

$$\text{Manure available [tonnes]} = \frac{\text{Livestock number [1000] x livestock weight [tonnes] x solid manure}}{\text{1000 kg of livestock}} \quad \text{(Equation 1)}$$

Table 11. Estimates for livestock weight and manure production: biomass (kg) per day (Aguilar & Nath, 1998)

	Live weight LW	*Total wet wastes per day*[1]		*Solid wastes/day*	*Total fresh wastes (solids only)*
	Kg	% LW	Kg	%	Kg/1000 kg LW/day
Cattle	210	6.2	13	69	60
Pig	54-72	6.0	3.5	47	60
Goat	30	7.0	2.1	47	70
Sheep	30	7.0	2.1	54	70

[1] Solid wastes and urine

Animal stocks

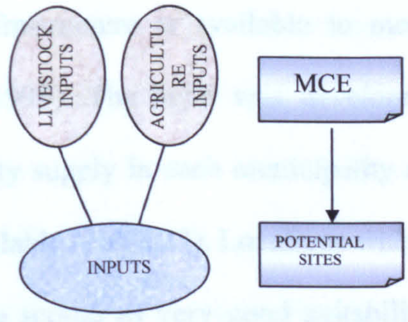
Municipality	*Cattle*	*Pig*	*Sheep*	*Goat*
Huimanguillo	140,992	23,438	6,835	411
Cardenas	35,830	17,765	1,400	42
Comalcalco	21,253	13,162	616	65
Cunduacan	24,790	6,653	369	33
Centro	104,580	20,691	3,148	143
Nacajuca	18,407	5,549	524	59
Jalpa de Mendez	16,761	8,727	487	90
Paraiso	4,241	4,667	158	8
Centla	43,803	6,125	732	43
Macuspana	140,129	18,170	5,510	425
Jonuta	59,113	6,963	2,550	27

INEGI (1998)

A layer was developed for each of the sources of manure and then they were added to estimate the total amount of manure available from semi-intensive and small-scale production units, which account for the 48.9% of a total of 28,466 production units (INEGI, 1997). The agricultural by-products availability layer was based on the type of crops. Both layers were reclassified according to the threshold shown in the Text box 11 and were then integrated using the MCE module (Figure 36).

Text box 11. Total manure amount available and agriculture by-products

Score	Manure (tonnes)	Crops (type)
1	< 2,000	No crops
2	2,000 – 10,000	
3	10,000 – 20,000	
4	20,000 – 30,000	Seasonal crops
5	30,000 – 50,000	
6	50,000 – 60,000	
7	60,000 – 100,000	
8	> 100,000	Crops all year



Mathematical expression

INPUTS= (livestock inputs x 0.75) = (agrinputs x 0.25)

Figure 36. Inputs sub-model

The resulting layers were integrated into a sub-model in which the author gave manure the highest weight, as livestock production is continuous through the year. Very good and fair suitability areas were found in Huimanguillo and Macuspana as shown in Figure 37. Good and fair suitability areas were found in Centro. Access to different sources of manure is relatively moderate, as most of the production units are small-scale based on family systems for chicken and pig (see Section 5.2.2).

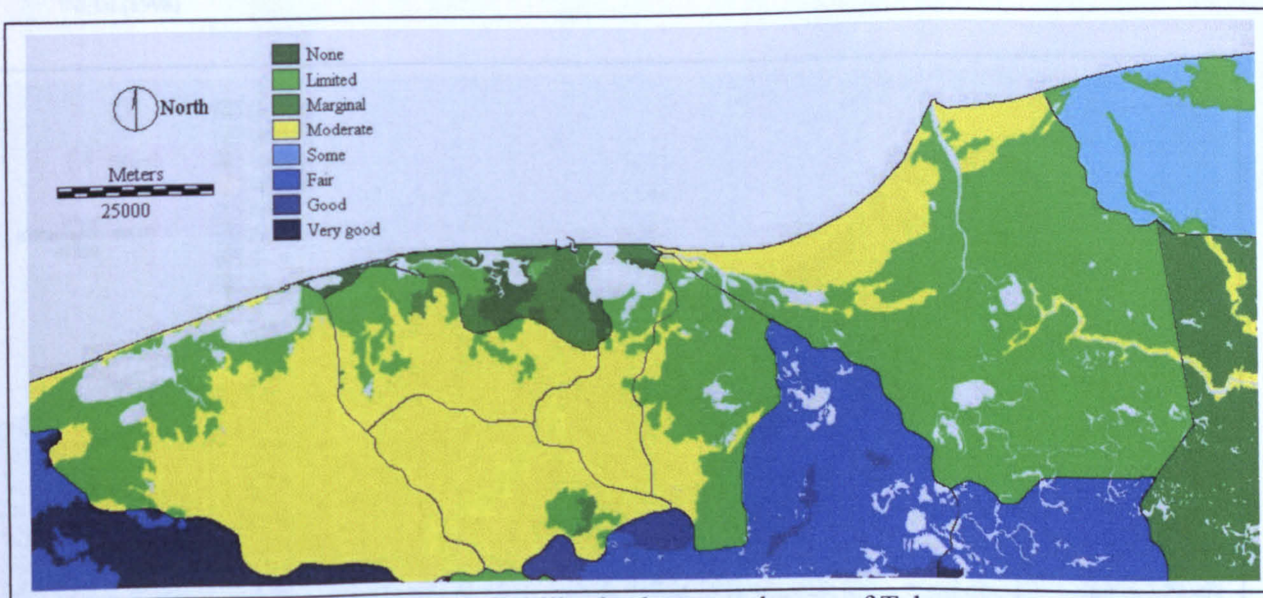


Figure 37. Inputs availability in the coastal zone of Tabasco

4.4.5 Energy

Energy supply is an important operating cost when planning for aquaculture development and it is dependent upon the intensity of the system. As for other activities, aquaculture requires that suitable infrastructure is available to meet operating costs in a sensible manner (Pillay, 1994). The layer was developed according to the percentage of domestic electricity supply in each municipality as an indication of energy infrastructure already available (Table 12). Localities where more than 87% of the houses have energy were scored as very good suitability areas (Text box 12) Good suitability areas (75-87%) were found in Huimanguillo, Macuspana and Jonuta municipalities (Fig. 38).

Table 12. Domestic energy supply

Municipality	*Total houses*	*Houses with energy*	*%*
Huimanguillo	28,877	22,812	79.0
Cardenas	40,001	35,880	89.7
Comalcalco	29,873	27,274	91.3
Cunduacan	18,817	16,766	89.1
Centro	104,153	101,653	97.6
Nacajuca	13,529	12,555	92.8
Jalpa	11,900	10,852	91.2
Paraiso	13,303	12,491	93.9
Centla	14,819	13,129	88.6
Macuspana	24,156	21,982	91.0
Jonuta	4,776	3992	83.6

INEGI (1998)

Tex box 12. Energy infrastructure suitability

Score	% of houses with electricity
1	0-12
2	12-25
3	25-37
4	37-50
5	50-62
6	62-75
7	75-87
8	87-100

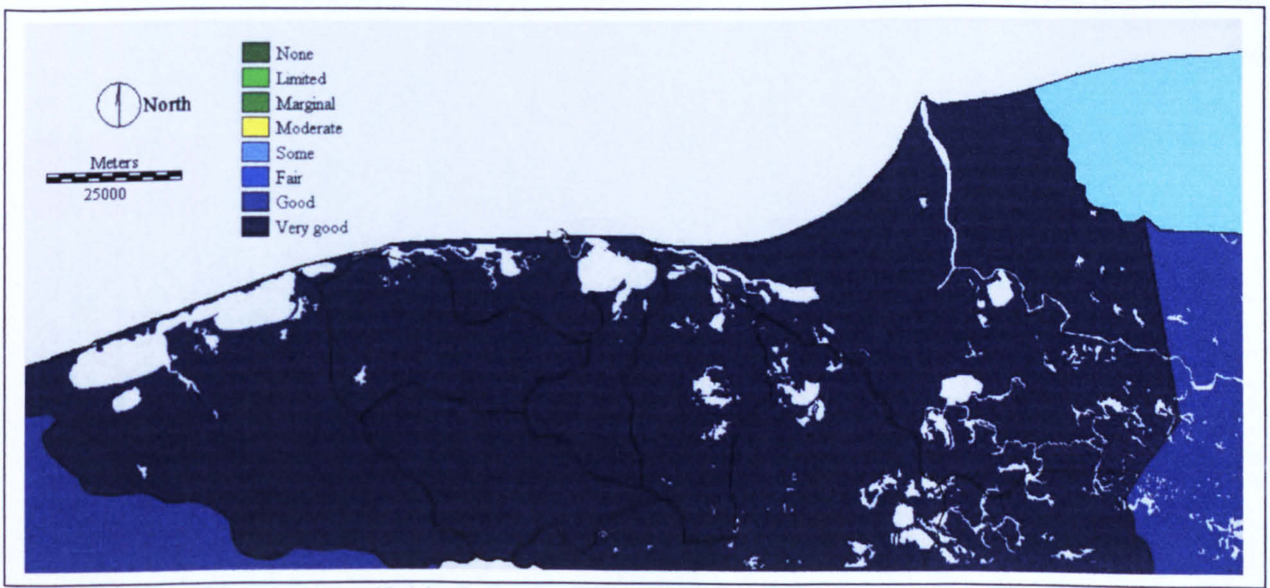


Figure 38. Energy available for aquaculture in the coastal zone of Tabasco, Mexico

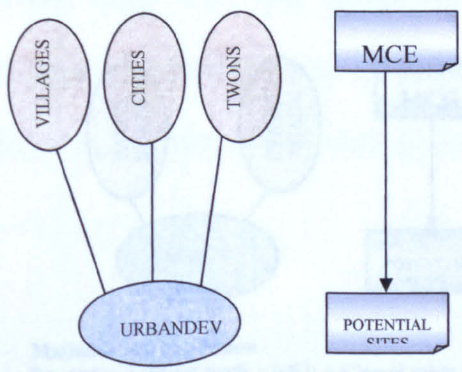
4.4.6 Urban development

The provision of infrastructure, access to markets and materials has to be specifically considered regarding the siting of aquaculture facilities. These may be integrated around urban centres to have an easy and simple access to resources and to meet population demand for aquatic products at a local level (Pillay, 1994; Nash, 1995).

The sub-model was developed from three layers based on distances from cities, towns and villages. Thresholds are shown in Text box 12. The layers were integrated into a sub-model, each weighted according to the size of urban centres (Fig. 39). The resulting layer shows that most of the urban centres with very good suitability score are concentrated in the Central and West part of the State (Fig. 40).

Text box 12. Distance to urban centres

Score	Description	Distance Km
1	No suitable	
	Cities	> 20
	Towns	> 4
	Villages	> 2
3	Marginal suitable	
	Cities	10 –20
	Towns	2 – 4
	Villages	1 – 2
6	Fair suitable	
	Cities	2– 10
	Towns	1 – 2
	Villages	500 m – 1
8	Very good suitability	
	Cities	< 2
	Towns	< 1
	Villages	< 500 m



Mathematical expression
URBANDEV = (cities x 0.50) + (towns x 0.35) + (villages x 0.15)

Figure 39. Urban development sub-model

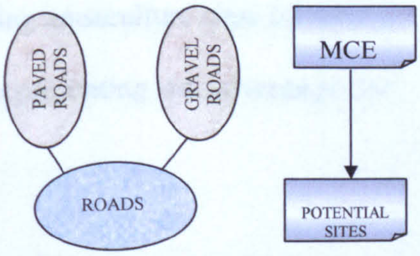
Figure 40. Access to urban resources and amenities

4.4.7 Roads

The availability of transport systems is essential to access amenities and for marketing aquaculture products. These represent important factors in estimation of operating costs according to distance for site development, travel time and access to local labour (Kapetsky *et al.*, 1988; Pillay, 1994). The sub-model was built based on the closeness to either paved or gravel roads (Text box 13). Paved roads layer was given a higher score as gravel roads close to swamp areas are subject to flooding (Figure 41). Very good suitability areas were found in Centro, Cardenas and Cunduacan where most of the road network has been improved. Moderate to marginal suitability was found to be the general condition on the rest of the State network (Fig. 42).

Text box 12. Roads sub-model

Score	Description	Distance Km
1	No suitable	
	Paved roads	> 3
	Gravel roads	>2
3	Marginal suitable	
	Paved roads	2 – 3
	Gravel roads	1 – 2
6	Fair suitable	
	Paved roads	1 – 2
	Gravel roads	500 m – 1
8	Very good suitability	
	Paved roads	500 m – 1
	Gravel roads	0 – 500 m



Mathematical expression
ROADSBM = (Paved roads x 0.60) + (Gravel roads x 0.40)

Figure 41. Road sub-model diagram

Figure 42. Roads sub-model

4.4.8 Existing aquaculture sites

Text box 14. Reclassification of suitable distances between existing oyster farms	
Score	Distance m
1	> 3,000
2	2,500- 3,000
3	2,000- 2,500
4	1,500 – 2,000
5	1,000 – 1,500
6	500 – 1,000
7	300 – 500
8	< 300

Estimations of the surface area and locations available for any kind of aquaculture amenity are important in the sense of the degree of cooperation generated by adjacent production units, and the effects of agglomeration on sharing or competing for resources and infrastructure (Kapetsky *et al.*,1990; Meaden & Kapetsky, 1991).

The layer was developed based on the existing oyster farming according to distance from another production units as shown in Text box 14. Fish farming was not included since location data were not available (Fig. 43). This factor was considered to have a positive effect because the existing aquaculture sites for oyster are managed by fishing cooperatives, potentially representing an advantage for aquaculture development in the area.

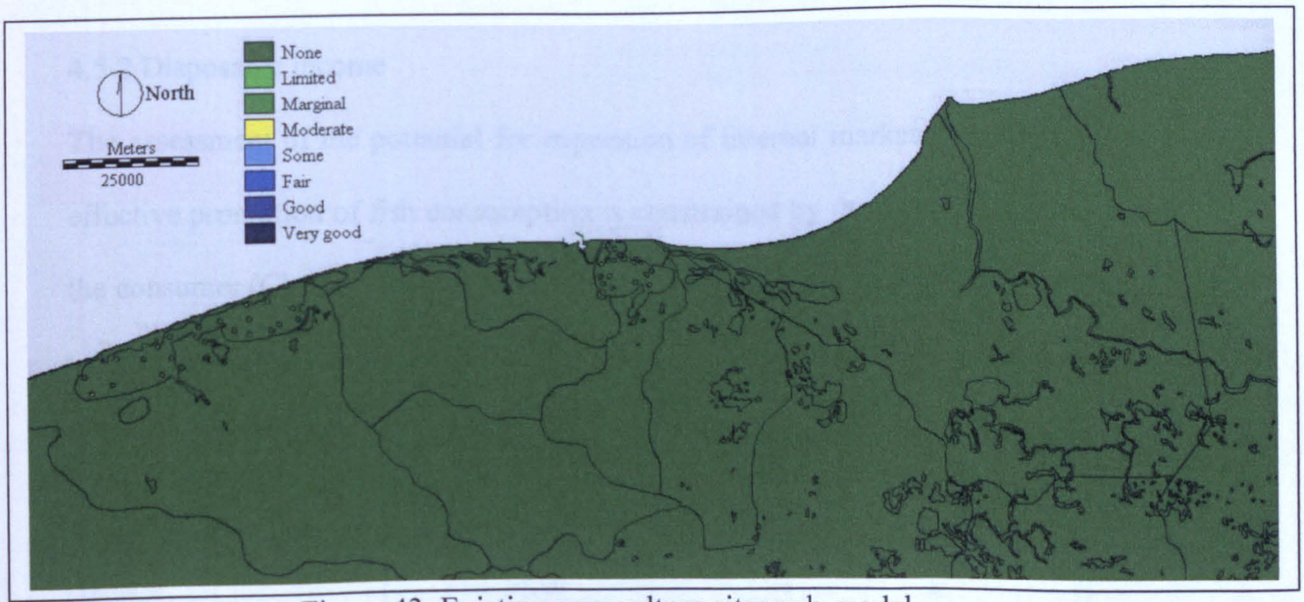


Figure 43. Existing aquaculture sites sub-model

4.5 Markets sub-model

4.5.1 Introduction

Effective site selection for aquaculture operations requires an adequate assessment of economic resources locally available as indication for market development and profitability rates, particularly in areas where a market-orientated approach may increase problems in co-ordinating capture fishery landings with production from aquaculture (Black & Truscott, 1994; Pillay, 1994). The potential for direct distribution (i.e. farm-gate sales) and levels of demand are important factors, particularly for small-enterprise or community based development, to estimate the quantities and economic activities involved at specific stages of production (Gutierrez, 1995; Muir, 1995). This model was proposed as a first approach to market availability for aquaculture products. Cost-benefit assessments on species and production systems are required and it is not assumed herein that aquaculture should be directed only for those with more purchasing power.

4.5.2 Disposable income

The assessment of the potential for expansion of internal markets is important, as effective promotion of fish consumption is constrained by the purchasing power of the consumer (Chaston, 1983). The layer was developed based on the percentage of minimum wage (mw) earned by the economically active population (Table 13).

Table 13. Minimum wage percentage earned by the economically active population

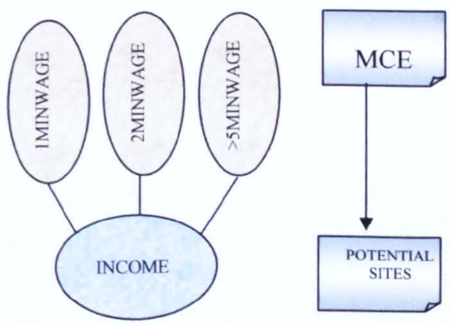
Municipality	*E. A. Population*	*Number of minimum wage/Population %*		
		1	2	>5
Huimanguillo	32,117	49	32	13
Cardenas	42,875	38	34	21
Comalcalco	32,558	45	28	20
Cunduacan	21,103	48	33	14
Centro	121,226	21	37	31
Nacajuca	12,327	31	42	22
Jalpa	12,839	43	32	20
Paraiso	14,373	32	33	28
Centla	16,089	43	33	18
Macuspana	23,663	42	29	23
Jonuta	5,931	60	26	09

INEGI (2000)

A layer was built for each of the income level groups according to their earnings (1, 2 and >5 minimum wage). The data from INEGI were reclassified based on the purchase power criteria according to the minimum wage distribution amongst the population as shown in Text box 15. The layers were then integrated by using the MCE module. The higher score was assigned to the population segment with the highest income (Figure 44). Based on the score for suitability (Text box 2), areas of marginal suitability were found in 90% of the coastal zone as shown in Figure 45. This suitability is directly related to the high weight assigned to the percentage of the population with more than 5 minimum wage income, as it was distributed between 09-31%.

Text box 15. Income level threshold

Score	%
1	0 – 12
2	12 – 25
3	25 – 37
4	37 – 50
5	50 – 62
6	62 – 75
7	75 – 87
8	87 – 100



Mathematical expression

INCOME = (1minwage x 0.19) + (2minwage x 0.29) + (5minwage x 0.52)

Figure 43. Disposable income sub-model

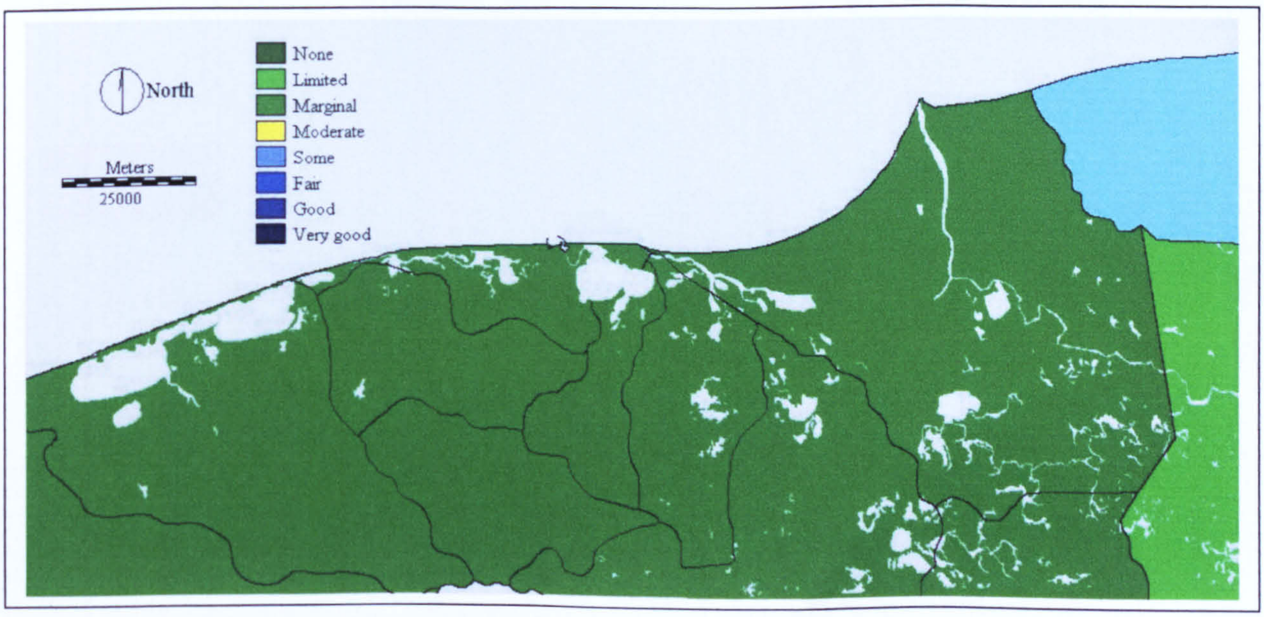


Figure 45. Multi-criteria image for market suitability based on the disposable income available in the coastal zone of Tabasco

4.5.3 Farm-gate sales

Positioning any business in relation to its market and the perceived relationship to competitors is an important issue related to growth success when competitive advantages, services and costumers are identified (Bridge *et al.*, 1998). The sub-model is an integration of the population density and population growth rate layers. Both layers were developed independently based on the population statistics from INEGI. Thresholds for each of the layers are shown in Text box 16. The reclassified images are shown in Figure 46 and 47.

Text box 16. Population density and growth threshold

Score	People/km^2	Growth rate
1	<50	< 1.5
2	50 – 95	1.5 – 2
3	95 –140	2 – 2.5
4	140 – 195	2.5 –3
5	195 – 230	3 – 3.5
6	230 – 285	3.5 – 4
7	285 - 330	4 – 4.5
8	> 330	> 4.5

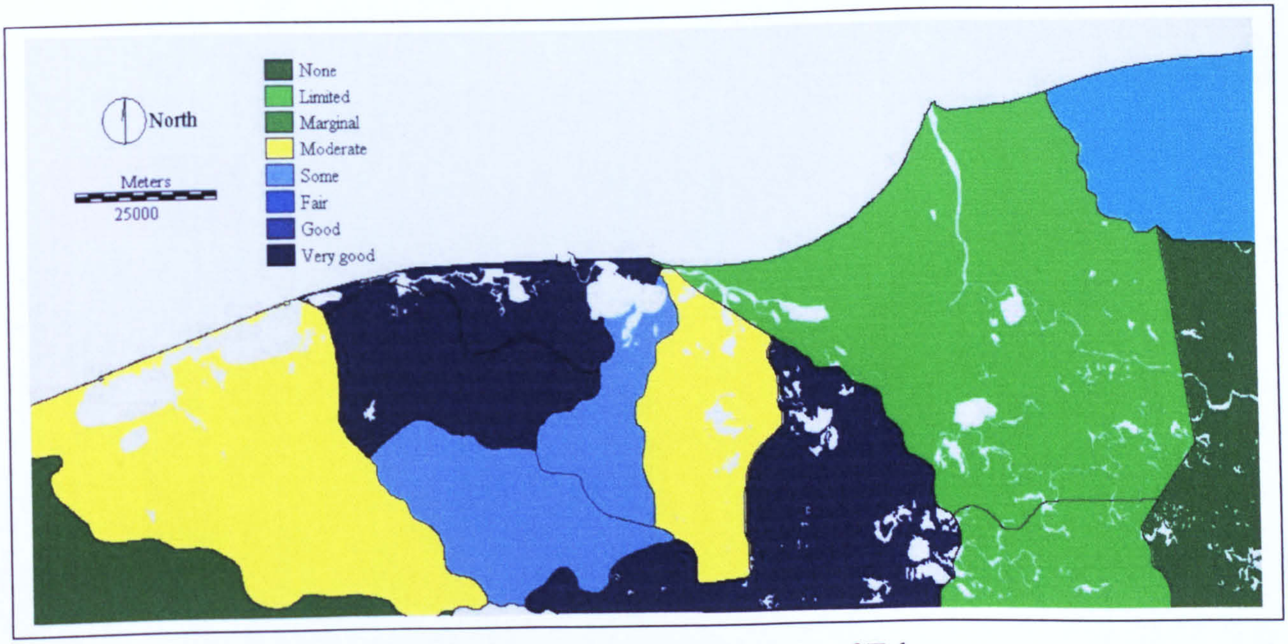


Figure 46. Population density in the coastal zone of Tabasco

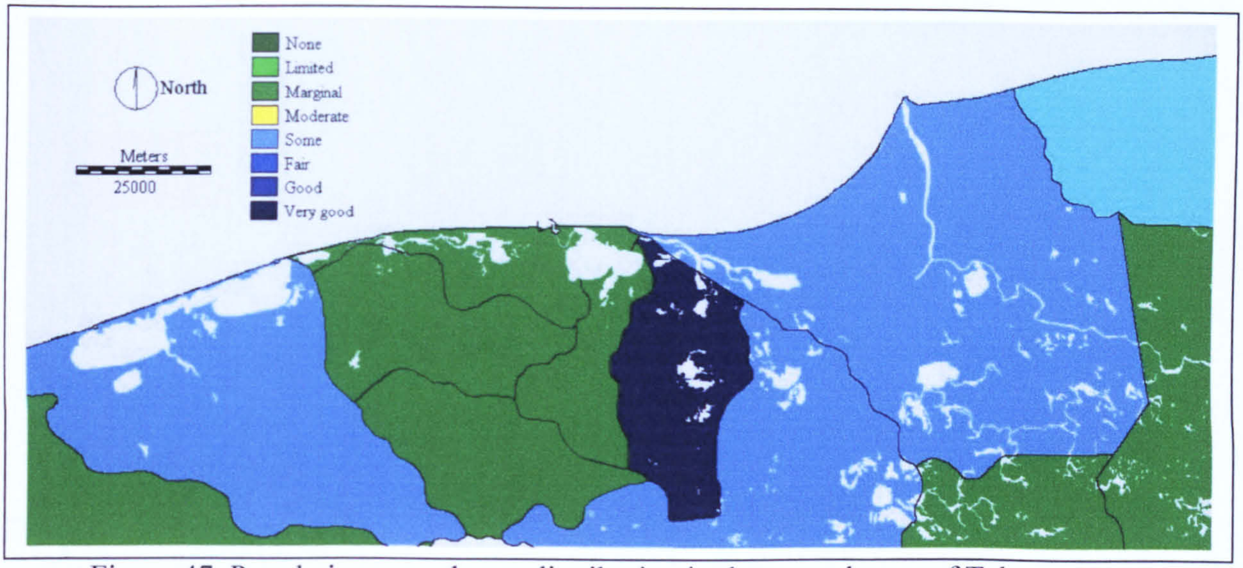
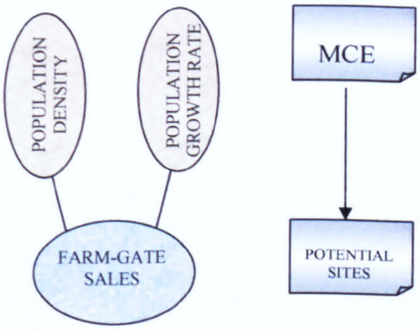


Figure 47. Population growth rate distribution in the coastal zone of Tabasco

The layers were integrated using the MCE module, giving the highest weight to population density (Figure 48). Figure 49 shows areas with good suitability in Centro and fair suitability areas were found in Nacajuca, Comalcalco and Paraiso municipalities. The municipalities of Cardenas, Cunduacan and Jalpa de Mendez were found to have a moderate suitability.



Mathematical expression
FARMGATE = (popden x 0.60) + (popgrow x 0.40)

Figure 48. Potential for farm-gate sales sub-model diagram

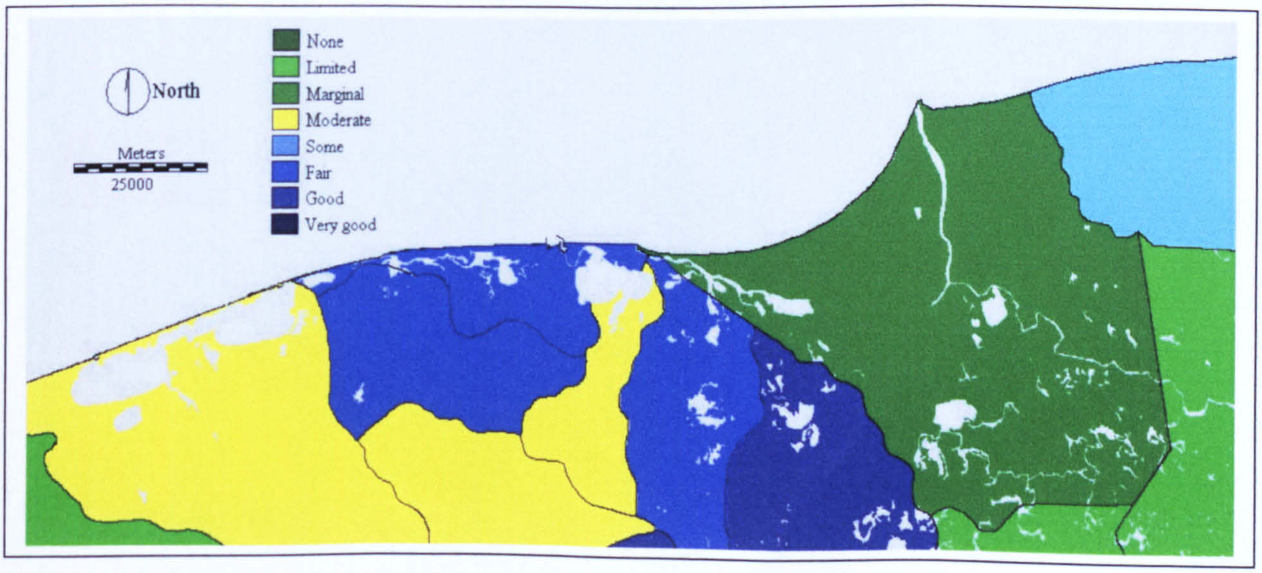


Figure 49. Potential for farm-gate sales in the coastal area of Tabasco

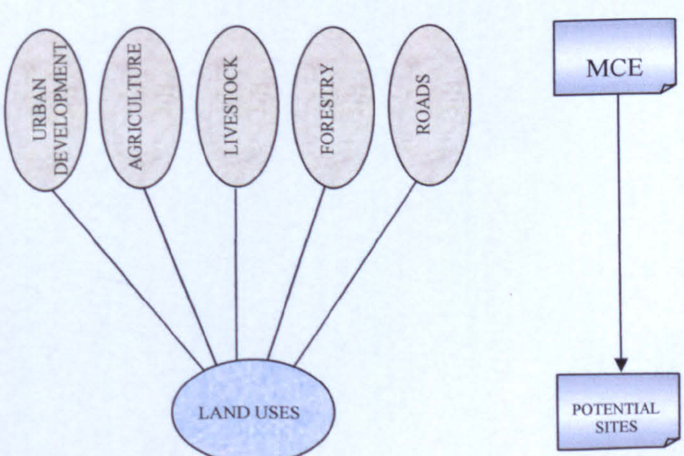
4.6 Models for coastal aquaculture development: Environmental factors

4.6.1 Introduction

As with any other human activity aquaculture produce changes in the environment. Concerns regarding environmental impacts of aquaculture have increased in parallel with the expansion and diversification of the sector. Significant limitations on the availability of land and water resources may also be diminishing aquaculture potential, particularly in developing countries where areas of high growth population are found (Welcomme, 1996; Bardach, 1997b). The sub-model was developed by integrating the layer for land and water resources suitability and oil industry land use.

4.6.2 Land uses

The land uses sub-model was built by integrating the layers developed previously for the land use evaluation of agriculture, livestock, forestry, urban areas and roads. (Figure 50) as an evaluation of suitability of areas where there may be potential pollution sources (Fig. 51). Weights were calculated by developing a pairwise matrix through the MCE module with the highest score being given to urban development.



Mathematical expression
LANDUSES = (urbadevel x 0.33) + (agriculanduse x 0.32) + (livestocklanuse x 0.18) + (forestuse x 0.08) + (roadsubm x 0.09)

Figure 50. Land uses sub-model

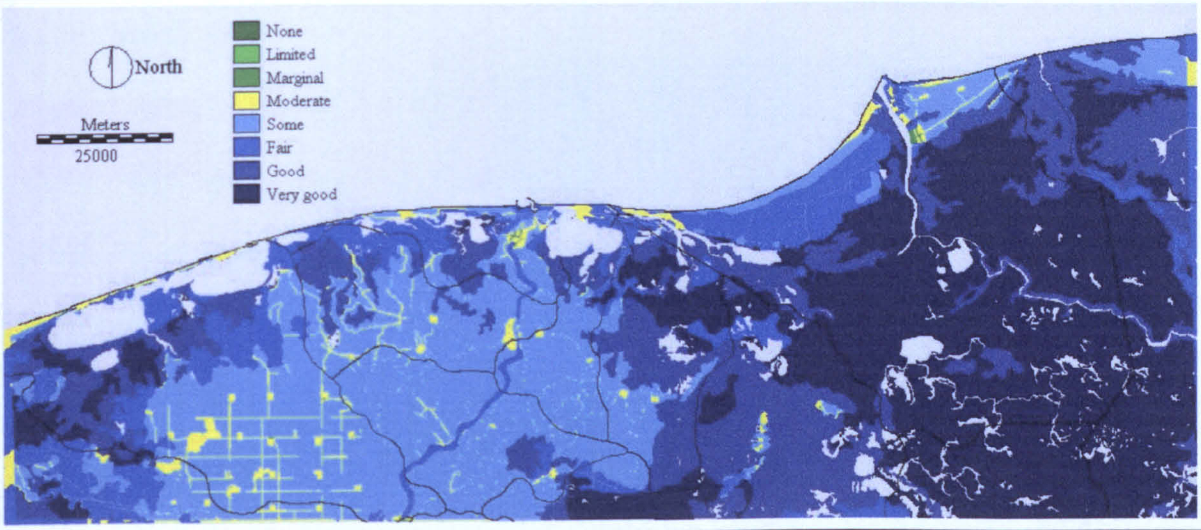


Figure 51. Multi-criteria image for land uses assessment in the coastal zone of Tabasco

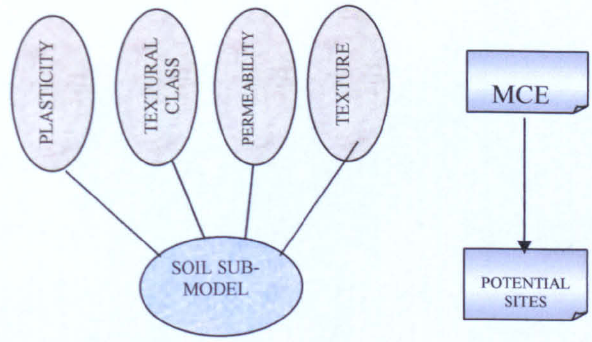
4.6.3 Soils

Soil quality has to be considered comprehensively in order to meet the requirements for site selection and building of earthen ponds. The integration of a layer regarding the physical characteristics of soils in the environmental model was considered due the effect of soil quality in site selection (Aguilar, 1996). Soil that is sufficiently impermeable will minimise seepage and maintain water fertility. Texture is an important feature of soil as the best areas for aquaculture are those with a soil with more than 50% of fine particles (Coche & Laughlin, 1985). The soil sub-model was developed for small-scale aquaculture based on the texture (textural class), structure (texture), plasticity and permeability properties of soils (Text box 17).

Text box 16. Soil types main characteristics of the coastal zone of Tabasco (INEGI, 1984; Coche, 1985).

Soil type	Texture	Score	Structure	Score	Permeability	Score	Plasticity	Score
Cambisol	Loam/clay	4	Medium/ coarse	1	Poor drainage	8	Slightly plastic	4
Regosol	Clay/silt	4	Medium/ coarse	1	Good drainage	1	Slightly plastic	4
Solonchak	Loam/ loamy sand	4	Fine/ medium	4	Impermeable	8	Non/Slightly plastic	1
Fluvisol	Silt/clay/ loam	4	Fine/ medium	4	Poor drainage	8	Plastic/ slightly plastic	4
Acrisol	Clay/sand	1	Fine/ medium	4	Poor/ moderate drainage	4	Slightly plastic	1
Vertisol	Sand/silt	1	Medium/ coarse	1	Poor drainage	8	Slightly plastic	4
Gleysol	Loam/silt/ sand	4	Fine/ medium	4	Poor drainage	8	Plastic	8

Each layer was develop using the INEGI soil map (1984) and integrated into a MCE model (Figure 52). A high weight was given to texture and low permeability (Aguilar, 1996; Salam, 2000). The resulting layer is shown in Figure 53. It shows that more than 85% of the total area has fairly suitable soils.



Mathematical expression
SOILS = (soiltextclass x 0.33) + (soilpermeab x 0.33) + (soiltex x 0.22) + (soilplasti x 0.13)

Figure 52. Soil sub-model

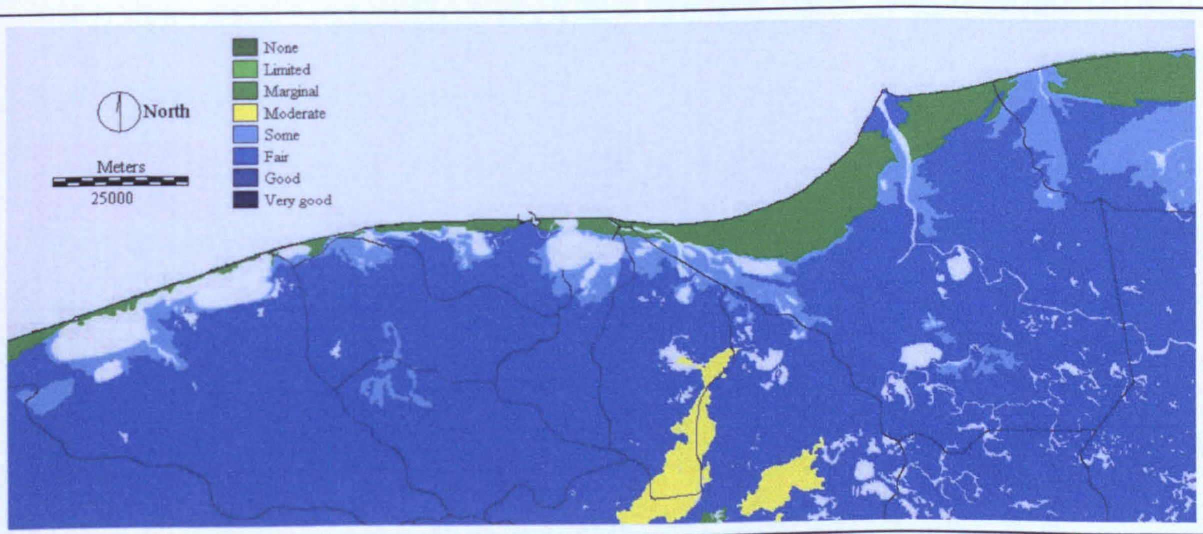


Figure 53. Multi-criteria layer for soils suitability in the coastal zone of Tabasco

4.6.4 Oil facilities

The oil industry is one of the region's major sources of environmental impact. The main oil facilities (i. e. extraction and petrochemical processing) are located in the coastal zone. For the environmental model, locations close to oil facilities were considered to be off-limit due to the high pollution risk. The thematic map used is shown in Figure 28.

4.6.5 Water resources

The quantity and access to water resources represents one of the most important factors promoting or constraining aquaculture development, particularly for pond culture. Factors influencing water supply are precipitation, evaporation, soil permeability (seepage) and distance to water sources (Yoo & Boyd, 1994; Kapetsky & Nath, 1997; Aguilar &Nath, 1998).

Water balance

According to Aguilar (1996) water requirement is well estimated by assessing the balance resulting from the relationship between the availability of rainfall and the rate of evaporation. As no data were available for seepage the calculation was based on the assumption of Aguilar and Nath (1998):

Water balance = (precipitation [mm] x 1.1) – (evaporation [mm] x 1.3) – Seepage (80mm/month) **(Equation 2)**

The mean annual precipitation map created by the National Water Commission was acquired from the CNA (1998) web site and digitised with Cartalinx (Fig. 54). The mean annual evaporation layer was developed through the interpolation of raw tabulated data obtained from State CNA meteorological stations (Fig. 55).

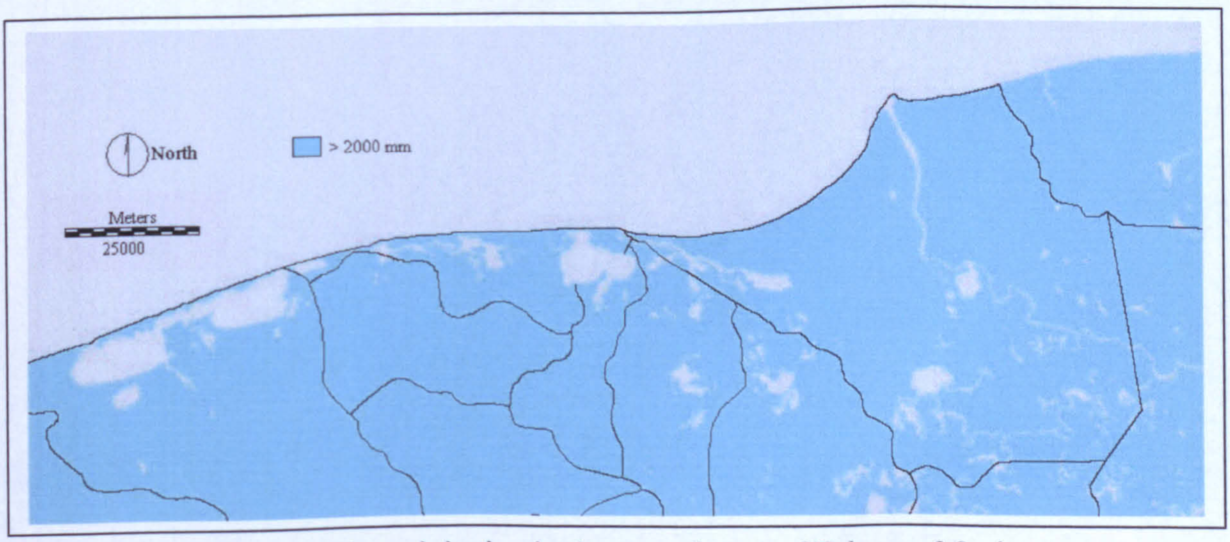


Figure 54. Mean annual precipitation in the coastal zone of Tabasco, Mexico

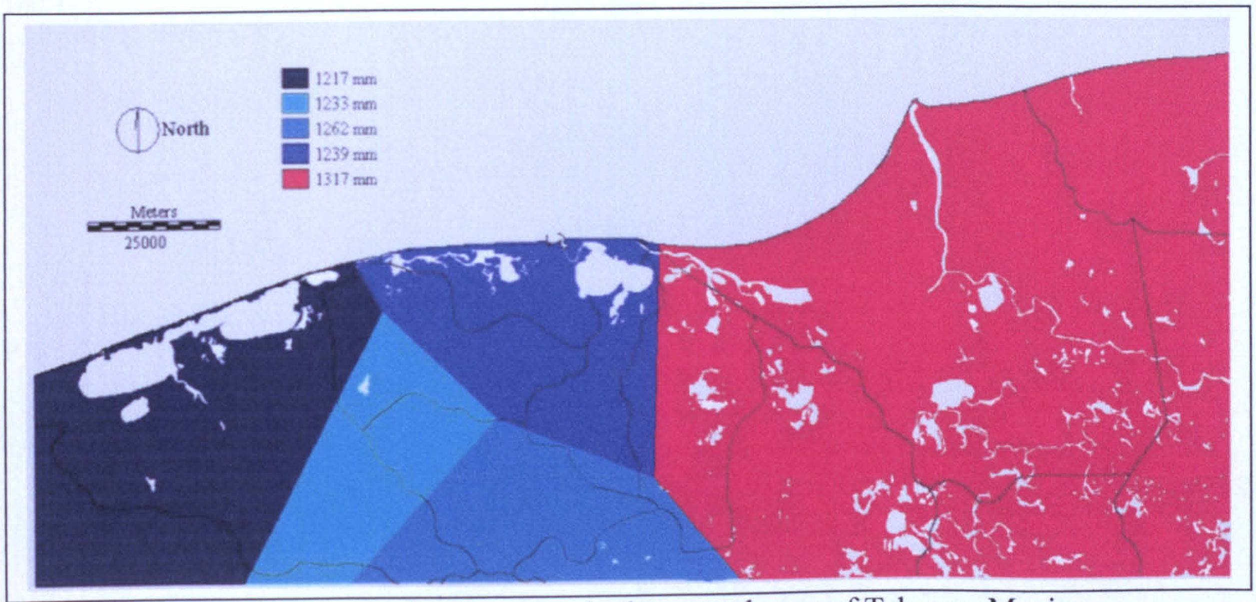


Figure 55. Mean annual evaporation in the coastal zone of Tabasco, Mexico

The water balance scores are shown in Text box 18. The trends show a homogeneous water balance through out the State with a mean annual water balance of 1947 mm (Fig. 56). Thus, water availability may be expected to be good throughout the year.

Text box 18. Water balance threshold

Score	mm
1	<300
4	300 – 1,500
6	1,500 – 1,900
8	> 1,900

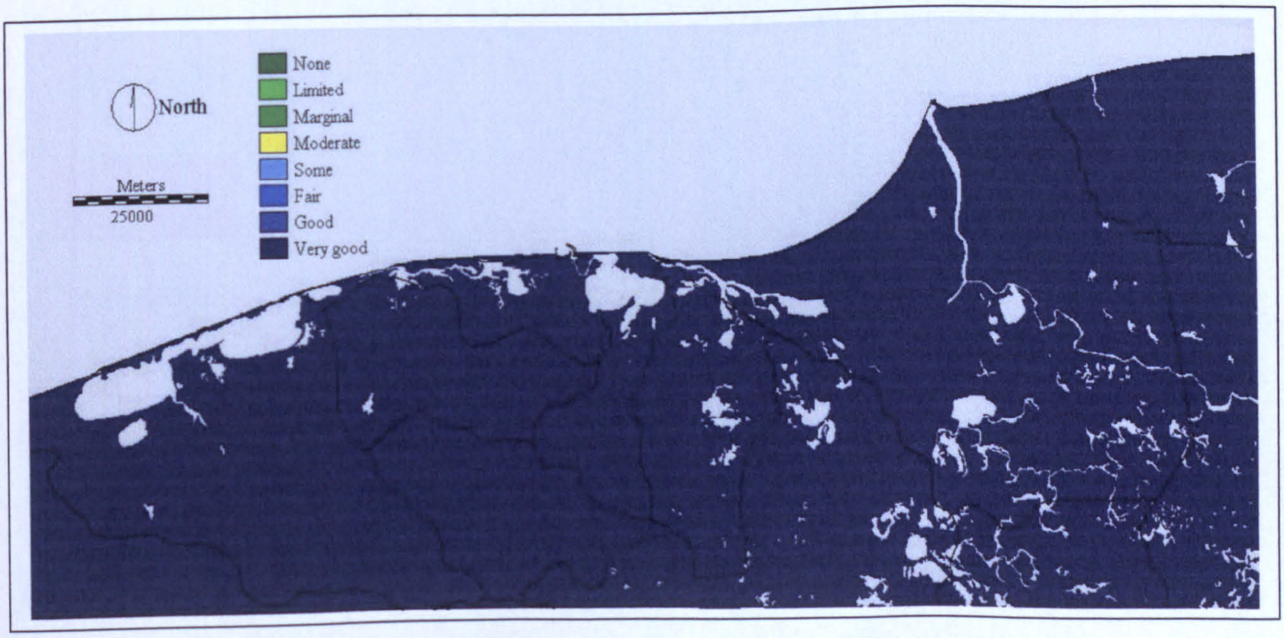


Figure 56. Water balance of the coastal zone of Tabasco

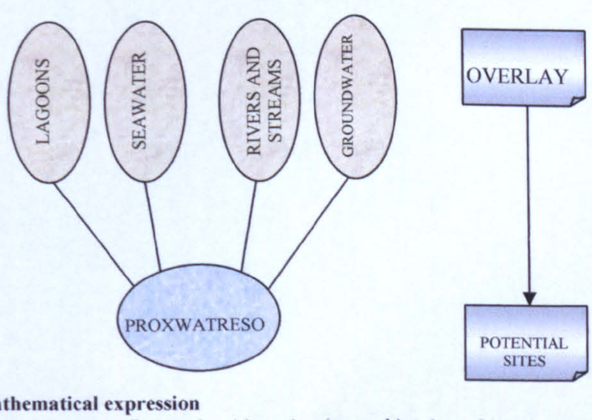
Water resources

Water resources has been identified as a disturbed capital due to increased population and economic activities which pollute water supplies and generate conflicts among different users from local to country level (Jones & Hollier, 1997). In order to incorporate sustainable aquaculture practices in coastal zones adequate access to water resources must be available. A certain number of components have to be identified as potential sources of water where conflicts may be minimised. These components are often water bodies (lakes and estuaries), catchment basements (rivers and streams), groundwater and seawater. The layers for these components were developed based on suitable distances from all the water sources (Text box 19).

Text box 19. Water resources distance suitability

Score	km
1	> 4
2	3.5 – 4
3	3 – 3.5
4	2.5 – 3
5	2 – 2.5
6	1.5 – 2
7	1 – 1.5
8	250 m – 1

The components were integrated into a sub-model to identify potential areas for aquaculture development using distance layers for lagoons, seawater, rivers and groundwater (Figure 57). The layers were overlaid considering that there are no important differences regarding their influence, as seasonal variations are proportionally similar on water availability due to the occurrence and duration of dry and rainy seasons (Rodriguez & Benitez, 1994; Velazquez, 1994). The resulting image is shown in Figure 58.



Mathematical expression
PROXWATRESO = (lagoonr) + (riversr) + (groundr) + (coastlr)

Figure 57. Water resources sub-model diagram

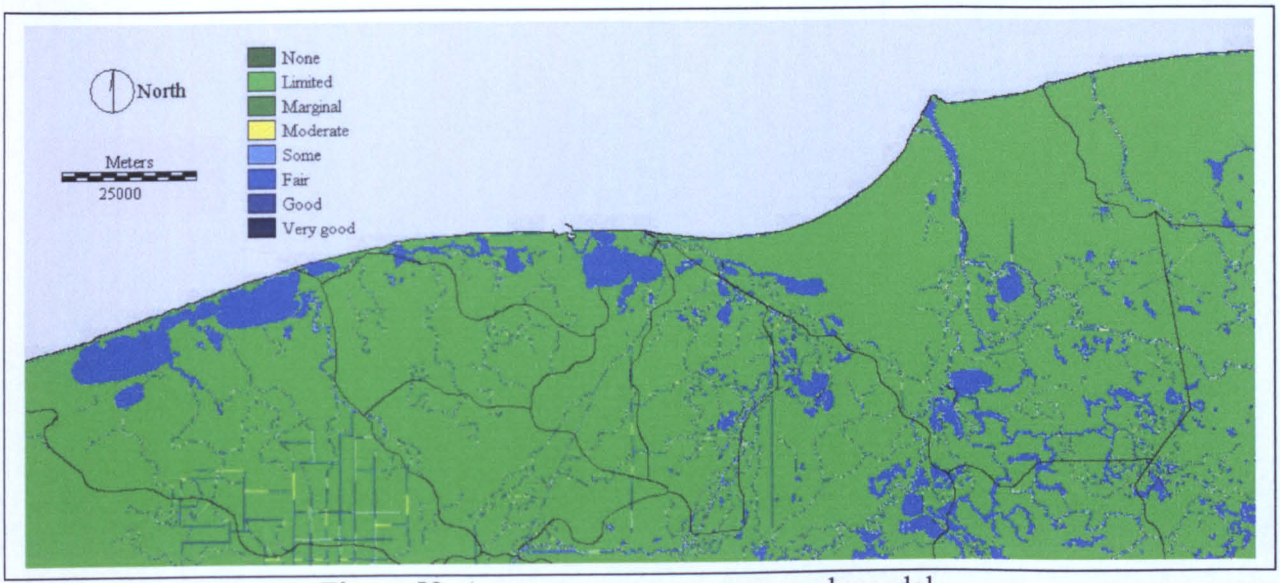


Figure 58. Access to water resources sub-model

The availability of water for aquaculture use will depend upon the total amount of annual precipitation that falls within a catchment's area and the distance from water resources. The figure 59 shows the combination of the water balance and water resources layer for the coastal zone of Tabasco. Areas of very good suitability to develop both water and land based systems were found close to water bodies and rivers. A moderate suitability condition was found in Cardenas and Centla. For more than 90% of the remaining area a marginal suitability was identified, which may represent a constraint in terms of access to water resources for developing land-based systems (Figure 60).

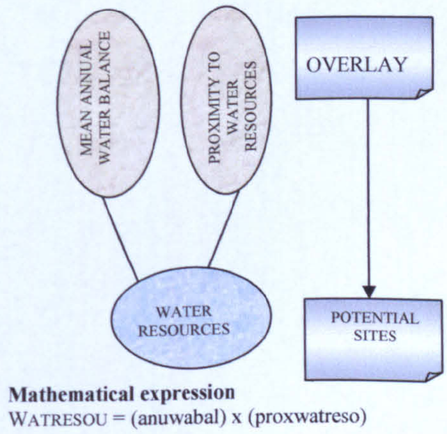


Figure 59. Water resources sub-model diagram

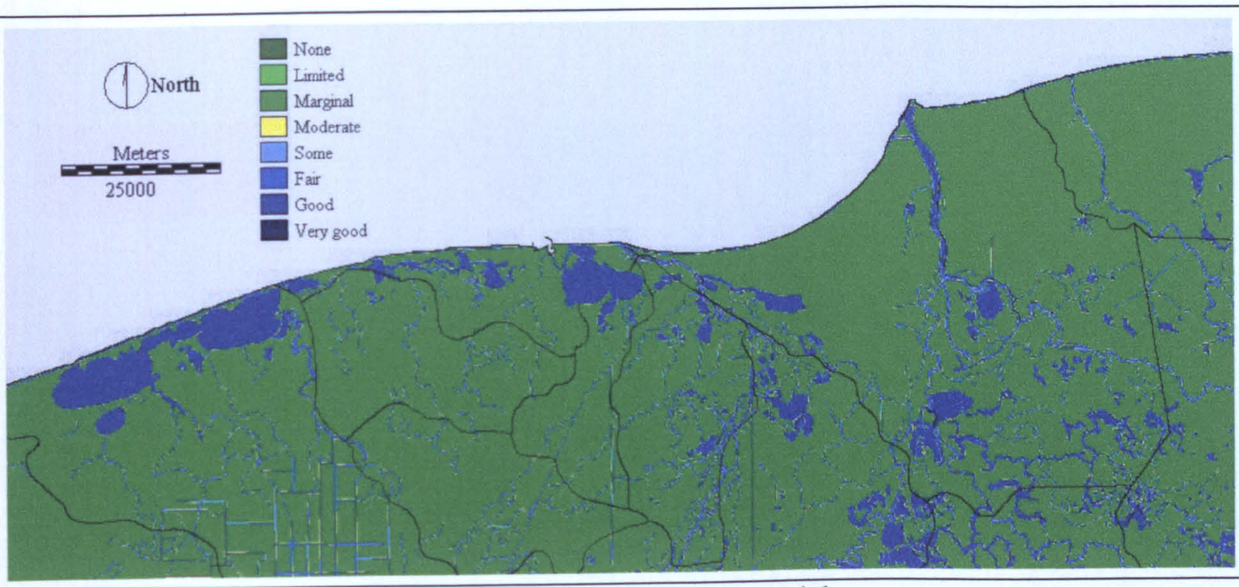


Figure 60. Water resources sub-model

4.7 Constraints

Areas with low or no suitability to develop farming activities were considered as constraints (areas with a score of zero) and reclassified according to proximity criteria (Text box 20). Thresholds were established in order to minimise the potential pollution problems from oil facilities, urban areas, roads and agriculture and to define proper distances to water resources and sensitive areas with respect to operating costs and environmental impacts. The layer was developed by overlaying all the constraints into one image (Fig. 61).

Text box 20. Constraint distances threshold.

Score	Constraints	Proximity
	Water resources	
0	Rivers	0 – 250 m
0	Lagoons	0 – 250 m
	Land uses	
0	Cities	0 – 2 km
0	Towns	0 –1 km
0	Villages	0 – 500 m
0	Roads	0 – 500 m
	Oil facilities	
0	Pipes	0 – 50 m
0	Wells	0 –2 km
0	Buildings	0 – 4 km

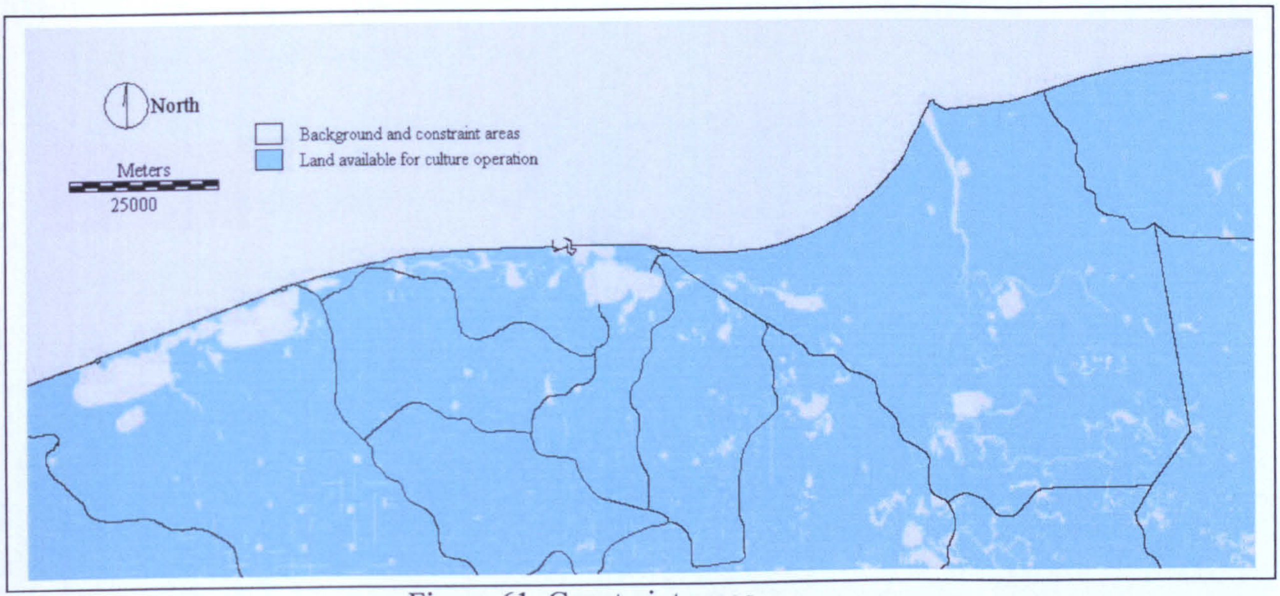


Figure 61. Constraint areas

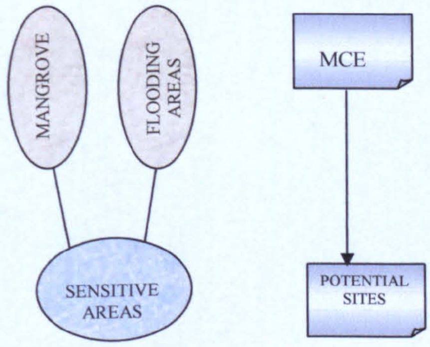
4.8 Sensitive areas

The watershed of the Usumacinta River is considered the largest remaining tropical forest north of the Amazon, often referred to as the Selva Maya (Hamann & Ankersen, 1996). Two internationally recognised RAMSAR wetlands lie within the Usumacinta watershed, Laguna del Tigre National Park in Guatemala and Pantanos de Centla (Tabasco) Biosphere Reserve in Mexico (RAMSAR, 1997).

Forest exploitation does not necessarily result in deforestation, but in the basin of the Grijalva-Usumacinta large areas have been stripped of timber and then settled by migrants who plant subsistence crops (i.e. maize). The productivity of the soil has been depleted over the years and these areas have been converted to grasslands for cattle grazing, while additional areas of forest are being cleared for maize. This process, plus the arrival of new settlers, has lead to rapid deforestation significantly affecting biological diversity, water resources and causing erosion by increased runoff (Hamann & Ankersen, 1996).

The Grijalva River has been dammed for hydroelectric power production. By contrast, the Usumacinta has never been dammed, although a potential to generate between 13.2 megawatts of electricity has been estimated and five feasible dam sites have been identified on the main stem of the river. The potential impact of dam projects is the flooding over 1,315 km^2 of land along 525 km of the Usumacinta River (Velazquez, 1994; Hamann & Ankersen, 1996).

As a result, these impacts of the substitution of land uses in a broad ecological sense produce changes in water balance and combined with high evaporation rates may reduce access to water resources. Based on the above a MCE (Figure 62) sub-model was built using the mangrove and swamps (flooding areas) maps developed by INEGI. Both layers were first reclassified according to distance (Text box 21) and then combined using the MCE technique. A buffer zone of 500 metres was set from the boundaries of the areas in order to minimise potential pollution or ecological changes.



Mathematical expression
SENSITAREAS = (mangrove x 0.60) + (flooda x 0.40)

Figure 62. Sensitive areas sub-model diagram

The criterion used to develop this sub-model was based on the non-exclusion of rural communities from areas where opportunities for human production activities are neither entirely restricted by seasonal events (i.e. drought and floods) nor

Text box 21. Distance suitability from sensitive areas

Score	km
1	500 m – 1
2	1 – 1.5
3	1.5 – 2
4	2 – 2.5
5	2.5 – 3
6	3 – 3.5
7	3.5 – 4
8	> 4

necessarily scarce (Dixon & Sherman, 1990). The GIS derived image in Figure 63 shows areas of good suitability where communities' livelihoods may not be compromised while conserving environmental quality of sensitive areas.

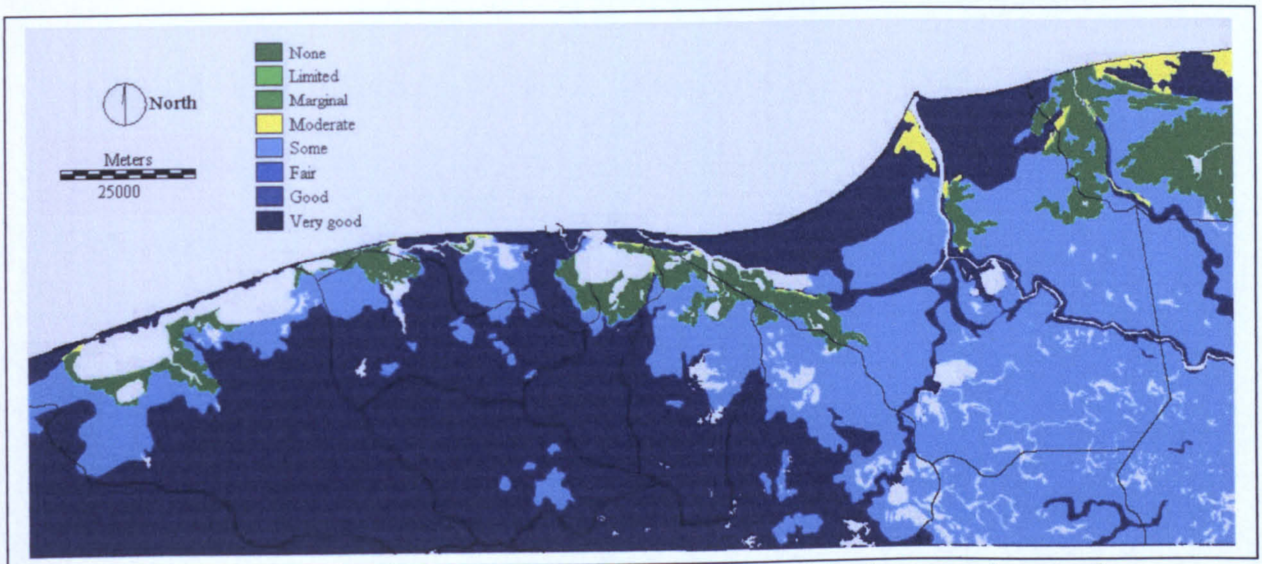


Figure 63. Sensitive areas (mangrove and flooding areas) in the coastal zone of Tabasco, Mexico

4.9 GIS assessment for coastal aquaculture in Tabasco, Mexico

4.9.1 Introduction

Coastlines represent some of the most rapidly growing and densely populated areas where competition for access to resources occurs under complex relations of interdependency among direct or indirect users. Regulation of access is a requirement when pressure over resources increases (Bailly & Paquotte 1996). Trade-offs among users may be established from different perspectives such as economic efficiency, preservation or equity. Resource requirements for aquaculture are directly dependent on the level of production and operational features, which affects neighbouring areas and local economy. Success or failure of any aquaculture venture can imply serious decision-making processes, as outcomes can have important effects on many people's livelihoods and opportunities (Nash, 1995; Shang & Tisdell, 1997).

Given the spatial component of coastal aquaculture, its interdependency with other users, and the trade-offs that may be established, alternative resource uses and minimisation of conflicts may be identified and quantified by delimiting space requirements over limited resources. In this manner, feasible resource allocation may be integrated through the iterative process performed by the multi-objective land allocation (MOLA) Idrisi32 module (Ren, 1997; Nath *et al.*, 2000). The data generated by MCE in the previous section were integrated to produce the MOLA models based on weighting verification, using the same criteria to develop secondary data. A questionnaire was completed by governmental officers, non-governmental organisations and fishermen for verification of factor weight.

The main objective of verifying weights through the questionnaire was to reduce the subjectivity of factor ranking made by the author and to integrate the criterion value of the factors considered to be the most important for decision-makers and interest groups. Spatial decision-making clearly involves a social consensus (Bojorquez-Tapia, 1993; Eastman *et al.*, 1993; Malczewski, 1996). Fishermen possess empirical knowledge of aquaculture. This knowledge has been gained and extended through development projects for oyster and tilapia farming. Government officers and non-governmental organisation extensionist have diverse experience on aquaculture development, ranging from technical expertise, project management to policy making.

In order to satisfy criterion fairness, the weighting verification process was carried out by developing a pairwise comparison matrix using the MCE module in Idrisi32. The pairwise matrix contains the ratings in terms of relative importance in achieving the stated objective. Ratings are scored on a 17-point continuous scale from 1/9 (least important) to 9 (most important). For example, if it is considered that soils are more important than population density in determining the suitability for pond culture, one would assign a score of 5 to soils and a score of 1 to population density. The matrix is symmetrical and weights are calculated with each column and then averaged over all columns. Weights were calculated directly using the WEIGHT module. 10 factors were selected for both the socio-economic and environment sub-models (Table 14). Aguilar (1996) suggests that even though logical results may be obtained from larger matrixes, difficulty and loss of accuracy increases and wrong weights may be chosen even if the consistency (CR) is within the ratio recommended by Saaty (1977) of equal to or less than 0.10.

Table 14. Assessment of 10 factors for aquaculture development in Tabasco coastal zone: Rating scale of Eastman (1999).

Socio-economics	*Human Resources*	*Job creation*	*Economic activities*	*Land ownership*	*Inputs*	*Urban areas*	*Existing farms*	*Population density*	*Income*	*Energy*	*Weights*
Human Resources	1										0.2675
Job creation	1	1									0.1815
Economic activities	1/4	1/2	1								0.1517
Land ownership	1/5	1/2	1/2	1							0.1194
Inputs	1/5	1/4	1/4	1/2	1						0.0988
Urban areas	1/3	1/2	1/4	1/4	1/3	1					0.0545
Existing farms	1/6	1/5	1/5	1/6	1/6	1/2	1				0.0388
Farm-gate sales	1/4	1/2	1/2	1/2	1/4	1/2	1/2	1			0.0442
Income	1/6	1/5	1/5	1/7	1/6	1/3	1/4	1/2	1		0.0231
Energy	1/7	1/7	1/7	1/5	1/5	1/2	1/2	1/2	1/2	1	0.0205
SUM											1.000

CR = 0.09

Environment	*Water*	*Soils*	*Roads*	*Oil industry*	*Agriculture*	*Livestock*	*Forestry*	*Existing farms*	*Urban areas*	*Population*	*Weights*
Water resources	1										0.2776
Soils	1/2	1									0.2159
Roads	1/5	1/5	1								0.1220
Oil industry	1/6	1/5	1/2	1							0.0865
Agriculture	1/5	1/3	1/2	1/2	1						0.0776
Livestock	1/3	1/2	1/2	1/2	1	1					0.0944
Forestry	1/6	1/6	1/4	1/3	1/5	1/3	1				0.0314
Existing farms	1/4	1/4	1/5	1/2	1/3	1/6	2	1			0.0400
Urban areas	1/4	1/4	1/5	1/3	1/4	1/3	1/2	1/2	1		0.0326
Population Density	1/5	1/5	1/6	1/5	1/4	1/3	1/2	1/2	1/3	1	0.0230
SUM											1.000

CR = 0.09

1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Extremely		Very strongly		Strongly		Moderately		Equally			Moderately		Strongly		Very strongly	Extremely
		LESS IMPORTANT										MORE IMPORTANT				

4.9.2 Single objective modelling

The factors were scored in a rank order from 1 to 10 to make questionnaires comprehensible and to assign each factor a proper weight for developing the socio-economic and environmental pairwise matrixes (Appendix E). The participants were asked to score each factor without repetition. The resulting matrixes are shown along with the calculated weights in Tables 15 and 16.

The resulting matrixes show a general agreement among government and NGO officers when scoring factors, as high scores were assigned to the most important factors. Scoring by fishermen for the socio-economics matrix was not uniform as scores were indistinctly allocated for each factor or high scores were allocated to factors considered not important by the other two groups.

Scores were analysed for level of agreement between the rankings made by the author and those made by the groups using the Kendall coefficient of concordance W (Equation 3), which is a proper test for analysing multiple ranks when there are several set of data. Rj stands for the sum of ranks; m is the number of ranking sets and n the number of individuals. W ranges from 0.0 indicating no correlation to 1.0 indicating high correlation (Kendall, 1970; Zar, 1996). The value of Friedman's χ^2_r (Equation 4) was also calculated to test the association significance of rankings:

$$W = \frac{\Sigma Rj^2 - (\Sigma Ri)^2/n}{m^2 (n^3-n)/12} \qquad \text{(Equation 3)}$$

$$\chi^2_r = m\,(n-1)\,W \qquad \text{(Equation 4)}$$

Table 15. Scoring and weighting of 10 socio-economic factors according to groups A, B, C, D, E = Respondents per group

Fishermen	*SCORES*							*WEIGHTS*				
	A	B	C	D	Mean	Rj	Rj^2	A	B	C	D	Mean
Human resources	8	10	7	7	8.00	42	1764	0.157	0.315	0.089	0.106	0.167
Employment opportunities	9	6	9	9	8.25	42	1764	0.231	0.082	0.211	0.210	0.184
Activity conflicts	5	3	3	4	3.75	23	529	0.064	0.046	0.049	0.045	0.051
Land ownership	3	2	1	2	2.00	15	225	0.033	0.038	0.022	0.035	0.032
Inputs	6	7	6	3	5.50	28	784	0.069	0.086	0.079	0.034	0.067
Urban areas	4	5	5	5	4.75	24	576	0.059	0.057	0.066	0.058	0.060
Farm-gate sales	10	8	10	8	9.00	40	1600	0.238	0.132	0.247	0.165	0.196
Existing farms	2	4	4	6	4.00	19	361	0.030	0.048	0.064	0.069	0.053
Income	7	9	8	10	8.50	36	1296	0.097	0.132	0.135	0.261	0.156
Energy	1	1	2	1	1.25	6	36	0.023	0.021	0.039	0.021	0.026
CR								0.09	0.09	0.09	0.09	0.090

n= 4

NGO officers	*SCORES*								*WEIGHTS*					
	A	B	C	D	E	Mean	Rj	Rj^2	A	B	C	D	E	Mean
Human resources	9	10	8	10	7	8.80	54	2916	0.225	0.264	0.138	0.278	0.108	0.203
Employment opportunities	10	9	10	9	10	9.60	57	3249	0.265	0.190	0.260	0.213	0.237	0.233
Activity conflicts	6	7	6	7	8	6.80	42	1764	0.082	0.110	0.084	0.089	0.147	0.102
Land ownership	2	1	1	2	2	1.60	15	225	0.037	0.021	0.023	0.038	0.040	0.032
Inputs	4	6	4	5	6	5.00	31	961	0.047	0.084	0.084	0.049	0.086	0.070
Urban areas	3	4	5	3	3	3.60	23	529	0.037	0.052	0.062	0.040	0.048	0.048
Farm-gate sales	8	8	9	8	9	8.40	46	2116	0.134	0.147	0.212	0.148	0.196	0.167
Existing farms	7	5	7	6	4	5.80	32	1024	0.099	0.064	0.090	0.077	0.054	0.077
Income	5	3	2	4	5	3.80	21	441	0.037	0.043	0.025	0.046	0.062	0.043
Energy	1	2	3	1	1	1.60	9	81	0.020	0.027	0.046	0.023	0.023	0.028
CR									0.08	0.07	0.10	0.06	0.09	0.000

n= 5

Government officers	*SCORES*							*WEIGHTS*				
	A	B	C	D	Mean	Rj	Rj^2	A	B	C	D	Mean
Human resources	10	10	10	9	9.75	49	2401	0.251	0.302	0.300	0.214	0.267
Employment opportunities	9	8	8	10	8.75	44	1936	0.218	0.126	0.135	0.272	0.188
Activity conflicts	7	6	5	2	5.00	28	784	0.113	0.098	0.062	0.032	0.076
Land ownership	2	3	3	6	3.50	21	441	0.032	0.045	0.035	0.082	0.049
Inputs	8	9	7	8	8.00	38	1444	0.136	0.163	0.093	0.125	0.129
Urban areas	5	5	6	5	5.25	26	676	0.056	0.060	0.084	0.064	0.066
Farm-gate sales	6	7	9	7	7.25	33	1089	0.093	0.104	0.179	0.105	0.120
Existing farms	3	4	2	3	3.00	15	225	0.040	0.056	0.031	0.034	0.040
Income	4	2	4	4	3.50	16	256	0.040	0.024	0.060	0.052	0.044
Energy	1	1	1	1	1.00	5	25	0.021	0.022	0.022	0.021	0.022
CR								0.07	0.08	0.08	0.08	0.078

n= 4

Table 16. Scoring and weighting of 10 environmental factors according to groups A, B, C, D, E = Respondents per group

Fishermen	*SCORES*							*WEIGHTS*				
	A	B	C	D	Mean	Rj	Rj^2	A	B	C	D	Mean
Water resources	10	9	10	10	9.75	49	2401	0.296	0.185	0.320	0.303	0.276
Soils	3	1	2	3	2.25	18	324	0.037	0.023	0.034	0.043	0.034
Roads	1	2	1	1	1.25	13	169	0.034	0.031	0.036	0.031	0.033
Oil industry	7	7	4	5	5.75	29	841	0.103	0.102	0.051	0.056	0.078
Agriculture	4	5	5	8	5.50	27	729	0.037	0.065	0.058	0.122	0.071
Livestock	8	8	8	4	7.00	35	1225	0.139	0.115	0.124	0.046	0.106
Forestry	6	4	6	7	5.75	25	625	0.065	0.040	0.065	0.081	0.063
Existing farms	2	3	3	2	2.50	14	196	0.036	0.035	0.047	0.043	0.040
Urban areas	5	6	7	6	6.00	27	729	0.054	0.075	0.051	0.064	0.061
Population density	9	10	9	9	9.25	38	1444	0.198	0.327	0.195	0.218	0.235
Consistency ratio								0.09	0.08	0.10	0.09	0.090

n= 5

NGO officers	*SCORES*								*WEIGHTS*					
	A	B	C	D	E	Mean	Rj	Rj^2	A	B	C	D	E	Mean
Water resources	10	10	9	10	8	9.40	57	3249	0.298	0.325	0.191	0.320	0.124	0.252
Soils	3	3	2	3	3	2.80	23	529	0.038	0.036	0.039	0.034	0.033	0.036
Roads	2	2	4	1	2	2.20	19	361	0.031	0.034	0.042	0.023	0.029	0.032
Oil industry	7	9	3	7	7	6.60	39	1521	0.106	0.216	0.040	0.086	0.090	0.108
Agriculture	8	6	8	9	9	8.00	45	2025	0.133	0.073	0.119	0.209	0.208	0.148
Livestock	9	8	10	8	10	9.00	52	2704	0.185	0.105	0.314	0.123	0.310	0.207
Forestry	5	4	5	6	5	5.00	27	729	0.072	0.037	0.068	0.071	0.073	0.064
Existing farms	1	1	1	2	1	1.20	10	100	0.023	0.028	0.022	0.031	0.021	0.025
Urban areas	4	5	7	4	4	4.80	27	729	0.042	0.062	0.087	0.037	0.038	0.053
Population density	6	7	6	5	6	6.00	31	961	0.072	0.085	0.079	0.067	0.074	0.075
Consistency ratio									0.08	0.09	0.10	0.09	0.10	0.092

n= 6

Government officers	*SCORES*							*WEIGHTS*				
	A	B	C	D	Mean	Rj	Rj^2	A	B	C	D	Mean
Water resources	10	9	8	10	9.25	47	2209	0.314	0.182	0.135	0.309	0.235
Soils	3	2	2	3	2.50	19	361	0.031	0.031	0.031	0.034	0.032
Roads	1	3	4	1	2.25	17	289	0.027	0.031	0.037	0.025	0.030
Oil industry	7	8	9	9	8.25	39	1521	0.076	0.130	0.178	0.212	0.149
Agriculture	9	10	7	6	8.00	37	1369	0.228	0.308	0.090	0.071	0.174
Livestock	8	7	10	7	8.00	39	1521	0.134	0.085	0.307	0.089	0.154
Forestry	4	5	6	4	4.75	21	441	0.036	0.082	0.083	0.037	0.060
Existing farms	2	1	1	2	1.50	10	100	0.027	0.022	0.028	0.030	0.027
Urban areas	6	4	3	5	4.50	21	441	0.075	0.045	0.032	0.070	0.056
Population density	5	6	5	8	6.00	25	625	0.052	0.084	0.082	0.125	0.086
Consistency ratio								0.10	0.10	0.08	0.08	0.090

n= 5

The results are summarised in Table 17. Analysis for the socio-economic factors showed a W=0.77 indicating that rankings were significantly associated [$P > 0.05$]. The environmental factors ranking were also found to be significantly associated [W=0.65, $P > 0.05$].

The socio-economics and environment models were developed using the MCE technique after weight verification was obtained. The models were run using both author's weights and groups' mean weights to compare spatial differences. In the environment model, areas of fair and good suitability were identified by author's weights covering 46% of the total area. The resulting model from the groups' weights showed fair and good suitability areas covering only 35% of the total area, mainly in Centla and Centro municipalities (Fig. 64 and 66).

Moderate and fair areas found by the socio-economic modelling accounted for 19% (author) and 4.2% (groups) of the total. Both images identified most of these areas to be located in Centro and Cardenas municipalities (Fig. 65 and 67).

The proportion and distribution of suitable areas found in each model varied according to the differences in the criteria for weighting each factor. On the one hand, the author ranking of factors were based on the literature available for coastal management, and general knowledge of the area of study. On the other hand, the ranking performed by each group was based on the current resource management projects and development policies (government officers and NGO) and local knowledge and production management experiences (fishermen).

Table 17. Kendall coefficient of concordance analysis for socio-economic and environmental factors between groups

Socio-economics	*Group*								*Author*			
	A	F	N	G	Rj	Rj^2	Mean Rj	Mean Weight		Score		Weights
Human resources	10	10	9	10	39	1521	10	0.222	Human resources	10	0.268	Human resources
Employment opportunities	9	9	10	9	37	1369	9	0.198	Employment opportunities	9	0.182	Employment opportunities
Activity conflicts	8	4	7	6	25	625	7	0.139	Existing farms	8	0.152	Activity conflicts
Land ownership	7	7	2	4	20	400	6	0.091	Activity conflicts	7	0.119	Land ownership
Inputs	6	2	3	3	14	196	4	0.085	Inputs	6	0.069	Inputs
Urban areas	5	5	4	5	19	361	5	0.070	Income	5	0.055	Urban areas
Farm-gate sales	4	8	8	7	27	729	5	0.057	Urban areas	4	0.044	Farm-gate sales
Existing farms	3	3	6	2	14	196	7	0.053	Farm-gate sales	3	0.039	Existing farms
Income	2	6	5	8	21	441	5	0.052	Land ownership	2	0.023	Income
Energy	1	1	1	1	4	16	1	0.024	Energy	1	0.021	Energy

W=0.77 X^2=27.7 $\chi^2_{r\ 0.05,4,9}$=7.08

A= Author, F = Fishermen, N = Non-governmental organisation officers, G = Government officers

Environment	*Groups*								*Author*			
	A	F	N	G	Rj	Rj^2	Mean Rj	Mean Weight		Score		Weight
Water resources	10	10	10	10	40	1600	10	0.258	Water	10	0.278	Water
Soils	9	3	3	3	18	324	5	0.145	Livestock	9	0.216	Soils
Roads	8	1	2	2	13	169	7	0.121	Agriculture	8	0.122	Roads
Oil industry	6	7	7	8	28	784	7	0.111	Population density	7	0.094	Livestock
Agriculture	5	6	8	7	26	676	3	0.107	Oil industry	6	0.087	Oil industry
Livestock	7	8	9	9	33	1089	8	0.069	Soils	5	0.077	Agriculture
Forestry	2	4	5	4	15	225	2	0.056	Forestry	4	0.040	Existing farms
Existing farms	4	2	1	1	8	64	4	0.052	Urban areas	3	0.033	Urban areas
Urban areas	3	5	4	5	17	289	4	0.049	Roads	2	0.031	Forestry
Population density	1	9	6	6	22	484	6	0.032	Existing farms	1	0.023	Population density

W=0.65 X^2=23.56 $\chi^2_{r\ 0.05,4,9}$= 7.08

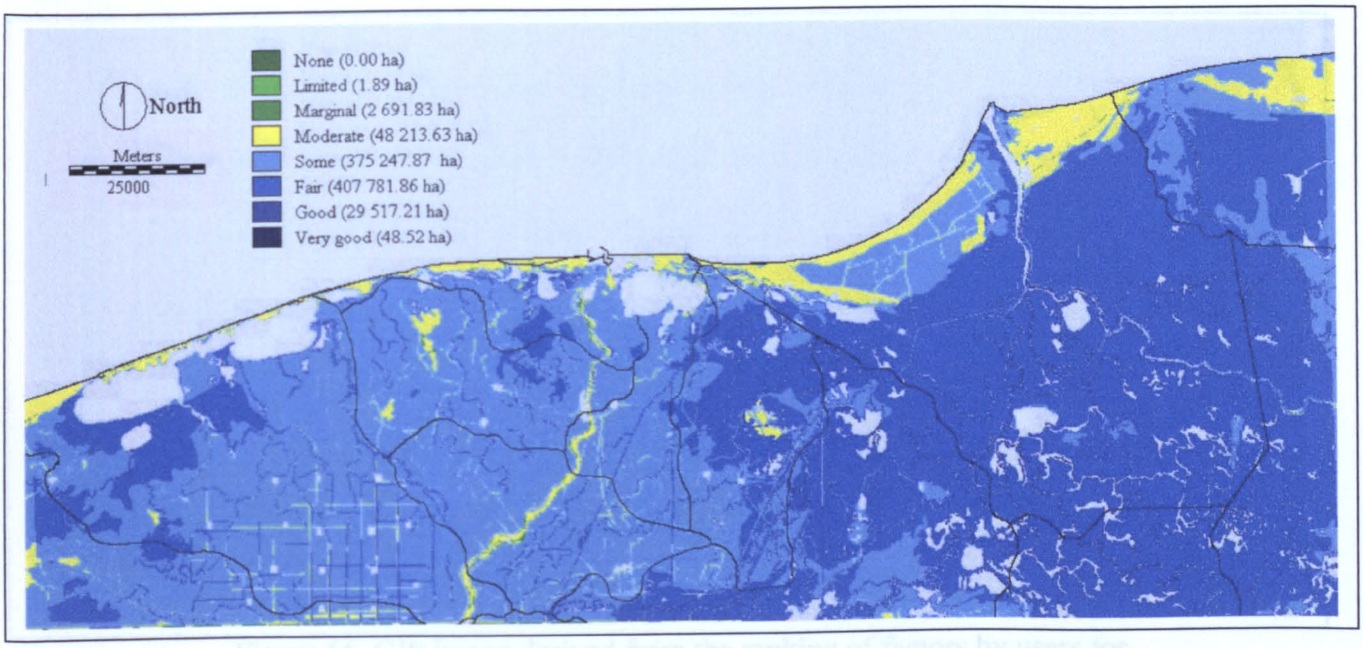


Figure 64. General environmental model derived from the ranking of factors by the author

Mathematical expression
ENVIRONMENT = (wateresour x 0.278) + (soilsbm x 0.216) + (lanuseroads x 0.122) + (oilfacil x 0.087) + (agriculanduse x 0.077) + (livestockuse x 0.094) + (forestuse x 0.031) + (agglome x 0.040) + (urbandevelanuse x 0.033) + (popdensity x 0.023)

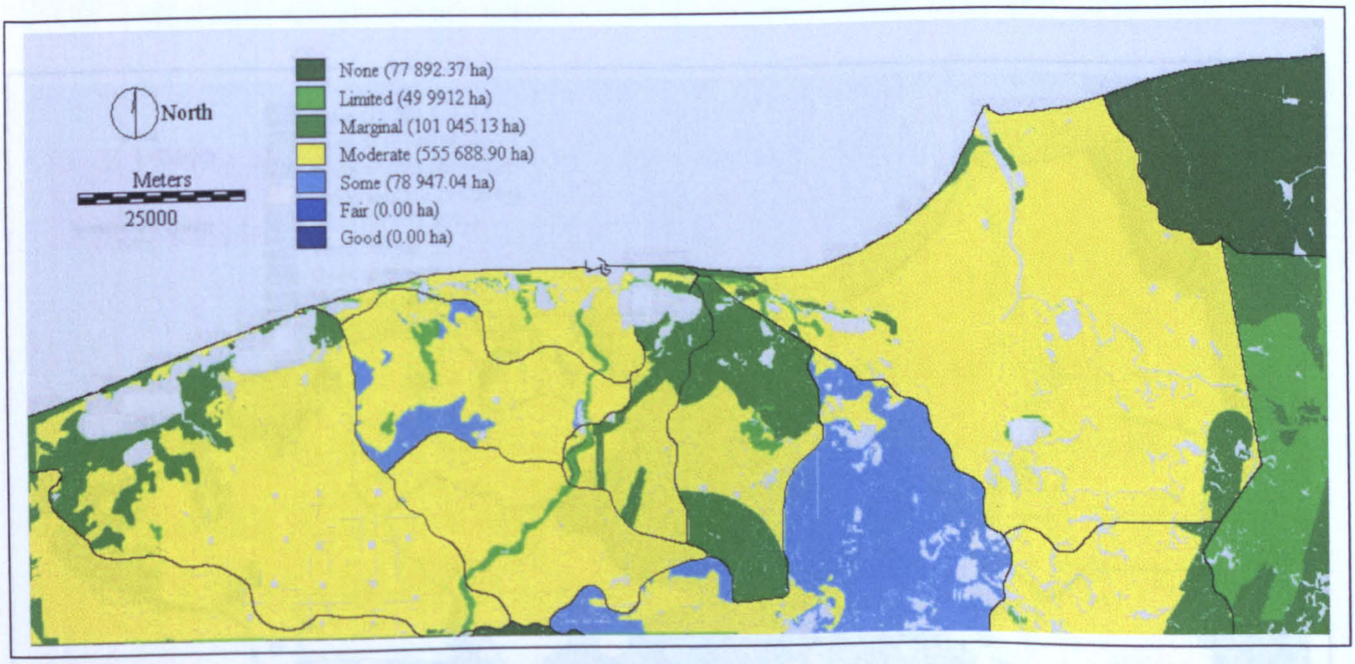


Figure 65. General socio-economics model based on the ranking of factors by the author

Mathematical expression
SOCIO-ECONOMICS = (humnaresubm x 0.268) + (employmnetopp x 0.182) + (ecoacti x 0.152) + (lanownershipsoc x 0.119) + (inputs x 0.069) + (urbandevpro x 0.055) + (aglompro x 0.039) + (income x 0.023) + (farm-gatesales x 0.044) + (energy x 0.021)

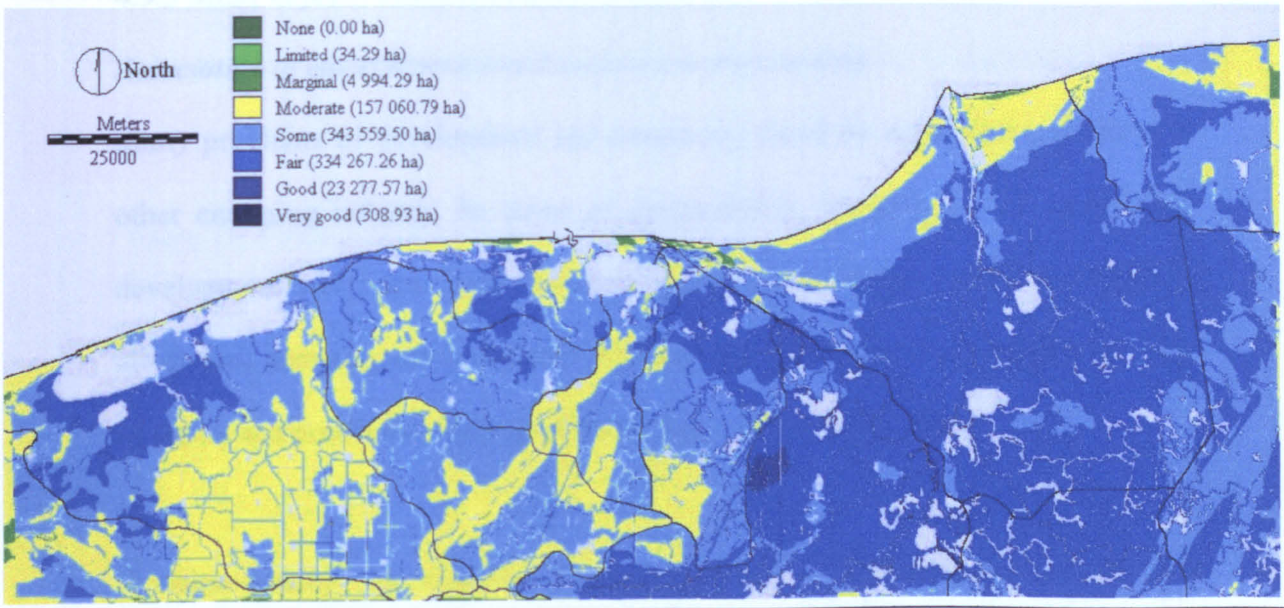


Figure 66. GIS image derived from the ranking of factors by users for environmental factors

Mathematical expression
ENVIRONMENT = (wateresour x 0.258) + (soilsbm x 0.069) + (lanuseroads x 0.049) + (oilfacil x 0.107) + (agriculanduse x 0.121) + (livestockuse x 0.145) + (forestuse x 0.056) + (agglome x 0.032) + (urbandevelanuse x 0.052) + (popdensity x 0.111)

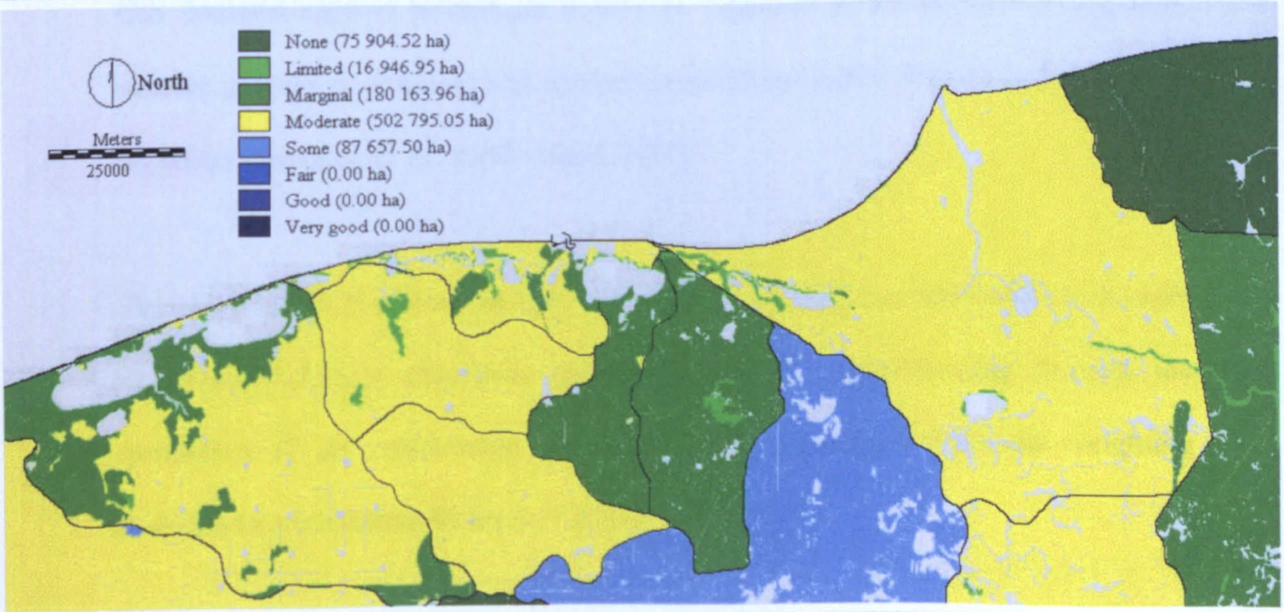


Figure 67. Socio-economic model derived from the ranking of factors by users

Mathematical expression
SOCIO-ECONOMICS = (humnaresubm x 0.222) + (employmnetopp x 0.198) + (ecoacti x 0.091) + (lanownershipsoc x 0.052) + (inputs x 0.085) + (urbandevpro x 0.057) + (aglompro x 0.139) + (income x 0.070) + (farm-gatesales x 0.053) + (energy x 0.024)

4.9.3 Multi-objective land allocation modelling

Association of environmental and socio-economics models

Many problems of development are commonly faced by aquaculture, as for any other emerging industry. In terms of sustainability, the potential of aquaculture development has been over-estimated regarding problems related to resource allocation, assessing environmental capacity, social and cultural perspectives, site selection and production requirements (Pillay, 1994; Moffat, 1996).

Decision-making on multiple problems requires consideration on whether objectives are conflicting or not. The capacity of GIS for integrating information from a variety of sources provides a well-suited tool for supporting decision-making. However, there are often factors that cannot be easily quantified, as objectives are not always absolute and are subject to some inaccuracy. Therefore, GIS decision-support techniques should be regarded as useful tools in decision-making process to evaluate and explore possibilities rather than to make the final decisions (Eastman *et al.*, 1993; Jones, 1997).

The previous MCE-derived images were used to identify land use conflicts in order to identify whether objectives are conflicting or complementing through the evaluation of the relationship between factors considered from the weighting matrixes as a consistent factor evaluation.

Crosstab module in Idrisi32 was used to compare the categories of the environment image with those of the socio-economics image (Table 18), as potential sites are not similar regarding environmental and socio-economical factors (Aguilar, 1996).

The resulting image is shown in Figure 68. Areas of very good suitability (123 777 ha) were found in the municipalities of Centro, Huimanguillo, Comalcalco, Paraiso, Centla and Macuspana. Fair and good suitability areas were found to be the largest.

Table 18. Cross-tabulation for aquaculture development in Tabasco's coastal zone weighted by the author (columns) and the focus groups (rows)

Suitability	*None*	*Limited*	*Marginal*	*Moderate*	*Some*	*Fair*	*Good*	*Very good*	*Total pixels*	*Commission error*
None	**23**	6275	0	454	0	0	0	0	**6752**	0.34
Limited	0	**398**	12648	8886	1250	0	0	0	**23182**	1.72
Marginal	0	21109	**4376**	200024	224821	38783	1002	0	**490115**	21.45
Moderate	0	747	10212	**63573**	265969	10077	22483	211	**373272**	17.03
Some	0	0	92	287391	**984629**	2431311	31435	107471	**3842329**	25.63
Fair	0	0	0	68	252853	**818416**	2269658	4272	**3345267**	24.46
Good	0	0	0	0	261	139022	**408783**	648377	**1196443**	34.17
Very good	0	0	0	0	0	0	112278	**206035**	**318313**	64.73
Total pixels	**23**	**28529**	**27328**	**560396**	**1729783**	**3437609**	**2845639**	**966366**	**16002000**	
Omission error	0	1.40	16.01	11.34	56.92	23.80	14.37	21.32		

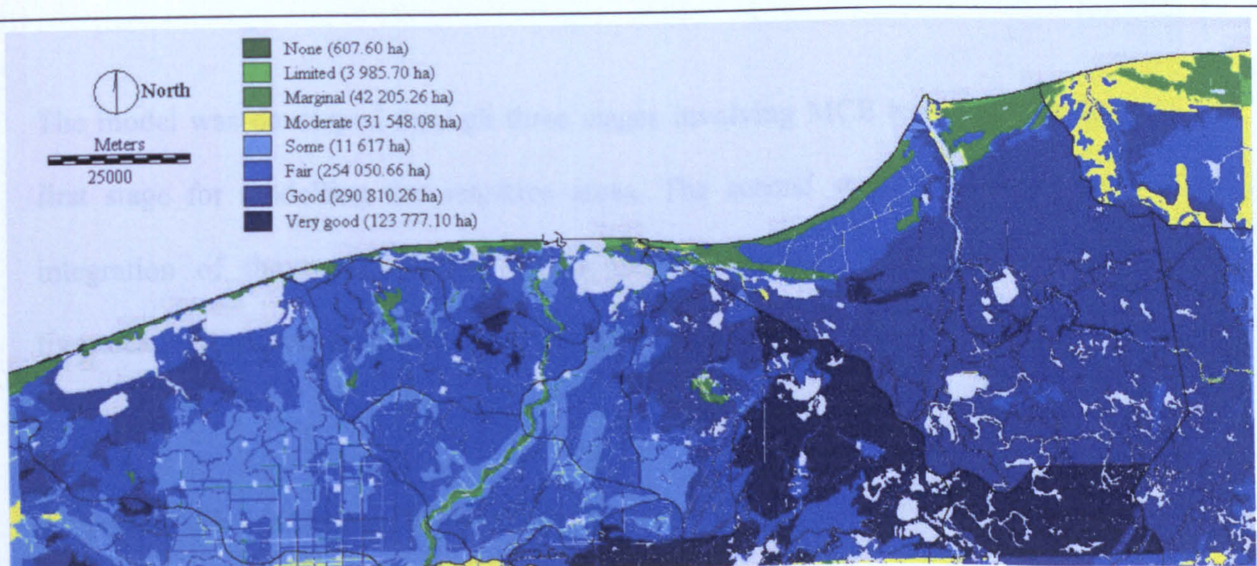


Figure 68. GIS-derived image for environment and socio-economics cross-classification

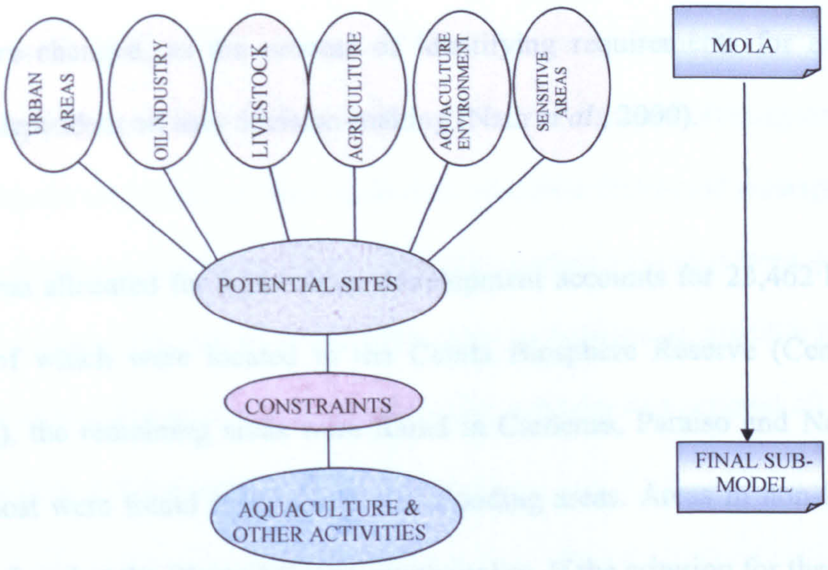
The proportion of reduction in error produced by the Kappa coefficient in the cross-classification process was 0.41, indicating a good proportion of pixels correctly classified. The cross-tabulation showed that there are areas of relative low conflict covering 90% of the State, while conflicting areas were found in the coastline and the Central part of the State. The factors found competing for the same areas of land were the oil industry, livestock, urban areas, aquaculture and agriculture.

Conflicting objectives

For cases with conflicting objectives the MOLA module provides a procedure for solving conflicts on land allocation based on suitability maps for each objective (MCE outputs), the relative weights to assign to objectives, and the amount of area to be assigned to each. Thus, the module provides a mechanism to maximise the suitability of lands for each objective given the weights assigned (Eastman *et al.*, 1999).

The model was developed through three stages involving MCE techniques in the first stage for modelling the sensitive areas. The second stage consists of the integration of the ranked layers corresponding to urban areas, oil industry, livestock, agriculture, aquaculture and sensitive areas (Figure 69).

An area of 3 km was established as area tolerance (i. e. pollution risks) that refers to the point at which MOLA determines that the iterative procedure has come close enough to satisfy the area needs for each objective. Area goals for the objectives were based on very good suitability areas found through the MCE technique. The resulting layer was integrated by overlaying the contingency areas' sub-model to produce the final image shown in Figure 70.



Mathematical expression
AQUAMOLA = (oilfacil x 0.25) + (livestocklanuse x 0.15) + (agriculanduse x 0.15) + (aquaenvi x 0.10) + (urbandevpro x 0.10) + (protectareas x 0.25)

Figure 69. Multi-objective land allocation model for aquaculture development in Tabasco coastal zone

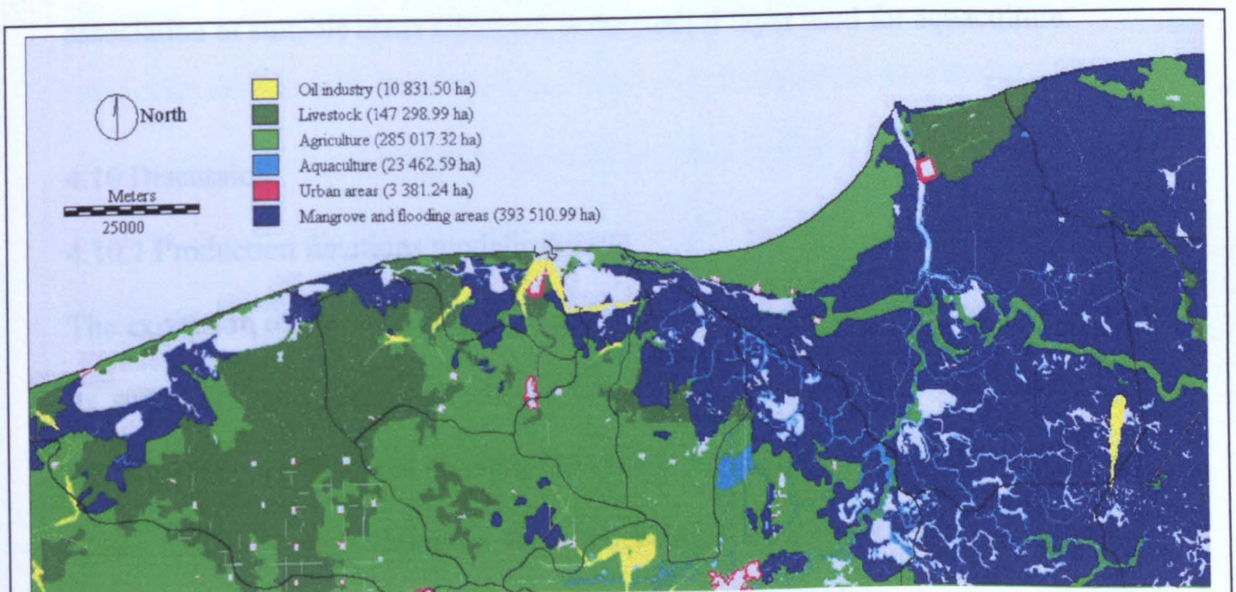


Figure 70. MOLA-derived image for coastal aquaculture development in Tabasco, Mexico

One of the powerful features of GIS is that statistical summaries of layers/coverages, sub-model and/or outcomes can easily be obtained, allowing interactive scenario development and evaluation, as criteria can be relaxed or restricted. Hence, different results may be obtained if criteria of suitability and area tolerance are changed, as the process of identifying requirements for a GIS is essentially dependent on user decision-making (Nath *et al.*, 2000).

The total area allocated for aquaculture development accounts for 23,462 ha (Fig. 71), 80% of which were located in the Centla Biosphere Reserve (Centla and Macuspana), the remaining areas were found in Cardenas, Paraiso and Nacajuca, although most were found in or nearby the flooding areas. Areas in non-flooding zones were found at the West of Centro municipality. If the criterion for the MOLA evaluation is relaxed (Fig. 70), it could be expected that larger areas would be allocated either in new sites and/or in those previously identified due the association of suitable areas allocated in the ranked layer used for aquaculture.

4.10 Discussion

4.10.1 Production functions modelling

The expansion of aquaculture related activities and the increased concern regarding its suitability have promoted the use of GIS for decision-making in aquaculture development. As discussed by Nash (1995) and Shang and Tisdell (1997) resources requirements for aquaculture are directly dependent on the level of production, and on operational features. This implies a serious decision-making process to identify effects on neighbouring areas and the local economy, which affects people's livelihoods and opportunities.

Although some of the estimations were based on established assumptions (e.g. seepage for water balance calculation), much of the data used in this study are reliable, being based on material from INEGI (National Institute of Statistics, Geography and Informatics), updated databases and first-hand information collected from the survey carried out by the author. For instance, the agglomeration layer was developed based on the distribution of oyster farms and managed areas from maps developed in the 1980's as updated mapping has not been produced through any source. The assumptions were made as realistic as possible but there are inherent errors. Future analysis must look for and take into account all existing aquaculture sites and systems.

Public perceptions for proper determination of resource access are included in this study to avoid subjectivity inherent to author's factor weights allocation. Differences in criteria for evaluating the matrixes may be attributed to the particular interest of each group interviewed and the nature of the functions utilised in the analysis, as conceptualisation and personal opinion are diverse. However, changes in conceptualisation have indicated that knowledge and social interfaces require comprehensive analysis to estimate conflicts over resources and identify land use possibilities related to social actors, when any given area presents similar suitability for different activities (Bojorquez-Tapia, 1993; Scoones & Thompson, 1994).

The results from weight verification through the questionnaires showed that a general agreement was found among government and NGO officers, while scoring by fishermen was not uniform as scores were inconsistently allocated. However, as discussed by Aguilar (1992) and Bojorquez-Tapia (*op cit.*) these different results may be expected as the production of weights differs between persons looking at the matrix from different perspectives according to their interests and needs.

The socio-economic modelling has shown that areas (502,795 ha) of moderate suitability are located in Cardenas, Huimanguillo, Comalcalco, Paraiso, Centla, Macuspana and Cunduacan municipalities (Fig. 68). The findings differ from those of Gutierrez (1995), which suggested that best socio-economics localities were found in Huimanguillo, Centla, Balancan and Centro municipalities. These differences may be caused by significant changes in socio-economic indicators (Table 19). Over the last five years factors such as population growth, which is higher than the National growth rate, and a enlarged economically active population were affected by the pattern of population distribution, as most of the localities are large rural areas where employment opportunities and disposable income were found to be marginal.

Table 19. Population density and growth in Tabasco coastal zone

Municipality	*Inhabitants*	*EAP*	*Growth rate*
National	97,361,711	53 490 524	2.1
State	1 889 367	944 683	2.7
Huimanguillo	154 577	32 117	2.3
Cardenas	204 810	42 875	3.1
Comalcalco	156 334	32 558	1.8
Cunduacan	97 698	21 103	2.3
Centro	465 449	121 226	3.3
Nacajuca	68 149	12 327	5.3
Jalpa de Mendez	64 282	12 839	2.1
Centla	77 543	14 373	1.8
Macuspana	123 024	16 089	2.8
Paraiso	65 266	23 663	2.0
Jonuta	24 792	5 931	2.1

Source: SEMARNAP, 1997 and INEGI, 2000.

However, regarding the availability of labour, skilled personnel and low impact from different economic activities, particularly from the oil industry, areas of very good suitability were found in Huimanguillo, Cardenas, Centro and Centla municipalities. Central areas were found with limited to some suitability because high population density and economic activities are concentrated in those areas as noted by Gutierrez (1995).

From the State fishery production figures and the availability of aquatic resources the expansion of aquaculture in the coastal zone is feasible, as the intensity depends on the local availability of inputs; particularly when considering the integration of aquaculture within rural communities (Meaden & Kapetsky, 1991; Bardach, 1997). Self-sufficient production systems based on local agriculture and livestock by-products have been proposed and implemented to some extent in Tabasco (Mancera, 1984; Micha *et al.*, 1984; Mendoza & Cordova, 1988; Halen *et al.*, 1991) and they may still represent a production alternative. However, the approach requires awareness among producers, market analysis and research to identify proper distribution channels to avoid production allocation failing in local markets as found by Rodriguez (1998) and in the field survey carried out by the author (See sections 6.2.2 and 6.3.4).

Areas of good suitability to infrastructure and markets were found to be concentrated in the central municipalities of Cardenas, Centro, Comalcalco and Paraiso where most of the population, production amenities and urban areas are concentrated. There may be significant advantage in the integration of adjacent production units, as sustainability prospects are higher in terms of marketing opportunities and extension efforts as described by Martinez-Espinosa (1996). However, less developed areas were found with fair suitability, and indications of potential aquaculture development may be identified as they match those in real conditions when comparing the results of this study with the previous models developed and surveys carried out respectively by Aguilar (1992) Gutierrez (1995) and IREBIT (1995).

From the potential benefits of aquaculture integration in tropical areas and particularly in Tabasco's coastal zone current practices may still be improved as current culture systems have had little adverse effect on ecosystems (De la Lanza & Arredondo, 1990; Arredondo *et al.*, 1993; Rodriguez, 1998). Furthermore, the recognition of ecologically sensitive zones such as the Pantanos of Centla Biosphere Reserve within international protection programmes has urged National and State government to promote and develop integrated coastal zone management frameworks (Hamann & Ankersen, 1996; RAMSAR, 1998; NOAA, 2000; Tortajada & Biswas, 2000).

Potential ecosystem modifications and extensive pollution from the numerous oil facilities and urban areas and the infrastructure related to those activities might reduce productivity and limit development success of aquaculture practices. Additionally, impacts from agriculture and livestock production are expected to a lesser extent, as these activities are low technology practices. However, areas converted into grasslands for cattle grazing by unregulated agriculture activities represent the major impact on resource access as deforestation has promoted soil nutrient depletion and increased sedimentation and turbidity of water bodies (Arredondo *et al.*, 1993; Contreras, 1993).

The land use sub-model showed that most of the moderate suitability areas are located in Cardenas and in the shore zones of the State. Suitable areas were found to be absent and limited as shown in the oil facilities image in the central area of the State, at the South end of Centla and in the North part of Humanguillo and Southwest of Cardenas.

Regarding the availability of water, modelling showed that the entire coastal zone of the State has a very good water balance. The calculations on mean annual precipitation and evaporation and an estimation of 80 mm loss by seepage were based on the assumptions of Aguilar and Nath (1998). Hence, careful attention must be drawn particularly to the areas where seasonal flooding takes place, which are located near to coastal lagoons and covering more than 70% of Centla and large areas Centro and Macuspana.

The monthly average of water availability from the relationship between rainfall and evaporation in Tabasco shows marked seasonal changes (Fig. 71). Monthly precipitation has important flooding impacts during the 'nortes' season, characterised by high precipitation rates of 210-380 mm from mid September to January with constant cloudy conditions and comparatively low temperatures (21-34°C) influenced by monsoon winds.

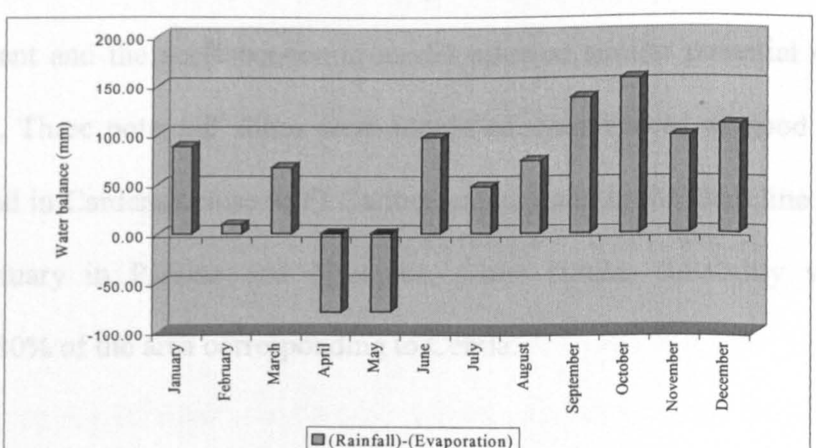


Figure 71. Water balance fluctuations through out the year in the coastal zone of Tabasco, Mexico

The 'seca' (dry) season occurs from mid February to mid June and high temperatures may be registered at 34-36°C with several days or weeks without rainfall, however, short periods of precipitation may occur in March and June and high evaporation up to 154 mm in May. During the season called 'temporal', from June to September, precipitation is originated by easterly winds and short periods of rainfall may occur with a precipitation between 200-250 mm associated with high temperatures (35-36°C) sometime reaching 39°C and a mean evaporation of 123 mm.

This explains the results from the water resources sub-model, which showed that the entire State has a moderate suitability to water resources with good and very good suitability close to water bodies. These areas represent an important component in seasonal subsistence fishing in flooding areas. The general environmental model showed that almost 50% of the coastal area has fair suitability while good suitability areas were located in Centro, Cardenas and Paraiso.

4.10.2 GIS-based resources allocation modelling

The comparison of categories for single objective evaluation between the environment and the socio-economic model allowed similar potential sites to be identified. Three potential zones were identified. Small areas of good suitability were found in Cardenas close to El Carmen estuary and in the shoreline of the Las Flores estuary in Paraiso and Nacajuca, while similar suitability was found covering 80% of the area corresponding to Centla.

The next zone and the largest regarding good and very good suitability areas were found in Centro and the South of Cunduacan. The third zone was found to be located on the riverside and swamp zones of the Biosphere reserve in Centla. However, the areas found in Cardenas, Paraiso and Centla are located within the flooding zone and development would require caution. As no single solutions may be identified, management approaches for sensitive areas such as mangroves and those where seasonal effects on land productivity may be beneficial (i.e. swamps and marshes) should be carefully considered to implement proper strategies to avoid ecosystem degradation and substantial impacts on livelihoods (Ruitenbeek, 1991; Barg, 1992).

The use of multi-criteria evaluation can be an important factor in determining the scope of decision makers in ensuring that the long-term benefits of development on livelihood assets of coastal communities can be realised. This could avoid the disappointing effects that development projects such as Chontalpa Plan have had in rural areas (Perez, 1998; Bebbington, 1999; Nguyen & Meyer, 1999).

Bearing the above in mind, the results from the integration of the MOLA model showed that areas allocated to aquaculture are significantly related to areas subject to flooding and mangrove forest. This represent a potential alternative to rural communities settled in the boundaries of these areas as they have traditionally relied on its extractable resources (Macias & Serrat, 1986). However, Clark (1992) notes that if a sustainable livelihoods approach is to be considered, special attention has to be paid to risk management actions when allocating or re-allocating resources among different stakeholder groups, due to possible socio-economic displacement.

Local populations offer an attractive market, and the size and spatial distribution is indicative of the quality and quantity of the labour force, which may positively influence investment returns. Even though per capita income remains low, market for some consumer goods may be further developed as communities' access to resources is improved through a less bureaucratic and stable legislative environment, as discussed by Nguyen and Meyer (1999).

The tolerance distance (3 km) established to run the model allowed the identification of non conflicting zones and it may be assumed from this that the integration of aquaculture with other economic activities is possible through out the coastal zone of the State. In the case of the oil industry potential impacts are low, as the area allocated for aquaculture is distant from oil facilities.

Coastal resources are important in particular to fishing communities, which depend on natural resources for food, employment and livelihood. The objective of economic development as discussed by Dixon *et al.* (1988) is to improve human welfare. However, successful economic development depends on proper project selection, planning and implementation. Though aquaculture is no panacea for providing the basic needs of rural communities the identification and enhancement of culture sites may aid the efficient utilisation of marginal areas for agriculture and livestock activities (Jolly & Clonts, 1993).

4.10.3 Development and output implications

To estimate economic benefits, potential outcomes in terms of income and employment were calculated, using a unit of one hectare as the basis for assessment. The scale of production was considered to be for small-scale production for tilapia and oyster (Table 20), which corresponds to current practices in the region.

Table 20. Economic evaluation of coastal aquaculture operations[1] in Tabasco per year[2], based on 1 ha of production

Item	*Oyster*		*Tilapia*		*Total (Pesos[3])*	
	Quantity	*Unit price*	*Quantity*	*Unit price*	*Oyster*	*Tilapia*
Capital costs						
Land requirements	0.25 ha		0.30 ha			
Site development (clearing, building, pond construction)	625 m^2	9.33/m^2	900 m^2	9.33 per m^2	5 812.00	8 397.00
Seed	100 000		30 000	0.20		6 000.00
Equipment						
Outboard engine	1	9 500.00			9 500.00	
Nets and lines	500 m	14.67	300 m	6.29	7 335.00	1 887.00
Miscellanies		4 000.00		3 000.00	4 000.00	3 000.00
Total					*26647.00*	*19284.00*
Operating cost						
Permanent labour	3	25.00/day	3	25.00/day	75.00/day	75.00/day
Labour (days/cycle)	130		190		3 250.00	4 750.00
Gasoline/motor oil	600 lt.	47.60			28 560.00	
Feed			3.96 t	3 500.00/t		13 860.00
Total					*35 060.00*	*28 110.00*
Yield per cycle	70 000[4]		7.9 t/ha			
Market size	6 cm		380 gr.			
Total costs per year					61707.00	47394.00
Contingencies 10%					6170.00	4739.00
Taxes 15%					9256.00	7109.00
Total costs					77133.00	59242.00
Sales per year	140 000[4]	0.70[4]	23.7 t/ha	4.00/kg	98000.00	94800.00
Total profit					*20867.00*	*35558.00*
Total profit US$					*2237.00*	*3811.00*
NPV[5]					*48197.00*	*105277.71*
IRR[5]					*42%*	*89%*

[1] Estimation is based on recent projects developed by Rodriguez (1998). [2] Three production cycles for Tilapia and two cycles for Oyster. [3] 9.33 Pesos = 1 US Dollar (May 2001). [4] Shell-on oyster. [5] Discount rate at 4% for six years (Weitzman, 2001). Maximum loan available = Pesos $ 100 000.00 (Interest rate 15%)

From these estimations, operations were shown to be profitable attaining an average market price of Pesos$ 0.70 per shell-on oyster and Pesos$ 4.00 per kg of tilapia, with an internal rate of return of 42% and 89%, respectively. Trends in value are not easy to discern, however prices used in the assessment are standardised values and not significantly different from those described by GDCI (1995), Muir (1995) and Rodriguez (1998). Although oyster may attain profitable levels, tilapia production may be more attractive as the number of production cycles annually might represent a more reliable source of income.

The suitable area identified through the multi-criteria evaluation provided a structure in which requirements for aquaculture development could be met. Although an important percentage was located in flooding areas (Centla municipality), an alternative approach for systems development may be considered (Micha *et al.*, 1984; Halen *et al.*, 1991; Hamann & Ankersen, 1996). Table 21 shows potential development issues for land-based systems and land requirements for water-based systems considering the area identified as suitable through the MOLA evaluation. Of the potential area, 15% was allowed for roads, services zone, office, warehouse, dikes, and inlet and outlet channels (Muir, 1995; Salam, 2000).

In terms of productivity/intensity, yields were considered to be at 2t h^1y^1 (Muir, 1995). Thus, an average output of 119 658t may be feasible from small-scale systems. The size of locations may vary according to the type of production organisation. Family or backyard production is generally carried out in areas of less than 1 ha (Fig. 72). Larger productions units may be established through the ejido system, where areas equal to or with more than 6 500 ha are available (IREBIT, 1995; INEGI, 1998).

Figure 72. Tilapia backyard pond at the North of the Mecoacan estuary, Tabasco, Mexico

Table 21. General considerations for potential land-based aquaculture in the areas identified through the GIS modelling

	Estimations
Suitable area identified (ha)	23 462
15% for services and infrastructure (ha)	3 519
Potential area for culture (ha)	19 943
Economics	Entrepreneurial/Commercial/subsistence
Water management	Pump/reservoir
Environmental impact	Moderate/little
Design and layout	Planned/little
Technical manpower	Experience based/skilled
Seed source	Wild/imported
Feed use	Natural/pelleted feed
Estimated production per year	119 658 t
Estimated profit USD$/year[1]	51.3 million
Potential permanent job/cycle[2]	6 647
Minimum wage (Mw) US$/day[2]	3.00
Mw/ person/ month	180.00

[1] 9.33 Pesos = 1 US Dollar (May 2001). [2] Based on the calculations from Table 15

On the basis of theses scenarios, areas located in Centro, Cardenas, Paraiso and Nacajuca municipalities may offer significant socio-economic and environmental advantages for aquaculture development. In these municipalities communication networks are well developed and population density is significant. Thus, economic prospects are favourable in terms of employment, distribution networks, and markets. However, the lack of technical and financial assistance for developing commercial enterprises has limited production levels to around 300 kilos per hectare. This has reduced market access and competitiveness for aquaculture production in Tabasco coastal areas (GDCI, 1995).

As the results from the GIS modelling are indicative, field verification must be done to gather information and generate adequate data to test the quality or accuracy of the classification thresholds used in the modelling, as the accuracy of maps is extremely important for suggesting actions to be taken by decision makers. This is an important step in remote sensing exercises in terms of coastal management as discussed by Mumby and Green (2000) and particularly when considering aquaculture operations within a rural wage economy like that of

Mexico, where the demand for short-term labour from fishing and tourism and migration represents a significant constraint.

The results of the GIS modelling have also provided an understanding of needs, resources, stakeholder motivations, constraints and suitability to develop initial concepts for rural aquaculture in potential areas. However, major social and economics questions centring on the development of aquaculture are whether or not resource uses conflict and competition will increase, and potential rewards (e.g. income) will be attractive enough to encourage adoption.

Transfer of appropriate aquaculture technologies and introduction of sustainable farming systems are major challenges (Ahmed et al., 1993; Black & Truscott, 1994). The study of farming systems is important as the potential of any proposal can be properly evaluated by this means. In the following chapters an assessment of a coastal community located in Paraiso municipality is provided in order to understand local attitudes, capabilities and processes, and evaluate whether such potential can be realised.

5.1 Introduction

5.1.1 Background

In the rural sector, sustainable development is difficult to implement because institutional arrangements, market forces, politics and research efforts may be biased against communities composition and organisation. A major challenge, therefore, is to create new policies that permit key sustainable development objectives to be operationalised by using a set of standards or indicators (Garcia & Staples, 2000; Garcia *et al.*, 2000; Rigby *et al.*, 2000).

There are different definitions of what an indicator is and different understandings of their primary role. There are also varying opinions on the use of quantitative versus qualitative indicators. In spite of the lack of consensus on the operational meaning several authors point out that in order to be able to compare across places and situations from a sustainable livelihood perspective, depending on the issues being addressed and the data available, the uses and desirable properties of indicators that can generally be defined to assess conditions and changes should be user derived (Ashley & Carney, 1998; Hoon *et al.*, 1999; Carney *et al.*, 1999; Howlett *et al.*, 2000).

In general terms indicators 'are often continuous variables indicating changes in the state of a system's components and important tools to communicate, and make accessible, key information of a statistical, scientific or technical nature to non-technical user groups with policy, decision-making, oversight and auditing functions' (Garcia et al., 2000). Hence, they can be used to assess focal issues of development and management conditions and trends.

Clearly indicators are not themselves a solution, only a way to define objectives, scope and priorities for development and to reinforce best practices, as sustainability is a multidimensional concept with nested and interactive domains, which could be analysed at various levels and scales. Basically, indicators should cover the key issues regarding the resource to be used in a sustainable manner, the social conditions and the goods and services gained from the system (Ashley & Hussein, 1998; Garcia & Staples, 2000).

5.1.2 Aims of the livelihood assessment of Mecoacan's coastal communities

Coastal communities are diverse in culture, socio-economic structure, development level and behavioural features of their members. Often the resources of the coastal zones are exploited by the small-scale sector typical of these communities. In contrast to industrialised activities, small-scale producers use more indigenous resources. It has been suggested that communities, particularly those involved in fisheries, may work in partnership with government to manage aquatic and coastal resources (Sunderlin & Gorospe, 1997; Conway, 2000).

Most of the population in the Mecoacan estuary are involved in small-scale fisheries. It has been stated by government agencies and research centres that the characteristics of coastal fishing communities have not been entirely described and many aspects remain unclear such as the social benefit of development programmes, integrated development of resources, livelihood issues and the availability of contingency plans for coastal areas subject to natural disasters (REDIMAR 1996; Rivera-Arriaga & Villalobos, 2001).

This research is based on the measurement of driving forces taking place at and above the level of household and cooperative organisation in Mecoacan estuary, using the sustainable livelihoods (SL) approach. SL has been defined as 'the secure access to adequate stocks and flows of food and cash to meet basic needs, where security is defined in terms of ownership of (or access to resources) and income-earning activities, embracing the need for reserves and assets to offset risk' (DFID, 2000; Pasteur, 2001).

The first section of this chapter aims a description of wealth distribution, fishing and culture technology and cooperatives organisational context. A first approach is also made to the economic and marketing of fisheries production. In the second section a test of the usefulness of group forming, external assistance and cooperative participation was carried out through users' attitude surveys towards aquaculture development as an alternative activity to fishing and agriculture.

The last section of this chapter aims to determine if intervention is warranted to define and how best to assist in community-based resource management, by analysing a set of indicators selected through the participatory rural approach.

5.2 Community households and livelihoods

5.2.1 Household characteristics

Family structure

Family size recorded was not excessively large, as 78.5% of families comprise less than seven members, which coincides with the National population census (INEGI 1996). The respondents were found to be heads of household in most cases.

On average, families constituted a father, mother and three children. Families larger than 9 members were found where two families are living in the same house; there usually being married sons or daughters and their families who shared the same house with parents or close relatives such as grandparents (Fig. 73).

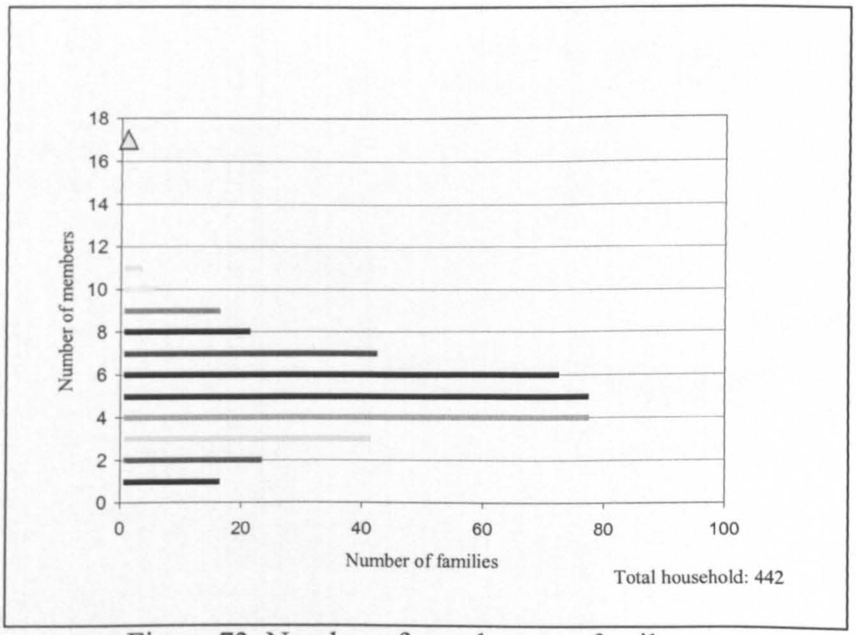


Figure 73. Number of members per family

Age and gender groups

The average age of the population is 20 years (0-78 years) (Table 22). 68% of the population was in the 15-60 years group, considered as the economically active group, primarily responsible for decision making. The population proportion represented by men is 53%, while women represent only the 47%. Elderly people (60+ years) represented only 8.51% of the population.

Table 22. Population distribution according to age

Age	*Total people*	*Percentage*
1-6 months	3	0.82
6-12 months	1	0.27
1-6 years	44	12.09
7-12 years	49	13.46
13-18 years	54	14.84
19-24 years	38	10.44
25-30 years	37	10.16
31-36 years	25	6.87
37-42 years	29	7.97
43-48 years	33	9.07
49-54 years	19	5.22
55-60 years	13	3.57
61-66 years	11	3.02
67-72 years	6	1.65
73-78 years	1	0.27

Education

The level of education was found to be relatively low. While 82.2% reached third grade of primary school, the percentage that attended secondary and high school reduced greatly to 24% and 8.4% respectively (Table 23), reaching to 2.3% at graduate level. This condition was related to the low income of families. Most of the graduate schools are located out of Paraiso Municipality and this implies high costs for transport and living expenses. Heads of families commented that when young people had finished high school it has to be decided who is going to college and who has to stay at home or look for a job to support the family, regardless of gender.

Table 23. Education level.

Group of Respondents	*Primary*	*Secondary*	*High school*	*Graduate*
Cooperative:				
Andrés García	774	220	80	30
Boca de los Angeles	280	65	12	1
Mecoacán	469	143	52	13
Puente de ostión	136	55	26	4
Independent fishermen (free riders)	75	26	12	2
TOTAL	1734	509	182	50

5.2.2 Economic access

Land tenure

Land is held by the *ejido* (parish) as the smallest unit of the municipality's political organisation for resource management. However, amendments to property laws in the last years have promoted the acquisition of these lands by individuals. Some *ejidos* are still held in common property and managed by community committees. In the study area the 85% of the families possess a land title where their household is located. It was found that 70% of this land tenure was inherited from the parents. Where the family holds more than one land title (10% of the cases) the second title often belongs to wives inherited most commonly from their fathers.

Animal enterprises and food

Women are likely to rear two types of animals: pigs and chicken. 95% of the households reported experience in animal farming as a family enterprise. Families had an average of 3 pigs and 20 chickens that are sold locally. Less than 20% of this backyard production is used for household consumption.

The main animal protein sources are chicken, and egg, fish, which are consumed 3-4 times per week (Fig. 74). Meat (beaf or pork) is consumed at least once a week. Animal protein was not equally accessible to all respondents due to the distance from market. The majority of respondents reported that poultry was the most accessible source. This is probably attributable to the fact that chickens are reared in backyard systems. Oyster is used to complement diet when fish is not available, with a frequency of 2 days per week. The major sources of vegetable protein are corn *tortillas*, rice and beans. Although other vegetable sources are locally available, the consumption of these grains is culturally related. Respondants reported that these are not produced locally as the land is not suitable for this kind of agriculture.

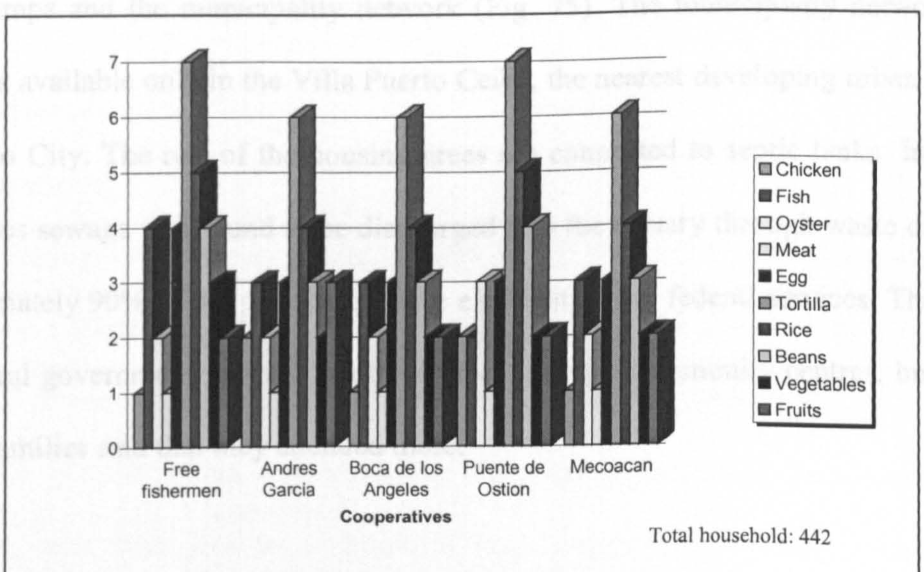


Figure 74. Protein consumption

Housing

The areas subject to urbanisation are classified as *villas* and *colonias*. However, most housing is classified as rural. These residential areas were developed during the prosperous time for oyster fisheries. Associated fishermen referred to this time as "when there was production, anyone who was intelligent saved his money and built his house, so the houses you see around were built 20 or 30 years ago". In a few cases fishermen noted that they were given grants for building through state government housing programmes in recent years.

5.2.3 Services

Water for human consumption and domestic use is obtained from three sources, wells, water pumps and the municipality network (Fig. 75). The municipality network for sewage is available only in the Villa Puerto Ceiba, the nearest developing urban centre to Paraiso City. The rest of the housing areas are connected to septic tanks. In some other cases sewage was found to be discharged into the estuary through waste ditches. Approximately 90% of the population have electricity from federal services. The state and federal government provide health services through community centres, but only 60% of families said that they attended these.

Most of the road network was developed in the early 1970's by the oil industry and the federal government. The roads connect the estuary with the three main urban centres in the area, Paraiso, Frontera and Comalcalco, and lead south to the capital, Villahermosa City. Airport facilities are available only at oil drilling sites. There is no rail network.

The main seaport belongs to the national oil industry and has been recently opened for commercial operations at the request of the state government, to help improve the regional economy.

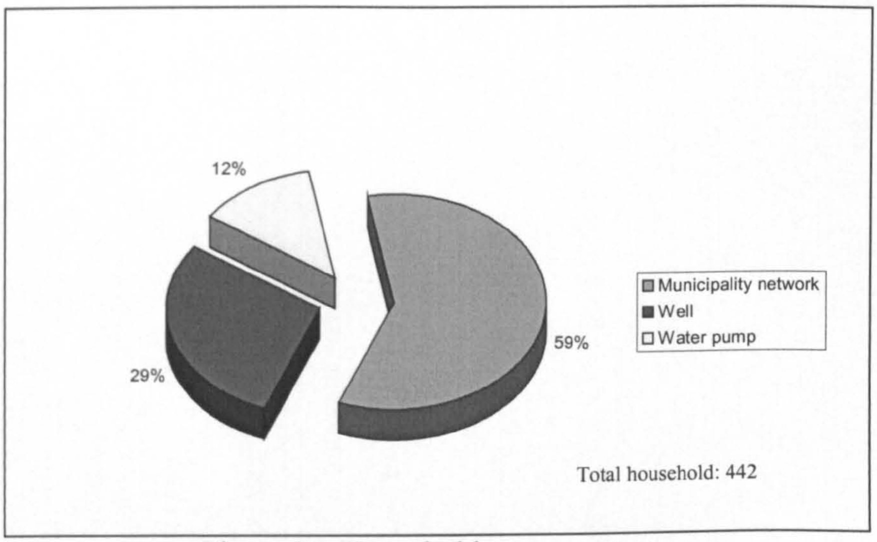


Figure 75. Household water sources

5.3 Livelihood characteristics

5.3.1 Employment

The distribution and sources of employment were found to be restricted among the independent fishermen (free riders) and those who are fishing cooperatives' members. The most representative jobs identified were fishing, oil, agriculture and general services. In general, whether associated or independent fishermen, respondents had second or even third jobs to complement their income from fishing, which was reported to produce lowest income contributions for those involved in estuary fisheries (Fig. 76). 23% of the fishermen work in marine fisheries where the most important commercial species are found at 500-800 meters from the coastline. The other 77% of the fishermen focused their effort on estuarine species.

Agriculture represents the second most important source of employment, particularly for coconut and cocoa, the major agriculture production activities in the area. Self-employment is common among women and children who sell food, oysters or other products in the community or at the roadside. Women also work as cleaners, maids or waitresses at local restaurants. For household employment distribution according to fishermen groups see Appendix E.

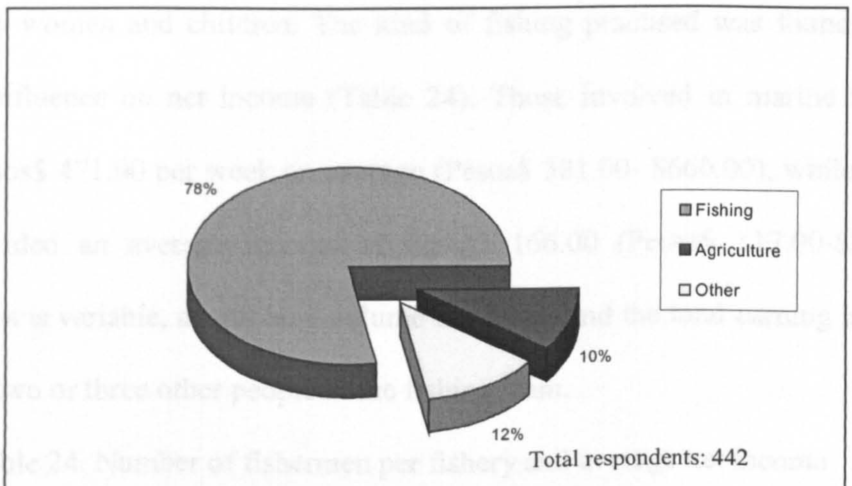


Figure 76. Employment distribution

Access to other sources of employment is restricted due the requirement for skilled personnel, particularly in the oil industry and related companies. Combined with the significant reduction in oyster and other estuary fisheries (Moguel, 1994) this has promoted the migration of people out of the municipality to major urban centres within the country and to the United States.

Women participate as fishery cooperative members until their male relative who is a cooperative member has died or has to emigrate for employment. Their membership only counts in cooperatives' general meetings. Women are not considered capable or skilled for fishing and their participation in the fisheries is reduced to the processing of the catch. They do not obtain a payment, as this activity is considered to be part of their family duties.

5.3.2 Income

In general, household income is in average Pesos$350.00 per week, about US Dollar $37.50 (Pesos$40.00-$3 000.00= US Dollar$4.30-321.50) including the income generated by women and children. The kind of fishing practised was found to be a significant influence on net income (Table 24). Those involved in marine fisheries obtained Pesos$ 471.00 per week on average (Pesos$ 381.00- $660.00), while estuary fishing provided an average income of Pesos$ 166.00 (Pesos$ 117.00-$260.00). However, this is variable, as catching volume fluctuates and the total earning has to be shared with two or three other people in the fishing team.

Table 24. Number of fishermen per fishery and average net income

Group of Respondents	*Estuary*	*Average net income* per fishermen*	*Average yearly income* per fishermen*	*Total net income**	*Marine*	*Average net income* per fishermen*	*Average yearly income* per fishermen*	*Total net income**
Cooperative:								
Andres Garcia	140	117.00	5, 616.00	786,240.00	70	660.00	31,680.00	2,217,600.0
Puente de ostion	33	260.00	12,480.00	411,840.00	8	612.00	29,376.00	235,008.00
Boca de los Angeles	79	149.00	7,152.00	565,008.00	3	421.00	20,208.00	60,624.00
Mecoacan	92	165.00	7,920.00	728,640.00	16	553.00	26,544.00	424,704.00
Independent fishermen (free riders)	19	161.00	7,728.00	146,832.00	8	381.00	18,288.00	146,304.00
TOTAL	363	166.00	7,968.00	2,892,384.00	105	471.00	22,608.00	2,373,840.00

* Pesos $/week 9.30 = 1 US Dollar

The fishermen stated that from catch proceeds, the *patron*[6], the owner of the boat and outboard engine, takes out the amount they spent in fuel and a percentage corresponding to either the rent or payment for the boat and outboard engine. After this discount has been made, the *patron* takes out his share, of 60%, leaving the rest for the fishermen.

[6] The *patron* is usually a middlemen or other fishermen who has lend money to buy equipment and cover fishing cost

Estuary fisheries are reported to produce low-income levels, as the species captured do not obtain good market prices. Most of estuary fishermen expressed their interest in getting involve in marine fishery, however, they also commented that the significant initial investment capital, the right contact to sell the product, and the requirement of physical strength and skills were the main constraints to get involved in marine fishery. In the case of marine fishermen, many of them are still involved in estuary fishing, but in a less extend. Thus, the general movement between the fisheries is moderate and highly dependent on fishermen access to financial resources.

5.4 Fisheries production

5.4.1 Fisheries general characteristics

At the time cooperatives were organised, fishing licenses were granted and quotas were established by the federal fishery office to extract oysters, as it was the major fishery. Marine fishing was not practised by local fishermen. The Fishery Ministry Research Centre, located in Carmen City, Campeche, establishes fishing seasons. These regulations are restricted to the catch of oyster from 1st August to 31st October and shrimp from 1st September to 15th November.

After the oyster fishery collapsed in 1992 (Moguel, 1994; INEGI 1996) the Mecoacan fishing cooperatives applied for shrimp, crab and marine fishing licenses in order to support their livelihood until the oyster fishery was recovering. These new fishery arrangements allowed fishermen to capture a wide range of species and acquire more fishing gear (Table 25). The crab fishery is an artisanal fishery despite the high market value it may reach i.e. Pesos$ 30.00 per kilo. Crabs are captured using a very elementary net called *naza*. The number of fishermen involved in crab fishery is low compared to fish and oyster fishery.

Table 25. Fishing gear

Group of Respondents	*Cast nets*	*Gill nets*	*Oyster grabs "Rasquetas"*	*Longline/fish hook*	*Nazas*
Cooperative:					
Andrés García	60	65	39	69	-
Boca de los Angeles	43	17	14	1	7
Mecoacán	65	34	7	9	35
Puente de ostión	22	18	8	6	-
Independent fishermen	9	4	1	6	1
TOTAL	190	134	68	85	42

These arrangements were taken by independent fishermen (free riders) as an opportunity to extract any species. Along with the associated fishermen, they claimed to have the same rights to protec their livelihood. Some of them have been granted fishing licenses. However, the activities of independent fishermen are not regulated and they capture species regardless of fishery laws, fishing season and zone. This has promoted conflicts with established cooperatives, as they stated that the issue of extending fishing licenses to independent fishermen was not discussed with them and considered this situation to be unfair as cooperatives pay for licenses and taxes.

Estuary fishermen spend around two hours to arrive at the fishing zone, where they have usually set the fishing gear overnight, as 65% do not own an outboard engine and fishing sites are some distance from harbour sites. Fishing takes place five days a week in average, with a divided schedule from 3:00 to 11:00 and 14:00 to 18:00. For those who practise marine fisheries the schedule is varied, but in general terms fishermen fish at sea from 2:00 till 17:00.

Boats and outboard engines are not commonly the property of fishermen. Those who own fishing equipment have spent an average of five years to buy it, or else it has been granted with a credit either from the government or a *patron*. Although 90% of the entervewees posses a boat, 65% often work with borrowed equipment and out board engines from friends and family (Table 26). Alternatively they rent from other fishermen a boat with an out board engine, which cost Pesos$ 30.00 per day. Regarding the equipment maintenance and operations, fishermen spend approxiamtely Pesos$ 800.00-862.50 per month in fuel, motor oil and repairs.

Table 26. Total number of boats and outboard engines owned by fishermen

Group of Respondents	*Number of boats*	*Number of engines*	*Ratio*
Cooperative:			
Andrés García	171	80	1:0.47
Boca de los Angeles	77	16	1:0.21
Mecoacán	96	35	1:0.36
Puente de ostión	33	17	1:0.52
Independent fishermen (free riders)	21	10	1:0.48
TOTAL	398	158	1:0.40

5.4.2 Aquaculture

Oyster culture has been the major aquaculture practice in the Mecoacan estuary, for restocking and extensive production. About 80% of fishermen have acquired experience and skills in oyster culture through different extension programmes for restocking, culture systems and stock management. Despite the training fishermen have received, oyster culture is now no longer practised and most of the culture facilities are abandoned. 83% of the entervewees have participated in oyster projects. In the case of tilapia and shrimp only 33% and 37%, respectevily, have participated in development projects (Table 27). The participation of fishermen in aquaculture projects was significantly related to their association in cooperative organisations

[Cramer's V= 0.414 (P <0.05)], but this is only true for oyster. For shrimp and tilapia projects, respondents have participated regardless of whether or not they are cooperatives' members, Cramer's V= 0.149 (fish), 0.168 (shrimp) (P <0.05).

Table 27. Participation of fishermen in aquaculture projects

Group of Respondents	*Oyster*	*Tilapia*	*Shrimp*
Cooperative:			
Andrés García	172	80	76
Boca de los Angeles	67	27	19
Mecoacán	96	29	52
Puente de ostión	32	11	17
Independent fishermen	7	1	0
Total number of fishermen	367	147	164

In the last fifteen years aquaculture has been promoted and introduced as an alternative to fishing, and fishermen had noted that extensive culture practices for tilapia and shrimp have been introduced in recent years. However, from the 30 groups organised for shrimp culture in Mecoacan estuary, only one enclosure nearby the estuary zone was found, managed by a group of six associated fishermen. This group collects shrimp postlarvae from the wild, stocks them in a 1.5 ha enclosure made with gill net at a density of 10,000 per ha and feeds them commercial pellet feed for pigs. The costs of feed were quoted as Pesos$17.5 per day for 5 kilos.

According to the fishermen, during the first production cycle, when working for the cooperatives they received a payment of Pesos$ 20.00 per night for guarding the enclosure. From the 3 tonne production obtained they only gained a total revenue of $200.00 Pesos each, which they considered to be too low for their labour. The second cycle was lost due to flooding and damage caused by seasonal hurricanes. The group of fishermen is now carrying out a third production cycle without cooperatives' participation. At the time of the interview they had finished the postlarvae collection. For this cycle they stated that they had already contracted their production to a local middleman and expected to produce one tonne of shrimp with an approximate value of Pesos$ 15,000.00 (USD$ 1,530.60).

One example of tilapia culture is carried out in ponds by a family group of fifteen people. Another two cooperative associated groups keep tilapia enclosures within the estuary coastline. Tilapia seed was supplied by the government hatchery located at the south of the state in Teapa municipality. However, production is low, at 300 kilos per hectare. The price of tilapia produced in ponds was quoted as Pesos$ 10.00-20.00 per kilo (US$ 1.00-2.00). The fishermen stated that due to limitations in technical and management support for developing a commercial enterprise, this is kept for family consumption or for sale to local traders and restaurants. Under these conditions, fishermen quoted a financial return of Pesos$4,500.00 (USDollars$ 438.80).

5.4.3 Marketing practices

Middlemen collect around 85% of fisheries production. Cooperatives trade 80% of oyster products and trade in a minor extent in shrimp and some marine species. The relationship between the association of fishermen and the trader they choose to deal with was found to be low [Cramer's V= 0.074 ($P > 0.05$)]. However, 65% of the entervewees trade with middlemen (Table 28). Fishermen trade either with cooperatives or middlemen depending on the payment offered for the catch and previous arrangements (e.g. repayment on equipment or gear). The areas in the

Mecoacan estuary where most of the trading takes place are Puerto Ceiba, Banco, Bellote, Torno Largo and Chiltepec. Distance between landing areas and trading places are in average 15 km. The most important commercial species are traded by middlemen in Mexico City, Alvarado (Veracruz) and Puebla (Puebla). Price is variable, as middlemen set it regardless of the consent of cooperatives, even though they are the associations entitled by law to manage and control market prices (See section 6.2.2).

Table 28. Distribution of fishermen according to major fisheries traders

Group of Respondents	*Cooperative*	*Middlemen*
Cooperative:		
Andrés García	75	142
Boca de los Angeles	57	47
Mecoacán	34	58
Puente de ostión	7	30
Independent fishermen	10	14
TOTAL	183	291

Two out of the four cooperatives carried out direct market transactions, but these were only for oyster products. The rest of fisheries products enter the market at the local level in two ways, through middlemen and through direct sales. They are then dispatched to major middlemen located in Mexico City, which in turn sell products to large retailers who reach the final consumer (Fig. 77).

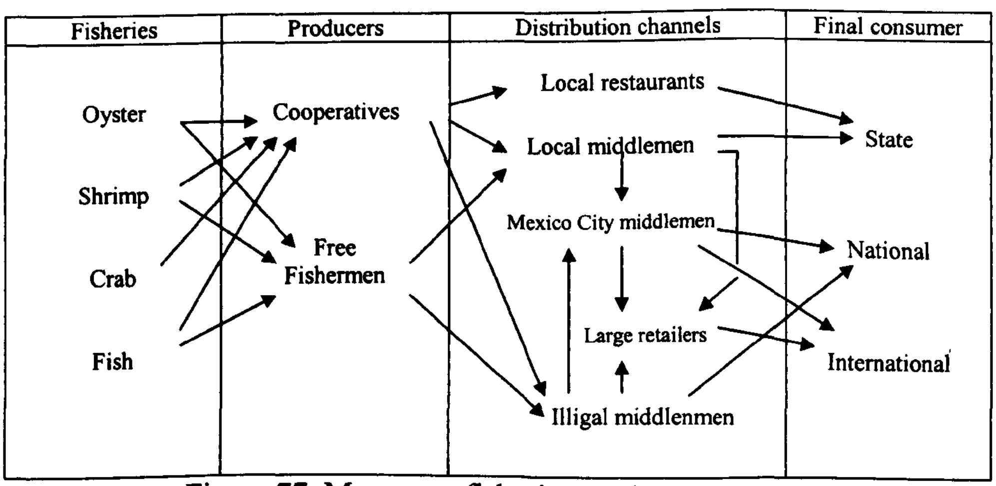


Figure 77. Mecoacan fisheries market structure.

Added value processing is not widely practised. The product is currently sold fresh and ungutted. In the case of marine fish species and to a lesser extent for shrimp, freezing is employed by fishermen not only to preserve the product but to be able to collect batches of at least one tonne and to make the shipment costs worthwhile. This is carried out mostly by local middlemen or by those fishermen working for a middleman in the main cities mentioned. The time required to collect batches is not longer than two days to avoid loss of product quality. Although, salted and dried products are sold locally, this is not a significant activity, as less than 1% of the enterviewees market these products.

5.5 Specific fisheries characteristics

5.5.1 Oyster

On average one oyster fisherman catches 230 kg, with a range between 73-387 kg fishing five days per week (Table 29). They use a thousand oysters as a unit, locally called *arpilla*, to sell the catch. To catch 1000 shell-on oysters, some 45 kilos, from the estuary they spend an average of 6 hours. The largest number of fishermen involved in oyster fishing was found in Andres Garcia cooperative. Prices vary between Pesos$ 39.00 and 47.00, with an average of Pesos$ 44.00.

Table 29. Average production of oyster

Group of Respondents	*Number of fishermen*	*Average volume kg/fishermen*	*Average price Pesos $/45 kilos*	*Yearly average volume Kg*	*Yearly average income per fishermen*	*Yearly average revenue Pesos$*
Cooperative:						
Andrés Garcia	113	99	47.00	581,724	5,376.80	607,578.40
Boca de los Angeles	65	86	46.00	290,680	4,571.38	297,139.55
Mecoacán	47	73	39.00	178,412	3,289.87	154,623.73
Puente de ostión	21	99	47.00	108,108	5,376.80	112,912.80
Independent fishermen	10	387	43.00	201,240	19,229.60	192,296.00
TOTAL	256	149	44.00	1,360,164	5,195.07	1,329,938.10

The oyster fishing season is closed during the rainy season from September to mid December. Although the Fishery Law states that oysters larger then 4 cm must be selected and any thing smaller returned to oyster beds, the size of shell-on oyster captured is between 3-4 cm. The selection practice is called *despicado* and it was reported to be observed by 44% of oyster fishermen. The fishery is artisanal and oysters are caught using a grab called a *rasqueta* or by diving (Fig. 78). The oyster catch is transported from the estuary directly to the households, as a family practice, as processing is no longer carried out in cooperatives' facilities.

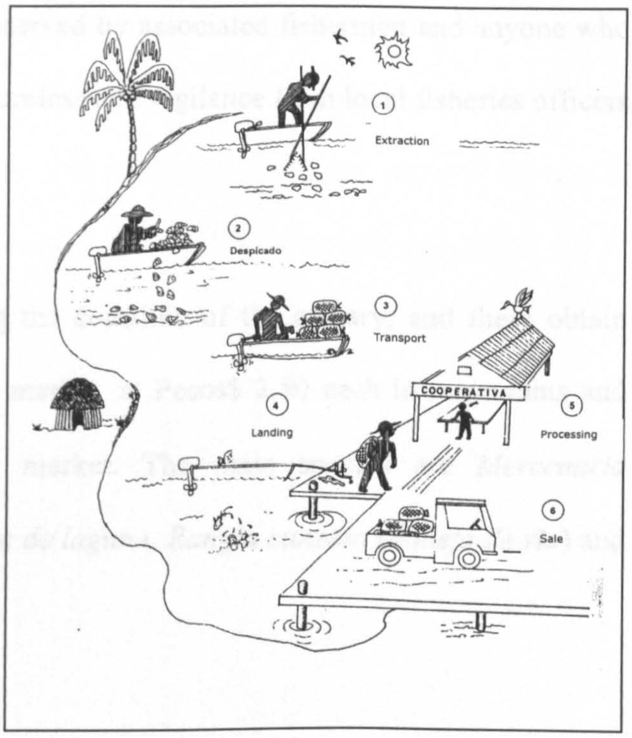


Figure 78. Oyster fishery (Rodriguez, 1994)

The meat is then taken to cooperative facilities where it is placed in plastic bags with cold water and then into containers with ice. The content of the plastic bags is not measured in wet weight, but by the number of oysters, in order to know how many oysters each fisher has brought, and be able to pay them equitably. Plastic bags are filled with 100, 300, 500 and 1000 oysters according to client requirements. The shells are no longer used as substrate for restocking oyster beds in the estuary or preparing culture ropes, but are used to fill holes in the road or as a building material. This is forbidden by law, which should be observed by associated fishermen and anyone who catches oysters. However people are careless and vigilance from local fisheries officers is minimal.

Mussel species are also caught along the coastline of the estuary, and these obtain better prices than oysters in the local market, at Pesos$ 2.50 each in restaurants and Pesos 0.60¢- $1.00 in the trading market. The main species are *Mercenaria campechiensis* locally known as *almeja de laguna*, *Rangia cuneata* (*almeja de rio*) and *Brachidontes recurvus* (*almeja negra*).

5.5.2 Fish

These are caught in both marine and estuary zones. 22% of the respondents were involved in marine fishing. The locals stated that marine fishing started approximately in 1996 with the arrival of marine fishermen from Veracruz state who were looking for fish stocks in Tabasco's coastline as fisheries were declining in the southern part of Veracruz. It was also stated that pollution and hydrological changes in the Mecoacan estuary had reduced fish stocks and fishermen have had to move out of the estuary to fish and to gain a livelihood. The main marine species are spanish mackerel *Scomberomorus maculatus* locally know as *sierra*, king mackerel *S. cavalla (peto)*, belted bonito *Sarda sarda (bonito)*, red snapper *Lutjanus campechanus* (*huachinango*) and cutlassfish *Trichiurus lepturus* (*cintilla*).

Most marine fishermen own only their fishing gear, while the patron own the boats and outboard engines. Fishermen have to deliver their catch to them as part of the credit arrangement for fuel, boat and engine. The patron's employees process the catch. Though it can increase their revenue, less than 10% of fish processing is carried out by the fishermen. In estuary fisheries, 85% of fishermen own the fishing gear, boats and engines, these being small boats and artisanal gear in 50% of cases. No processing is done and fishermen sell catch whole and ungutted to middlemen either at their facilities (*neveras*) or on arrival in harbour. The total number of *neveras* in Mecoacan estuary is 17.

Catch prices vary with species and season, fluctuating from Pesos$ 1.00 to $30.00 (recorded during Easter). The rest of the year prices fluctuated between Pesos$ 1.15-5.50 with an average of Pesos$ 3.41 per kilogram (Table 30) (according to prices established by brokers in Mexico City and Veracruz state middlemen set seasonal prices). The fishing season lasts from February to November, subdivided into three periods according to the most important species, cutlass fish (Jan-Jul), snapper (May-Oct) and mackerel (Feb-Jun/Oct-Nov).

Table 30. Fish production

Group of Respondents.	*Number of fishermen*	*Average volume Kg/week*	*Seasonal price average Pesos$/Kg*	*Total revenue Pesos$*	*Average revenue Pesos$/ fishermen*	*Yearly average volume Kg*	*Yearly average revenue Pesos$*
Cooperative:							
Andrés Gracia	115	11,318	1.50	16,977.00	147.63	452,720	679,080.00
Boca de los Angeles	24	523	1.15	601.45	25.06	20,920	24,058.00
Mecoacán	41	1,131	4.40	4,976.40	121.38	45,240	199,056.00
Puente de Ostión	19	522	4.50	2,349.00	123.63	20,880	93,960.00
Independent fishermen	13	1,400	5.50	7,700.00	592.30	56,000	308,000.00
TOTAL	212	2,979	3.41	32,603.85	202.00	119,152	260,830.80

5.5.3 Crab and shrimp

These fisheries usually alternate, the shrimp season commonly following the crab season. However, both are captured all year long regardless of the *vedas*, official periods of time when these species are not supposed to be captured. Fishermen capture these species as alternative source of income, when weather conditions are not good enough for marine fishing; but crab captures are mainly done by elderly fishermen and those who have not been able to get involved in marine fishing. Prices for shrimp fluctuated between Pesos$ 10.00-30.00 per kilo. The fishermen stated that high prices for shrimp are only available when dealing with middlemen or during the *veda*. Significant fluctuations for crab prices (Pesos$ 4.80-6.40) were not recorded. On average a fisherman catches about 8-20 kilos of crab and 8-10 kilos of shrimp per week, with an average value of Pesos$ 66.70 for crab and Pesos$ 131.60 for shrimp (Table 31).

Table 31. Crab and shrimp production per week

Group of Respondents	*# Fishermen*	*Crab kg/week*	*Average kg/fishermen*	*Average price/kg*	*Average earnings per fishermen**	*# Fishermen*	*Shrimp kg/week*	*Average kg/fishermen*	*Average price/kg*	*Average earnings per fishermen*
Cooperative Andrés Gracia	6	52	8.6	6.00	51.60	51	449	8.8	10.00	88.00
Boca de los Angeles	9	81	9	4.80	43.20	38	207	5.4	12.00	64.80
Mecoacán	23	198	8.6	6.40	55.40	29	229	7.8	17.40	135.72
Puente de ostión	0	0	0	0.00	0.00	21	68	3.2	25.00	80.00
Independent fishermen	1	20	20	6.00	120.00	7	74	10.5	30.00	315.00
TOTAL	49	351	11.5	5.80	66.70	146	1027	7	18.80	131.60

*Pesos 9.30= 1 USDollar

Fisheries are still artisanal; very simple nets made with spare material from fish nets are used to capture crab by laying them flat at the bottom of the estuary. These *nazas* form a sort of bucket with a conical or flat bottom (Fig. 79). Shrimp is captured using gill and cast nets. The main species for crab are *Callinectes sapidus* and *C. similis* and for shrimp *Penaeus setiferus*, *P. aztecus* and *P. duorarum*.

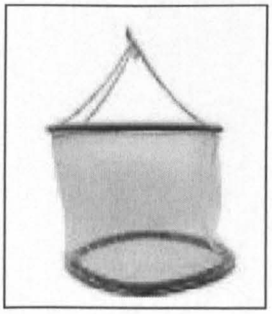


Figure 79. *Naza* net used to capture crab

Icing is the only processing done for shrimp. The trip from the site where the nets are placed to harbour can take an average of two hours. Usually the fishermen take with them a container filled with ice to place the catch from previous night and then transport it to the harbour sites where it is handed to the buyers or refilled with ice and taken to the *neveras*. Crabs are captured alive in the estuary shoreline. Fishermen take the catch to the household where it is cooked and the meat separated and packaged in plastic bags or containers for transport to external markets or local sale.

5.6 Resource management

The fishermen were questioned regarding the resources available in the Mecoacan estuary. The concept is poorly understood, but after rephrasing the question with local expressions it was found that 85% of the respondents agreed that fisheries were the most important resource and stated that they have not been allowed to participate in its management and allocation, or to parcipate in decision-making for aquaculture development.

As confirmed by formal sources, associated fishermen stated that until the 1980's oyster fishery and culture was regulated and use rights granted only to fishing cooperatives by the local federal fisheries office, which distributed oyster beds and culture sites among cooperatives for production operations under government funded programmes (Fig. 80). However, after the oyster fishery collapsed in 1992 (Moguel, 1994) oyster beds and culture were gradually abandoned and the fishery became an open access resource.

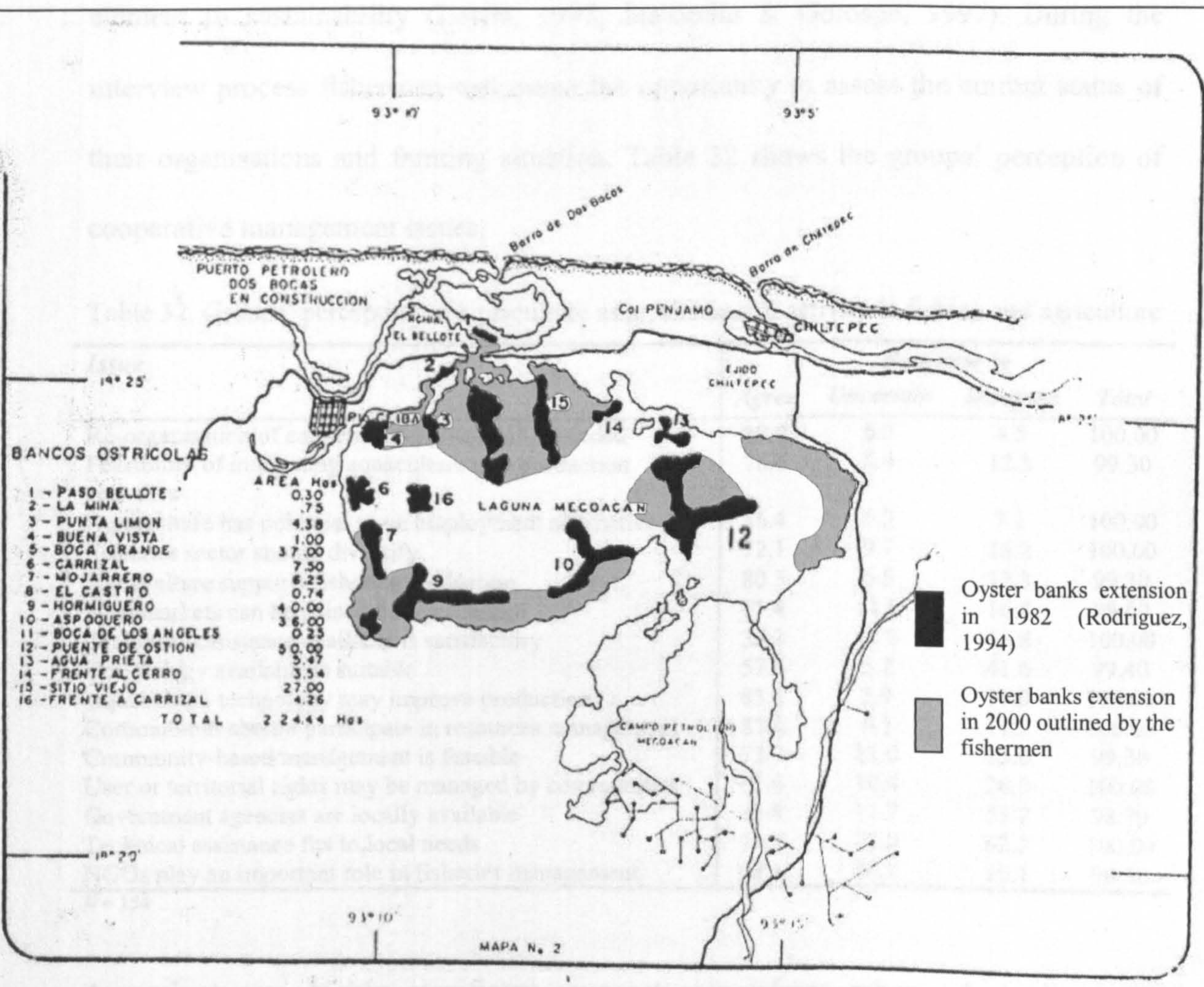


Figure 80. Location and extension of Oyster banks in the Mecoacan estuary

5.7 Fishing co-operative membership: Effects on resource access

5.7.1 Attitude to cooperative management

In the past, the neglect of community participation in management had been an important factor in decreasing research and extension support. The need for community involvement in management has been widely proposed as an important element in sustainability (Lewis, 1997; Sunderlin & Gorospe, 1997). During the interview process fishermen welcomed the opportunity to assess the current status of their organisations and farming situation. Table 32 shows the groups' perception of cooperative management issues.

Table 32. Groups' perception of aquaculture as an alternative activity to fishing and agriculture

Issue	***Response %***			
	Agree	***Uncertain***	***Disagree***	***Total***
Re-organisation of cooperative institutions is needed	89.0	6.5	4.5	100.00
Feasibility of integrating aquaculture into production activities	78.6	8.4	12.3	99.30
Aquaculture has potential as an employment alternative	86.4	6.5	7.1	100.00
Fisheries sector should diversify	72.1	9.7	18.2	100.00
Aquaculture supports fisheries production	80.5	6.5	12.3	99.30
New markets can be gained by aquaculture	71.4	11.0	16.2	98.60
Technical assistance available is satisfactory	33.2	11.0	55.8	100.00
Technology available is suitable	52.6	5.2	41.6	99.40
Aquaculture technology may improve production	83.1	5.9	11.0	100.00
Communities should participate in resources management	81.8	6.5	11.7	100.00
Community-based management is feasible	72.7	11.0	15.6	99.30
User or territorial rights may be managed by communities	63.6	10.4	26.0	100.00
Government agencies are locally available	31.8	11.7	55.2	98.70
Technical assistance fits to local needs	24.7	13.0	62.3	100.00
NGOs play an important role in fisheries management	59.1	20.1	20.1	99.30

N = 154

Agreement was highly significant amongst respondents when asked about the importance of the reorganisation of cooperative institutions. Participation, collective decisions and attention paid to financial aid were considered as particular issues to be improved through restructured cooperatives (Fig. 81). Fishermen stated that they would like to be involved in the management and decision-making processes.

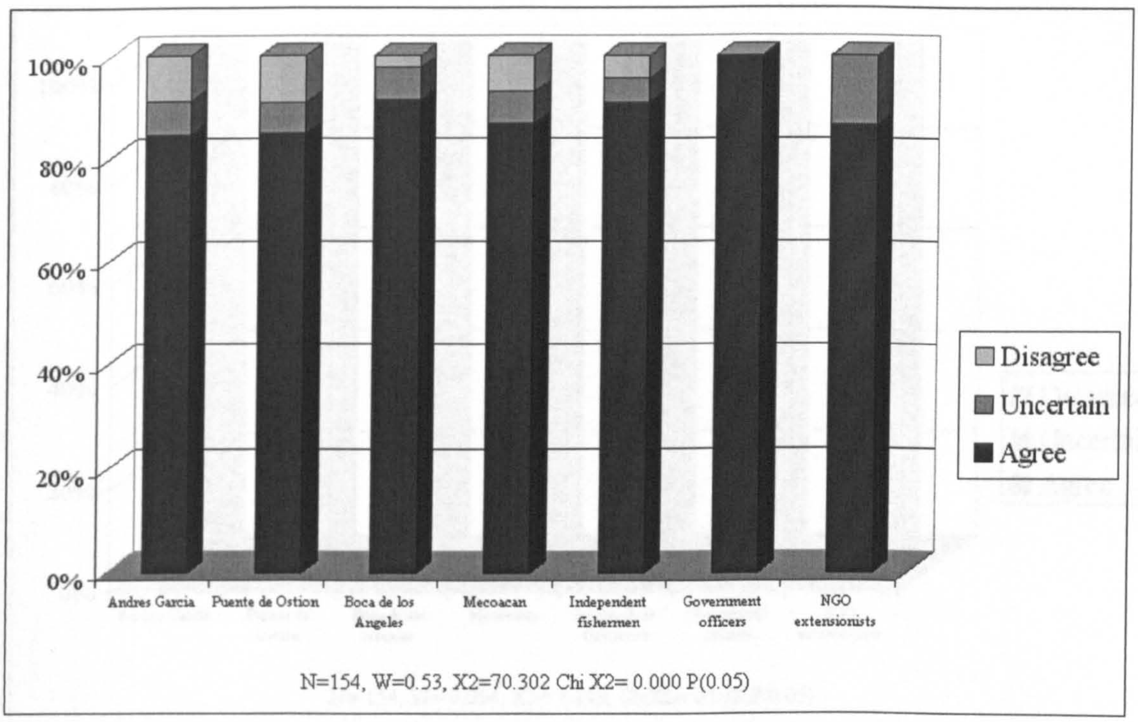


Figure 81. Reorganisation of cooperative institutions

5.7.2 Attitudes to aquaculture

The availability of diverse economic opportunities where there is perceived production scarcity influences the way people weigh and adopt those alternative opportunities. In the face of regional economic and development changes, and conflict over resources 78.6% of the respondents agreed that aquaculture might still represent an alternative to improve income-generating activities (Fig. 82). However, the level of concordance was low [Kendall's W= 0.054]. The main concern expressed by respondents was previous losses through poaching and flooding, which have made site selection an important issue among the cooperative members with aquaculture experience.

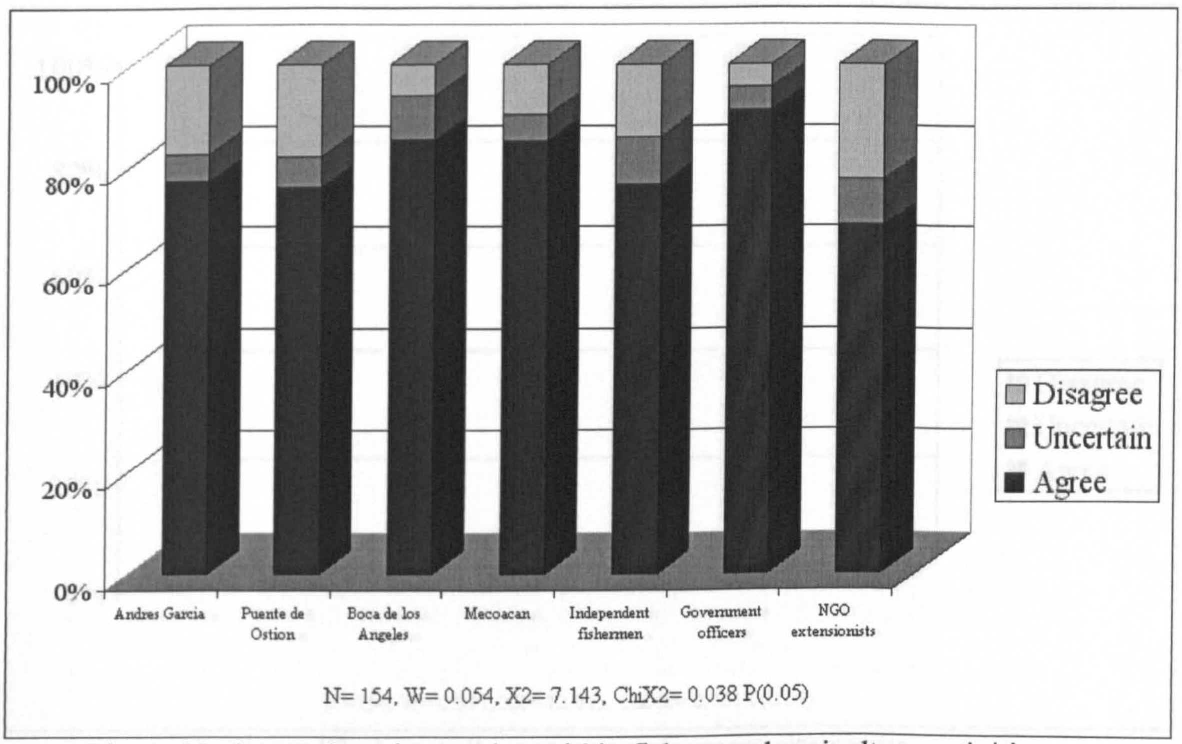


Figure 82. Aquaculture integration within fishery and agriculture activities

Aquaculture was perceived strongly as an income and employment generation activity in the estuary area, as 86.4% of the respondents considered that long-term job opportunities might be gained (Fig. 83). As it can be observed from the low level of concordance between independent fishermen (free riders) and the members from three of the fishing cooperatives, the problems in the area can be related to inadequate development policies.

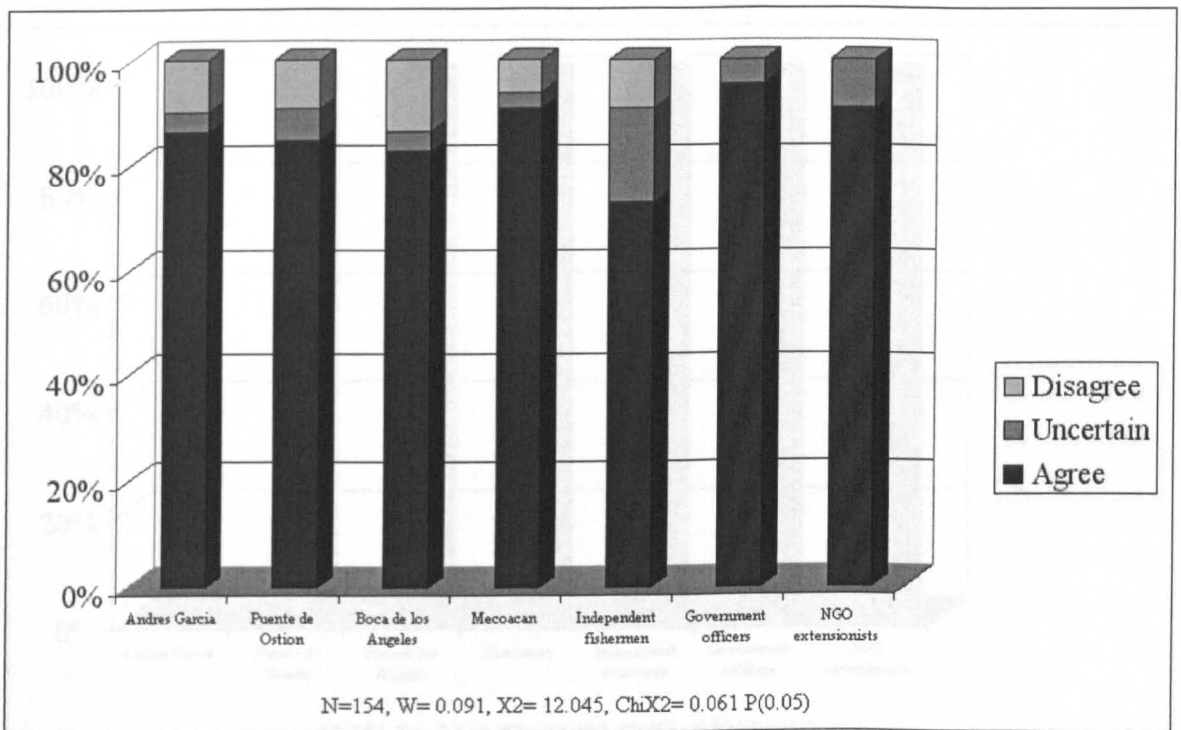


Figure 83. Aquaculture as an employment alternative

All the groups were interested in diversifying the fishery sector and considered aquaculture as an alternative to current production practices (Fig. 84). Although the coefficient of concordance is low, a highly significant agreement was found, as 72.1% of the respondents were aware of the potential impact of sustainable aquaculture practice in positively influencing communities' livelihoods. However, among independent fishermen (free riders) the level of agreement is very low, as 50% of the respondents disagree or were uncertain of the positive effects of aquaculture activities amongst the communities. This may be related to the low access or participation that independent fishermen have had in development projects for improving current or promoting new culture practices, as discussed in the previous section.

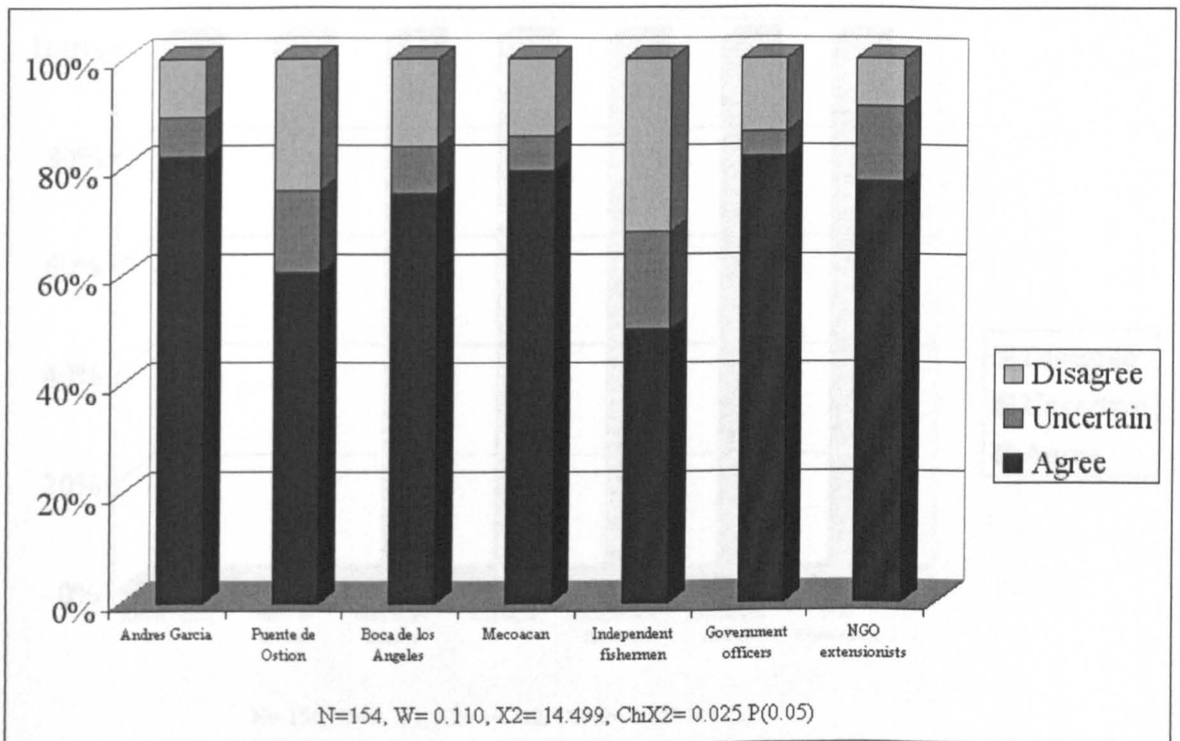


Figure 84. Attitude towards sector diversification

In order to continue over the longer term, all organisations have to generate a surplus of income over expenditure. The current status of fishing cooperatives in Mecoacan is of low profitability, which has led to a run down of equipment and facilities and clear member dissatisfaction. These conditions within cooperatives have affected negatively independent fishermen's perception of associations, promoting disbelief and reluctance to join any fishing organisation. A highly significant agreement was found when respondents were asked if aquaculture could represent an alternative production system to complement their fishing activities (Fig. 85). Although 80.5% of the respondents agreed on this issue, the low Kendall's coefficient may be related to the significant proportion of disagreement and uncertainty found between independent fishermen and the NGO.

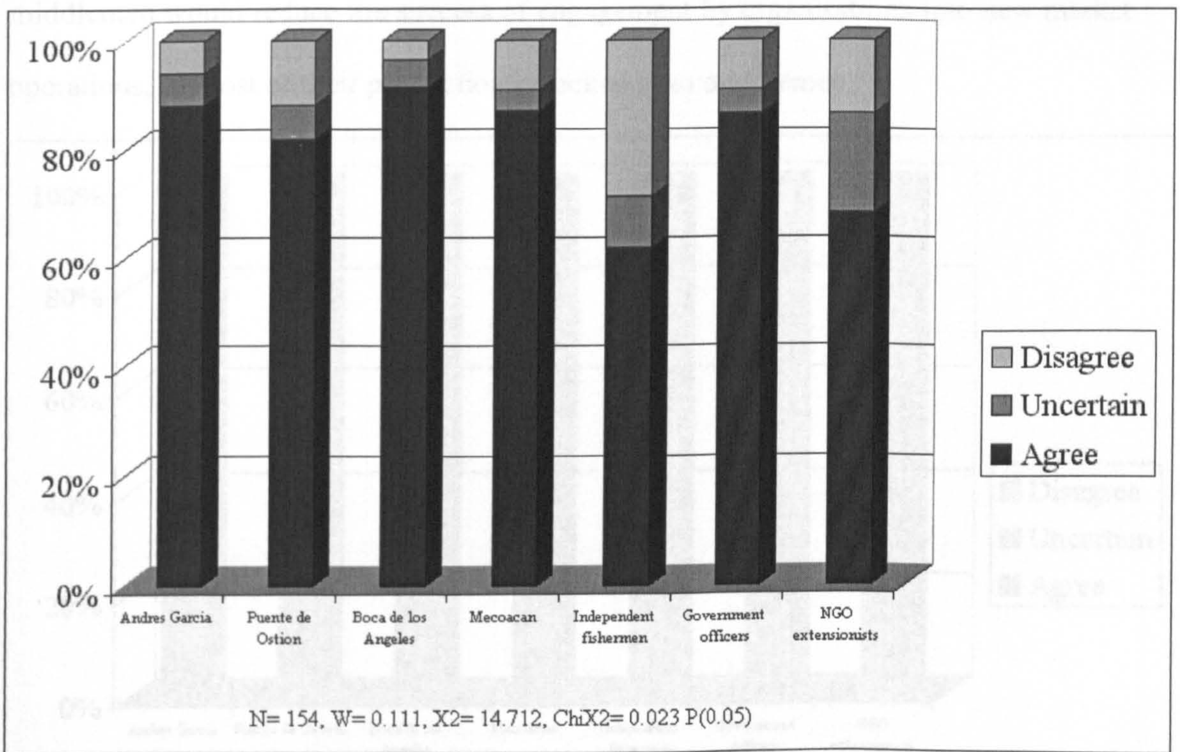


Figure 85. Aquaculture supports fishery production

5.7.3 Attitudes to market opportunities

The organisations have an important local market, although most of them sold to distant markets through middlemen. They tend to operate frequently in monopoly within a small proportion of the national market and to a lesser extent in the export market. Although market conditions are controlled by traders (e. g. pricing), there is the possibility to engage into a larger market offering the opportunity of greater sales, access to new and/or broader distribution networks, and the possibility to reduce their dependency on middlemen if they could produce more.

The level of agreement regarding aquaculture as means of gaining new markets was highly significant (Fig. 86) in spite of the reduced proportion of agreement by independent fishermen, which may indicate that competition and strength of middlemen would reduce the success of engagement by organisations into new market operations, as most of their production is locked in to middlemen.

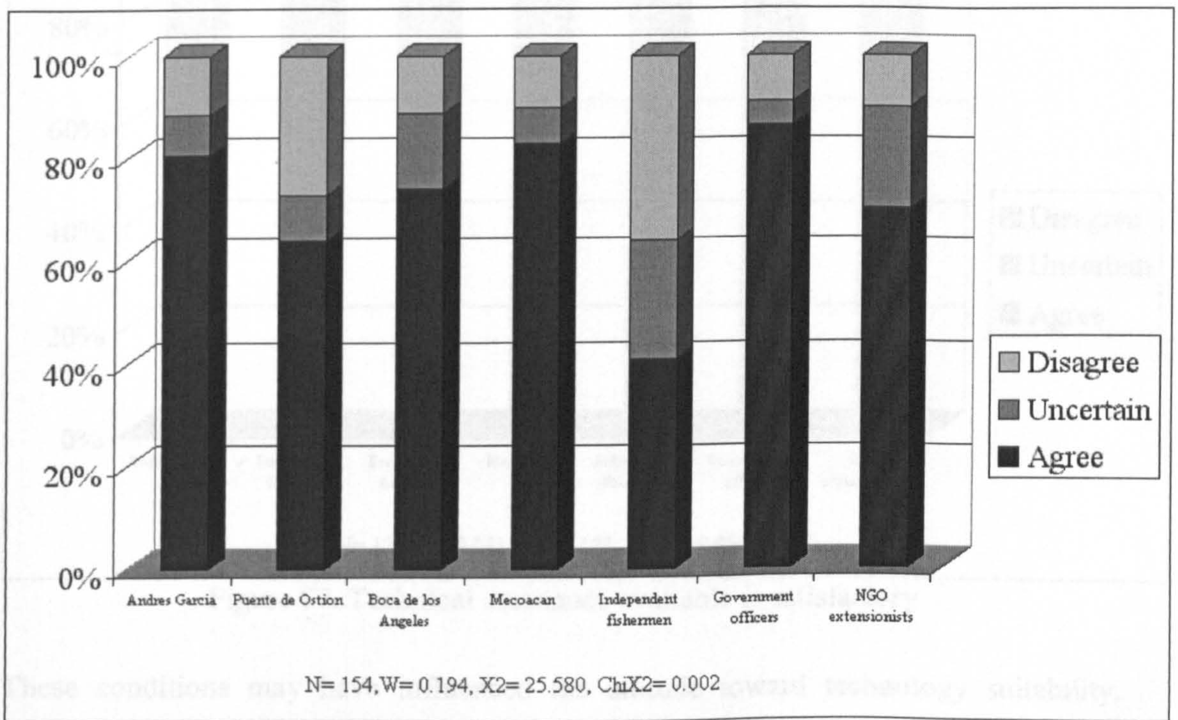


Figure 86. New markets gained by aquaculture

5.7.4 Access to technology

Technology has important ecological and economic dimensions. Site development has been neglected as ecological changes have occurred in the estuary making existing technologies outdated or ineffective. No significant differences were found, as the level of agreement between groups was low with 55.8% disagreement and 33.1% agreement when asked about the technical assistance available (Fig. 87).

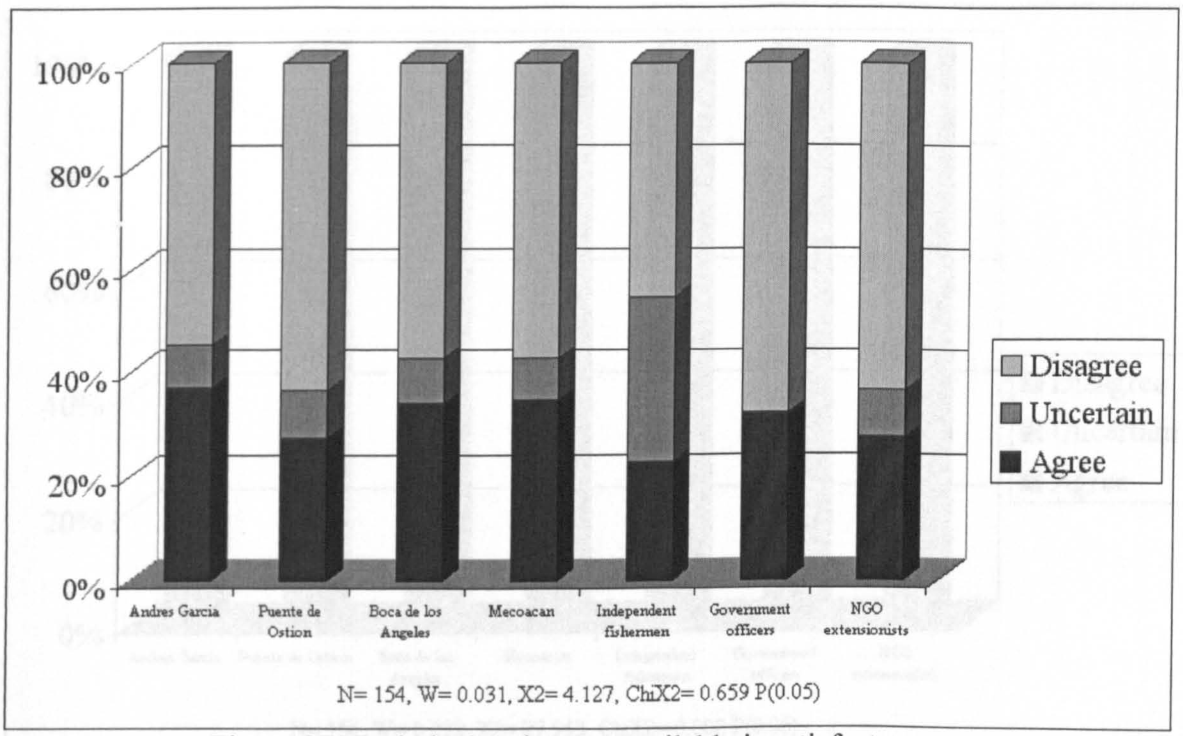


Figure 87. Technical assistance available is satisfactory

These conditions may have influenced the attitude toward technology suitability. Fishermen possess empirical knowledge of the patterns of production of the estuary. This knowledge has been extended through development projects, which have focused on oyster and fish culture systems implementation and management. A highly significant level of agreement was found between the groups. About 52.6% agreed that aquaculture technology available is suitable (Fig. 88).

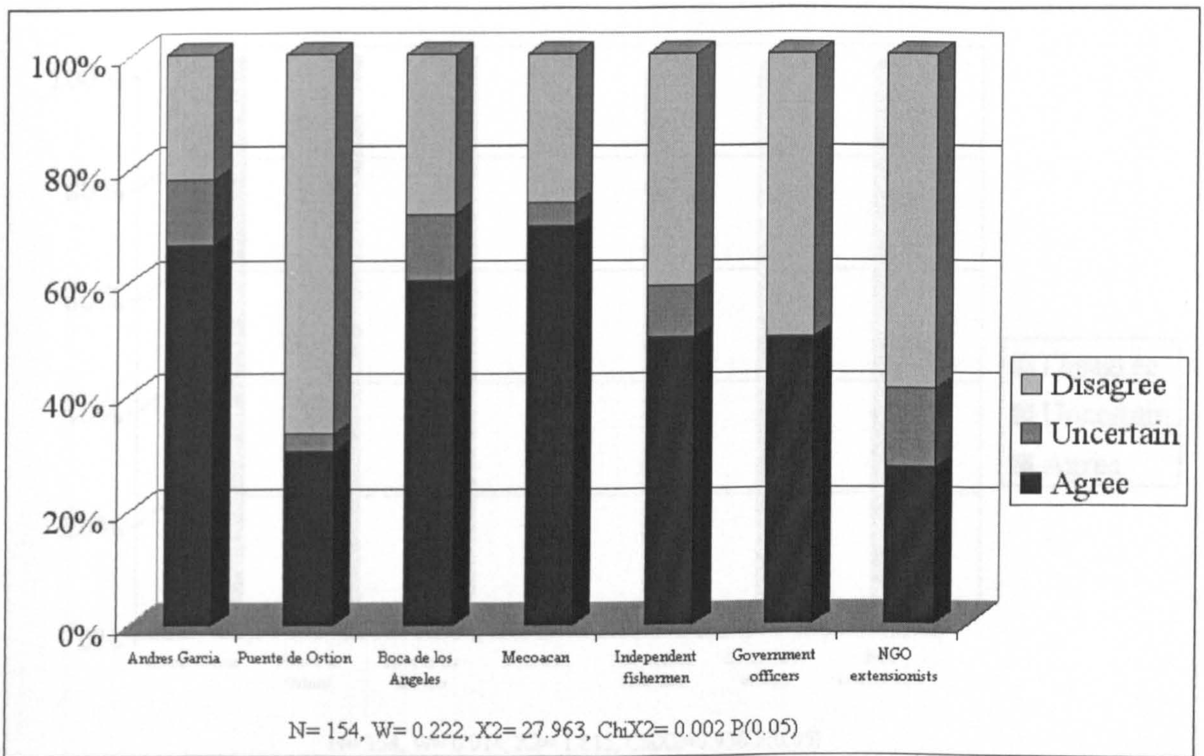


Figure 88. Aquaculture technology available is suitable

83.1% of the respondents acknowledged aquaculture technology as an alternative to improve production as shown in Figure 89. Similar responses were found between independent fishermen (free riders) and the members of the smallest cooperative, while a similar level of agreement was found between the NGO agents and the second smallest cooperative, Boca de los Angeles.

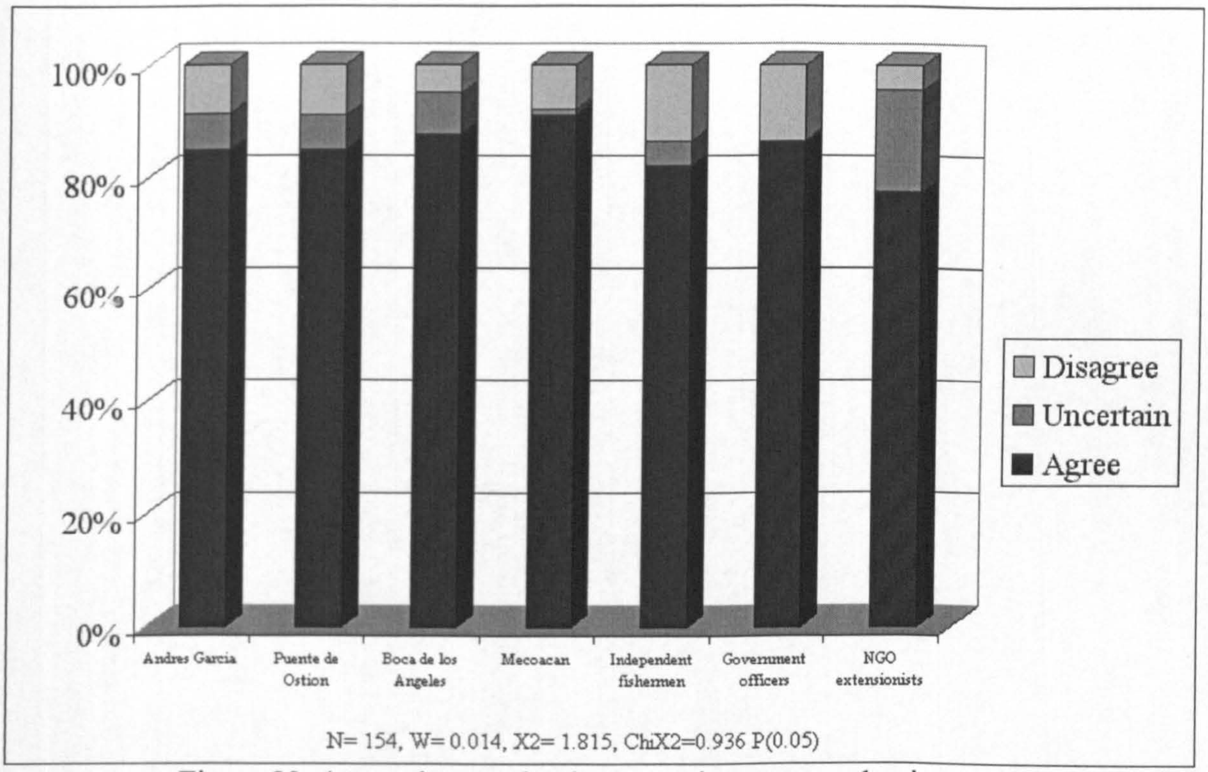


Figure 89. Aquaculture technology may improve production

5.7.5 Attitudes to decision-making

Although no significant differences [W= 0.061] were found in the level of agreement among groups regarding community participation in decision-making, more than 81.8% of the respondents from each group agreed on collective participation for resources management (Fig. 90). Associated fishermen commented that their influence in the management of cooperative resources is minimal, as organisations are less responsive to members' needs or participation. To a large extent, problems faced by cooperatives in controlling market conditions may be due to the low participation of members in the decision-making process. The general agreement on the suitability of community-based management for Mecoacan resources is high (72.7%) (Fig. 91).

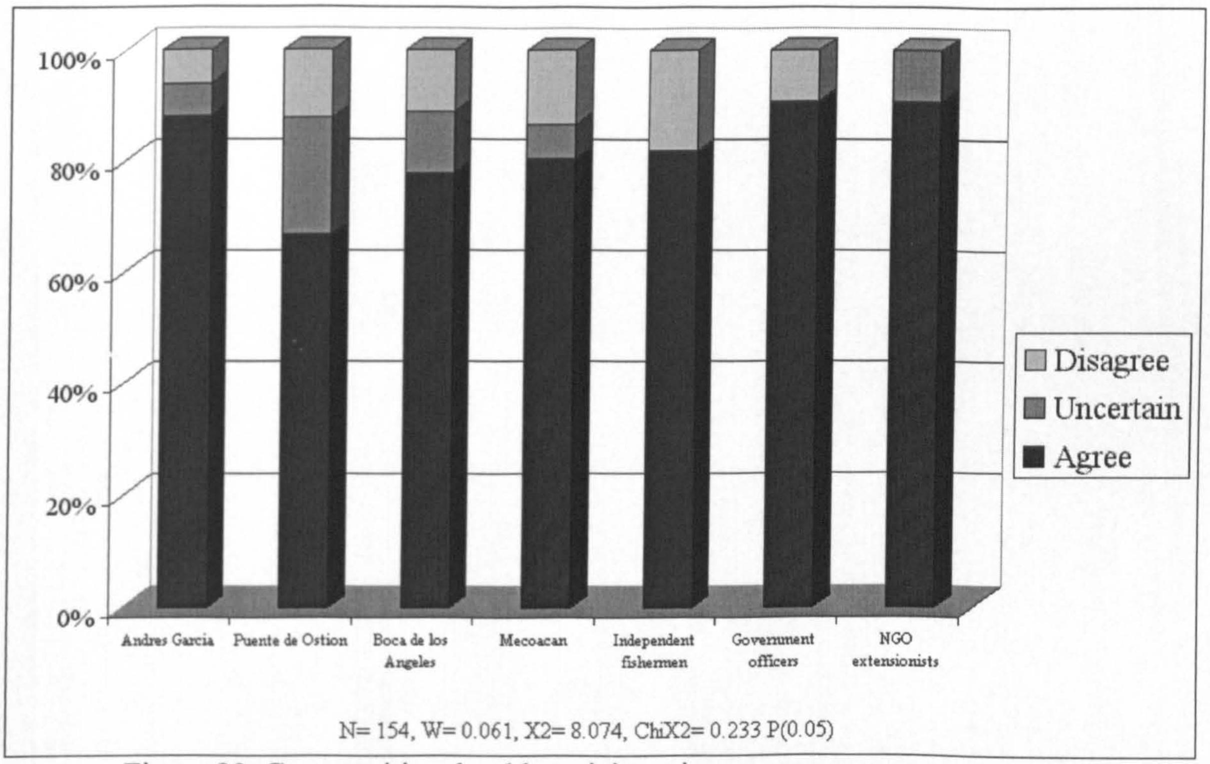


Figure 90. Communities should participate in resources management

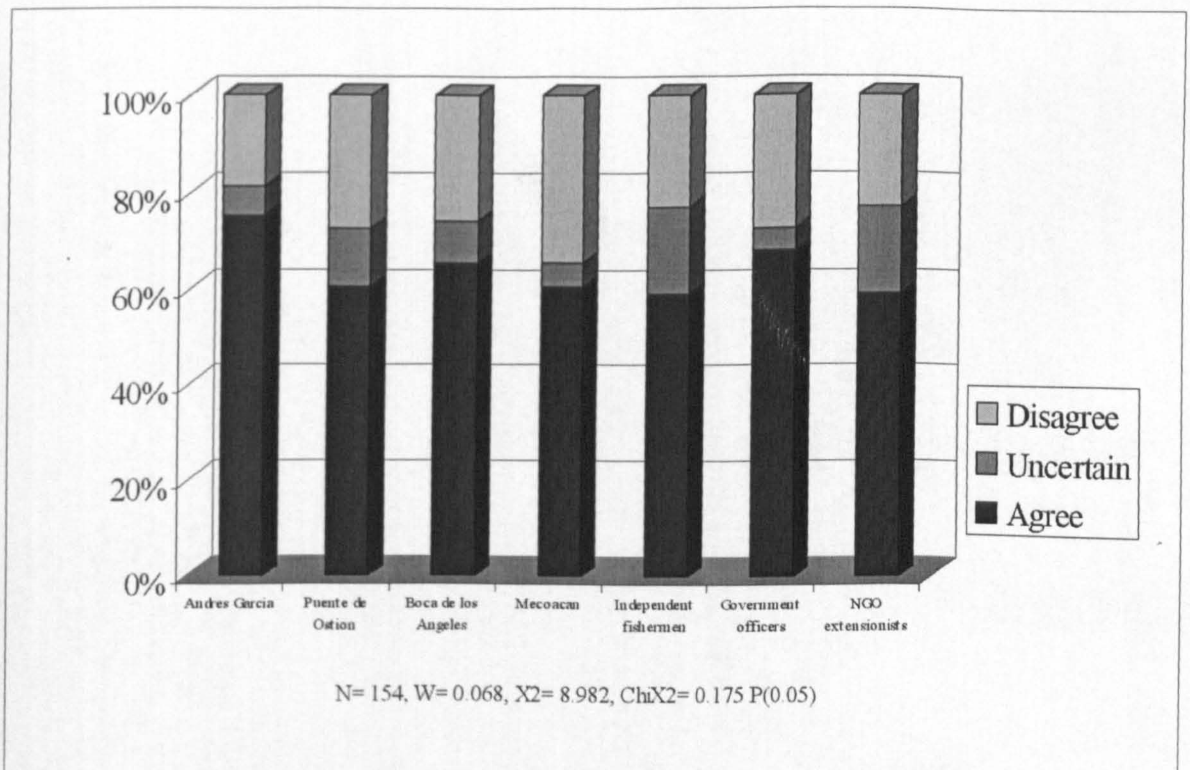


Figure 91. Community-based management is suitable

These have resulted in the desertion of members from organisations, and their hire as labour to middlemen for sea fishing, due the perceived higher income. All organisations were reported to have a prevailing history of dishonesty, as reported by members and fisheries officers; hence trust in the management of the organisation has deteriorated due to corruption and mismanagement of resources. This condition may have influenced the responses, as differences were found between Andres Garcia cooperative and the other groups regarding use or territorial rights (Fig. 92).

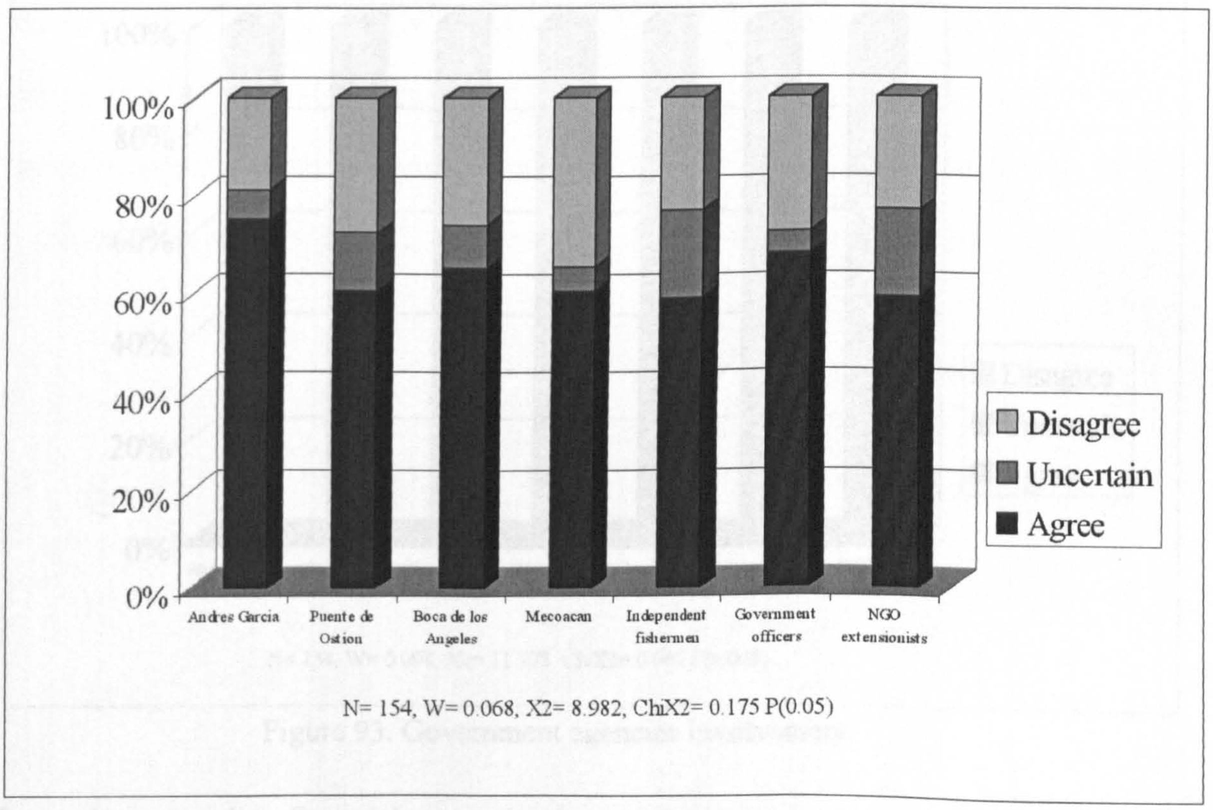
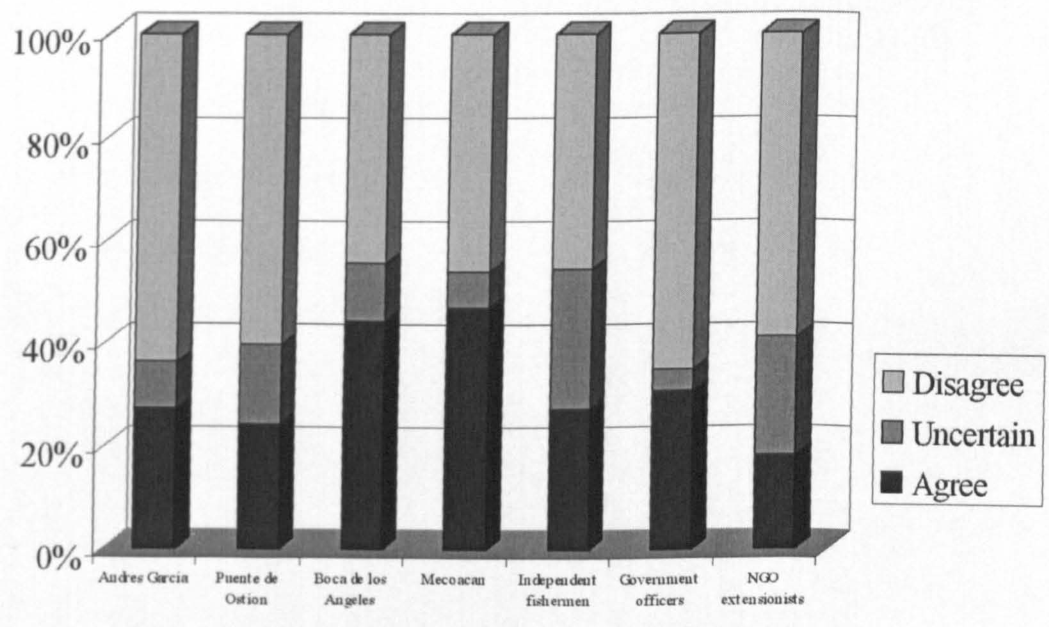


Figure 92. Communities may manage user or territorial rights

5.7.6 Attitudes to government support

Attitudes toward government involvement were found not to be significantly related, as 55.2% of the respondents disagree that the government involvement in fishing organisations was satisfactory (Fig. 93). Although government intervention is regarded as an important factor in supporting and promoting cooperative organisation (McManus, 1995; Roy, 1999), the involvement of government agencies in conflict solving has been low.



N= 154, W= 0.098, X2= 11.778, ChiX2= 0.067 P(0.005)

Figure 93. Government agencies involvement

Perceptions regarding financial support such as government loans and subsidies were among the most commonly raised issues when groups were asked about government involvement and representation in the sector. One of the major drawbacks in cooperative organisations has been the great interference by government, leading to a state of apathy in members and conflicts among organisations, as financial dependency on government funds has encouraged the feeling that organisations do not have to be financially self supporting.

Gains in technical knowledge were significant in the implementation of farming practices. The low level of involvement of government as the main aquaculture technology facilitator has influenced negatively the appreciation of fishermen towards the link between technology and potential benefits and improvement of livelihoods. 62.3% of the respondents disagree that available aquaculture technology is linked with current socio-economic features of the communities. This may be related to the low impact of programmes for employment and income generation, as they have failed to accommodate the increased population in the area of the estuary. The attitude of respondents towards these conditions was found highly significant (Fig. 94).

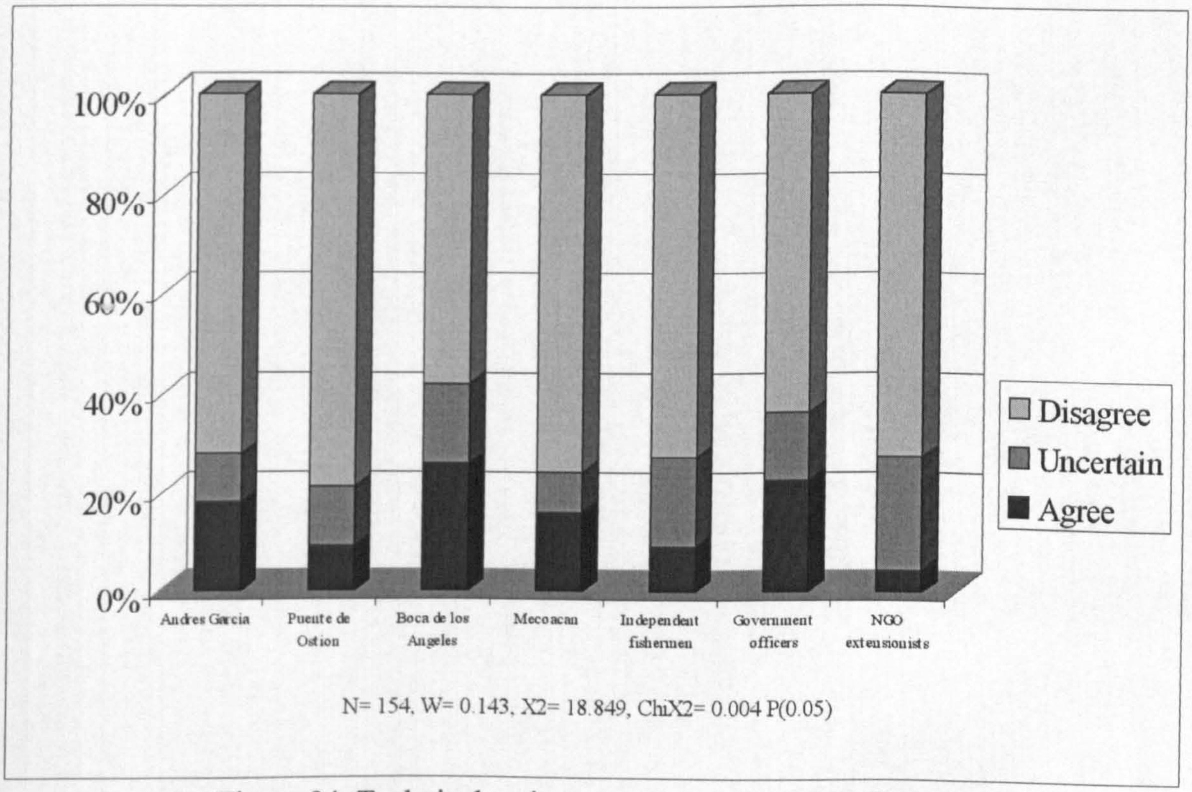


Figure 94. Technical assistance proper to local needs

5.7.7 Attitude to NGOs

Linkages are important in creating awareness, training farmers, setting up production units and securing political support and cooperation. The level of agreement was found highly significant with 59.1% of the respondents considering the participation and involvement of NGOs in community affairs to be important (Fig. 95).

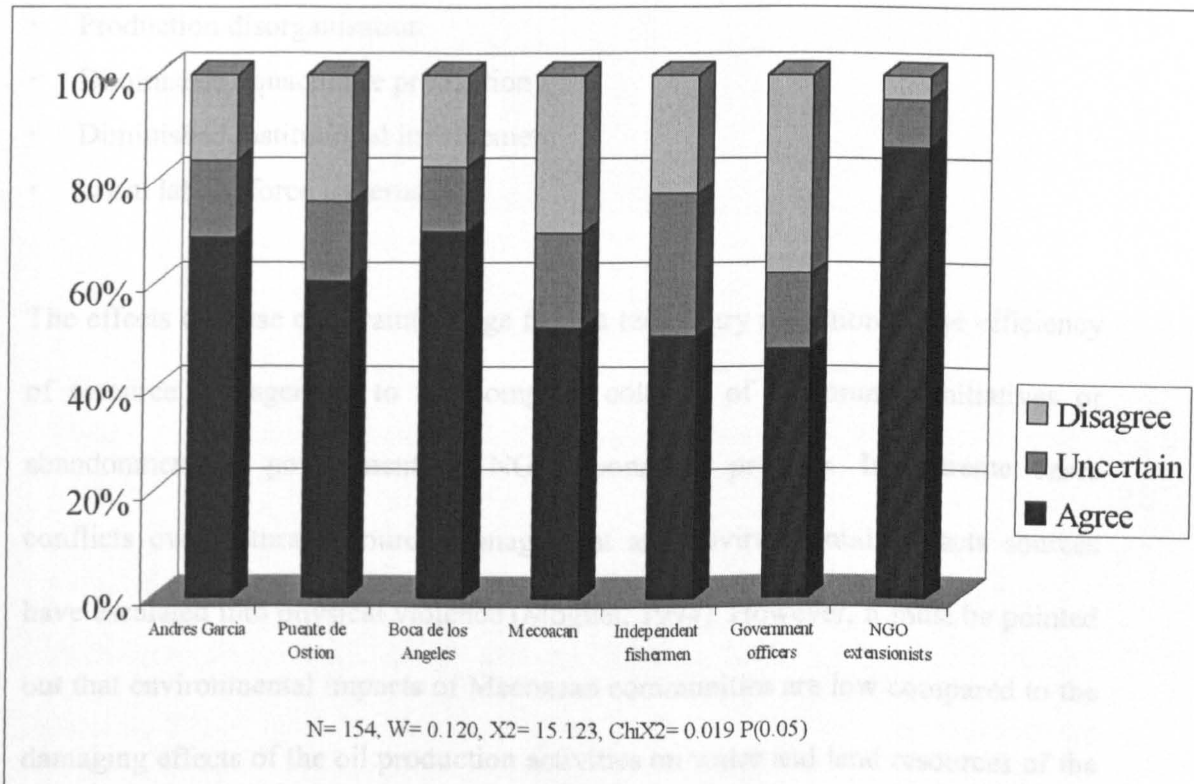


Figure 95. Non-governmental organisations role in fisheries management

5.8 Livelihood indicators of Mecoacan fishing communities

5.8.1 Stakeholder analysis

After the preliminary assessment of the socio-economics issues of fishing communities of Mecoacan the following areas of concern were identified:

- Increased conflicts due to open access conditions
- Unmanaged ecosystems
- Poor and unmanaged cooperative organisations
- Poor market conditions and regulation
- Production disorganisation
- Diminished aquaculture production
- Diminished institutional involvement
- Local labour force underused

The effects of these constraints range from a temporary reduction in the efficiency of resource management to the complete collapse of community initiatives or abandonment of government or NGO sponsored projects. In extreme cases conflicts over natural resource management and environmental impacts sources have escalated into physical violence (Moguel, 1994). However, it must be pointed out that environmental impacts of Mecoacan communities are low compared to the damaging effects of the oil production activities on water and land resources of the area.

Causes of problems involve complex inter-linkages between the biophysical, technological and socio-economic conditions at the local level and the socio-political structures at the national level. There are few options for a predominantly rural society under Mexico's new neoliberal development polices to improve their activities in a competitive market coupled with an uncertain economy (Fig. 96).

Most problems largely derive from the dominant oil industry development policies in the region, and the attempt to delineate a strategy for sustainable development in the context of a North-South partnership may represent a complex task due to the rural dislocation produced by the overlooked development policies through NAFTA (Fraser & Restrepo-Estrada, 1996; McDonald, 1997).

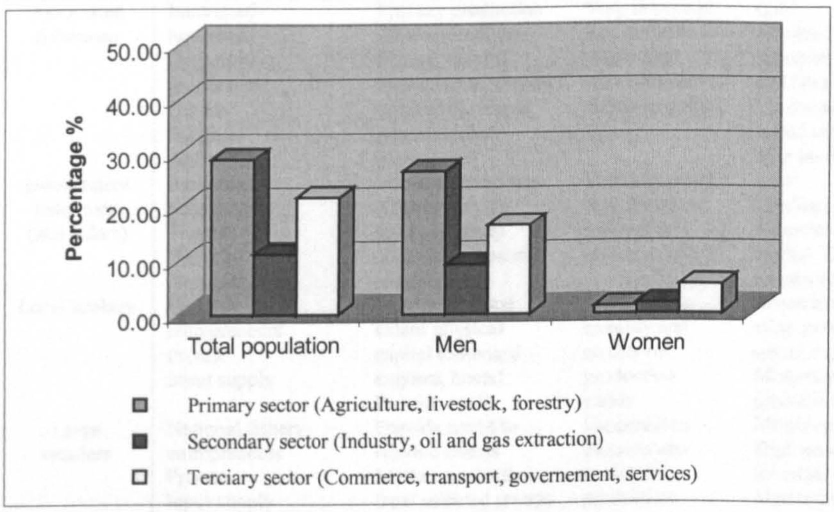


Figure 96. Tabasco's population distribution according to activity by production sector and gender (INEGI, 2002)

Among the different groups in the area, competition exists because of a combination of political change and the physical limits of renewable natural resources. These have become underlying causes of conflicts, as most of the stakeholders described in Table 33 may interact inside and outside fishing cooperatives through diverse kin relationships, and group control exists by the wealthy few over the poor or low income households.

The use of participants' local knowledge and experience produced an appropriate and effective identification of social relationships, environmental impacts, accessibility to assets and technical constraints. The analysis of Mecoacan stakeholder composition showed different levels of participation and the impact of social relationships on access and use of resources. Fishermen have low or minimal power over financial and physical capital. Although they are key decision-makers over resource use they have low or minimal control of natural capital.

Table 33. Stakeholder composition in Mecoacan estuary

Stakeholder		*Sector*	*Function*	*System importance*	*Power over capitals*
Category	*Label*				
Primary	Associated fishermen	Individual-household Organised-production Private Fishing Agriculture	Primary production (Estuary and sea fishing, harvest oyster farms, shrimp enclosures, tilapia ponds, coconut plantations)	Very important Key decision maker over resources use and farm output	Low Minimal power over financial, physical and natural capital. Moderate power over social capital. Control over human capital
Primary	Independent fishermen (free riders)	Individual-household Private Fishing Agriculture	Primary production (Oyster and sea fishing, shrimp enclosures, coconut plantations)	Very important Key decision maker over resources use	Low Minimal power over financial and physical capital. Control over human capital
Secondary	Local brokers	Fishery-entrepreneurs Private Input supply	Provide in some extent physical capital (outboard engines, boats) Provide credit	Important to quantity and quality of production yields	Moderate High power over social capital. Moderate power over physical capital
Secondary	Large retailers	National fishery-entrepreneurs Private Input supply	Provide credit to reliable clients Market production from selected groups	Important to quantity and quality of production yields	Moderate High power over financial capital Moderate power over physical capital
Secondary	Local and national illegal middlemen	Fishery-entrepreneurs Private Input supply	Provide physical capital (outboard engines, boats) Provide credit in exchange of labour	Important to quantity and quality of production yields Significant to farm operations	High Moderate power over natural capital. High power over social, physical and financial capital. Moderate power of human capital
Secondary	NGO fishery and agriculture delegates	Technicians Non-profit-organisation Private	Promote group organisation Linkage organisations to credit institutions Provide technical and financial advice	Important Alternative influence over fostering social association Vital in giving advice	Moderate Low power over physical capital. Moderate power over financial and natural capital. Moderate power over social and human capital
External	Delegates of the fishery secretariat	Fishery bureaucrats and technicians Local government Public	Provide technical advice Influence group membership. Represent fishery regional sector at national level. Linkage organisations to other government institutions. Provide credit. Oversees fishery production and regulation	Important source of credit Facilitates farm operations Significant influence over social interactions	High Moderate power over physical capital High power over social and natural capital

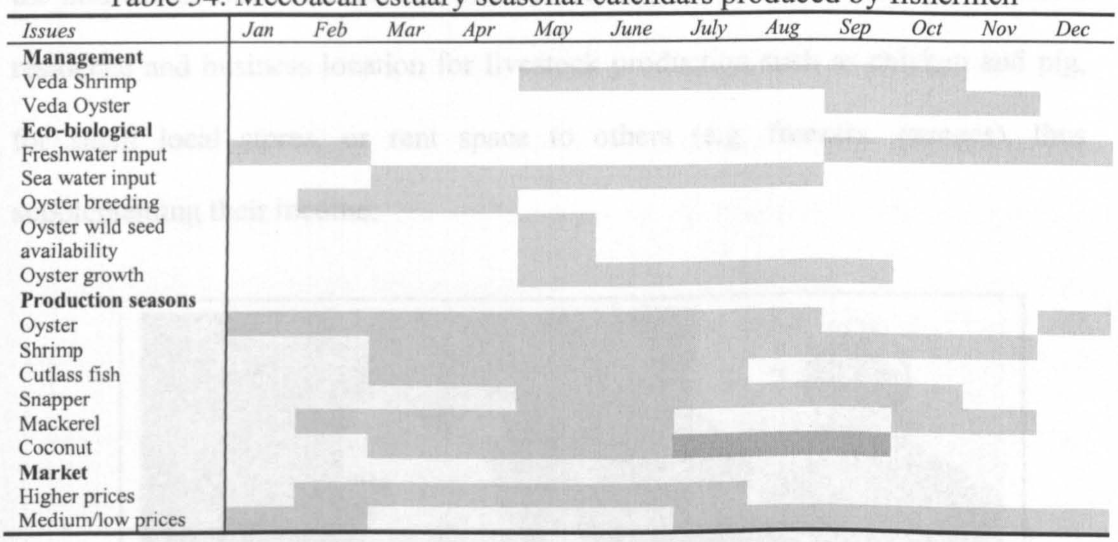
5.8.2 Seasonal calendars

Ecological changes in Mecoacan estuary have been widely discussed in the literature. Although there has not been an agreement of whom (e.g. fishermen) or what (e.g. oil industry) is producing these changes, what this does not change is the fact that the estuary is under pressure from several natural processes and human activities (Galaviz *et al.*, 1987; Arredondo *et al.*, 1993; Burreson *et al.*, 1994; Diaz *et al.* 1994; Moguel, 1994; Sima *et al.*, 1996; Lopez *et al.*, 1997; Velazquez & Meza, 1996; Rodriguez, 1998; Valdes, 1998).

Most of the strategies of the people from the Mecoacan estuary depend on the capacity for building opportunities within the area, despite significant constrains produced by environmental and economic conditions. Fishermen commented that environmental impacts induced mainly by the oil industry are the most significant concern due to pollution shocks and changes in estuary ecology. However, they also acknowledged that seasonal changes (e.g. rainfall, temperature) are significant factors decreasing capture fishery volume and value, and physical limitations of agro-ecosystems due to drought, flooding and marginal soils have lead to insecurity and migration. According to fishermen, the most significant macro and microeconomic factors effects on local communities have been the price variation of fishery produce as a result of trends in devaluation and inflation, and the prevailing market system controlled by local illegal middlemen and large retailers located in Mexico City.

The seasonal calendar produced from PRA meetings with local stakeholders is shown in Table 34. Aquaculture and fishing practices vary along the year and are significantly affected by eco-biological conditions and the *vedas*. Fishermen activities are varied and they may participate in different levels of fishing and aquaculture activities, as described in the section 5.2. The breeding and grow out season of oyster is relevant for all fishermen dependent on this fishery. They commented that freshwater (September-February) and seawater (March-August) inputs are the major events they observed in order to identify the areas where the most of the oyster seed would occur, either to collect and transfer to on-growth systems (May-September) or to be able to calculate the harvest time for natural banks (December-August).

Table 34. Mecoacan estuary seasonal calendars produced by fishermen



The effect of market prices is highly significant. Fishermen have access to better value per catch from February to July, with the availability of high value species and high market demand due to religious traditions and tourism. Fishing is only reduced during the rainy season (October-January). During this period some fishermen get involved in agriculture activities, mainly in coconut production, which is the most important agrarian commodity for export in the area. Others put all their fishing effort on oyster and other estuarine species, and a reduced number keep fishing marine species, as they possess more and better equipment and experience. Cash flow hardships are concentrated at this period when fishing activities are reduced and only low payment activities are available, making household debts increase through informal credit.

One way for families to sustain income is by employing more family members as wage earners. Most households use labour as a buffer against adverse economic conditions, drawing on labour reserves of women when infrastructures such as schools free up time for employment. In several cases children are also involved (Fig. 97). Housing also represents a buffer against economic difficulties, as most of the households have secured title to land and are able to use their homes as both a residence and business location for livestock production such as chicken and pig, for small local stores, or rent space to others (e.g. freezers, garages), thus supplementing their income.

Figure 97. Family members as wage earners

The transfer of technology for rural production has not yet provided viable solutions in many areas, as impacts of economic policies have translated into increased poverty and social atomisation among the communities (Calzada, 1997). Household decision making or coping strategies by associated fishermen has led to less dependence on oyster fishing and culture, partly because there has been a shift into subsistence agriculture (coconut, lime, chilli) and fishing of high value marine species. In the case of independent fishermen (free riders) the converse occurs, in that most of their activities move towards oyster fishery and on fishing less valuable estuary species. However, this is not an indication that fishermen associated in cooperatives are wealthier than free riders. The situation is that cooperative fishermen with low income more easily gain access to government programmes, either for agriculture and fishing support or poverty reduction, while low-income independent fishermen may not be eligible.

Although most households provide for the basic subsistence needs of food, clothing, and shelter, they also consume goods or make expenditures related not only to production, also to the achievement or validation of status and prestige. Most households sponsor public ceremonial events connected with the day of the dead, Christmas, baptisms, weddings and to some extent Easter. For those in administration, office holding requires expenditures of time, which is taken from productive activities. Based on the above, household strategies of Mecoacan communities are significantly vulnerable to the seasonality of sources of income. Cash flow hardships are concentrated at the end and beginning of the year due to the significance of socio-cultural activities, which contribute to household debt increase through informal credit.

5.8.3 Indicators analysis

As the aim of the study is to assess the effectiveness of an ICM framework for aquaculture development in Tabasco coastal zone a list of indicators was produced from the PRA interviews with fishermen and cooperatives' management committees (Howlett *et al.* 2000; Rigby *et al.*, 2000) to explore livelihood priorities of local people and institutional intervention effects (Fig. 14). The list of indicators was developed based on stakeholders' assessments of success and failure of past and current aquaculture experiences. A more general list was then generated by combining the lists of success and failure indicators (Table 35).

Once the combined indicator list was produced, in order to address the specific, relevant question of whether aquaculture can develop collectively, a multi-criteria evaluation was carried out to identify potential indicators. The items provided by the stakeholders were condensed by similarity into a sub-set of 20 indicators based on a consensus among the respondents and according to the availability of data (Garcia *et al.*, 2000; Garcia & Staples, 2000). The evaluation was then done through a ranking exercise using the indicators considered being the most important for fishermen (Appendix C).

Table 35. List of indicators for aquaculture success and failure

Indicators of successful farming	*Indicators of farming failure*
Small groups of participating household	Household lack of participation within large groups
Efficient technology transfer	Lack of technology to improve aquatic produce
Storage facilities available nearby aquaculture sites (freezers)	Lack of storage facilities (freezers)
Planning for production	Lack of planning for production
Resilient timing for aquaculture operations	Lack of follow-up procedures in scheduled operations
Size selection to improve oyster on-growing systems, tilapia pond management	Lack of stock and pond management
Perimeter fences and surveillance to avoid poaching	Diminished or abandoned surveillance and free access to sites
Set of combined indicators: Indicators identified by household heads	
Availability and access to extension services and knowledge	
Availability of market for produce	
Availability and capacity of land	
Group interest in aquaculture enterprise	
Availability of good aquatic sites for semi-intensive production	
Access to capital for investment	
Restructure of cooperative organisations	

The ranks corresponded to subjective thresholds defined by the author (Text box 1). Table 36 shows the score given to each indicator. The assessment is based on qualitative data in order to be able to display ranks and avoid having to aggregate through different scales (e.g. having to aggregate income level and quality of water resources). The multi-criteria analysis provided a convenient means to define their hierarchical structure. Non-parametric statistical analysis of the survey data indicated a significant level of agreement among stakeholders.

Although this assessment only reflects value judgements, underlying information was conserved through the aggregation of indicators and it was possible to examine further the data by correlating their distribution effects into spatial models, as a means to identify alternative resource uses to minimise conflicts.

Table 36. Indicator ranking for aquaculture development

Environmental indicators	*Ranks*					*Socio-economic indicators*	*Ranks*				
	A	*B*	*C*	*D*	*Mean*		*A*	*B*	*C*	*D*	*Mean*
Water resources	10	10	9	10	9.8	Human resources	10	8	10	7	8.4
Soils	9	3	1	2	3.6	Employment	9	9	6	9	8.4
Roads	8	1	2	1	2.6	Activities interaction	8	5	3	3	4.6
Oil industry	6	7	7	4	5.8	Land ownership	7	3	2	1	3.0
Agriculture	5	4	5	5	5.4	Inputs	6	6	7	6	5.6
Livestock	7	8	8	8	7.0	Urban areas	5	4	5	5	4.0
Forestry	2	6	4	6	5.0	Farm-gate sales	4	10	8	10	8.0
Existing farms	4	2	3	3	2.8	Interaction between existing farms	3	2	4	4	3.8
Urban areas	3	5	6	7	5.4	Income	2	7	9	8	7.2
Population density	1	9	10	9	7.6	Energy	1	1	1	2	1.2

A= Associated fishermen, B= Independent fishermen (free riders), C= NGO extensionist, D= Government officers
Good= 10-8, Fairly good= 8-6, Moderate good= 6-4, Poor= 4-2, Very poor= 2-0
$W = 0.53$ $X^2 = 50.45$ $\chi^2_{r\ 0.05,4,9} = 7.08$

The results from the ranking matrix of indicators produced by fishermen showed that the most valued assets are human resources, employment and water resources. Effects of institutions and other processes have also reduced people's ability to access resources, as indicated by the low rank given to activities and proximity between farms. Examples include the absence of proper regulations or enforcement regarding the access to resources by unemployed populations and free riding fishermen who capture species regardless of fishery laws and fishing season or zone, as they claim to have the same rights as associated fishermen to extract any species to support their livelihoods.

This leaves fishermen' organisations unable to access opportunities that could assist them in managing the estuary's resources properly. This condition is exacerbated by the inconsistent and disjointed services administered by different local authorities and the entry of private aquaculture investors without the participation of cooperatives, in the allocation of culture sites (Fig. 98).

In reality the problems are more complicated, as deeper conflicts prevail regarding structural inequalities inherent in legal definitions of resource use. Other causes of conflict are the increasingly complex arrays of developmental regulation, which can skew access to natural resources, accentuating latent levels of competition and concentrating resource degradation within small areas, as government agencies rarely consider the management of resources from the rural communities' perspective.

Figure 98. Private oyster farm located at the boundaries of national oil industry facilities

5.8.4 Human capital

The concern of fishermen regarding the job market in Mecoacan is that there are few long-term prospects in the area. These concerns were expressed through the ranking survey, as human resources and employment were highly ranked. The precarious employment opportunities present a significant risk of a skilled population loss from the area as young people seek careers in larger towns and cities. This migration and the poor level of services and facilities in the area signifies the depletion of human capital as the job market is rapidly changing, making communities more vulnerable to marginalisation and isolation due to economic decline and financial insecurity. These conditions are more evident in larger cooperatives.

Fishermen are highly concerned about their resources and will work toward conservation if approached in a positive manner and permitted to have input into management plans, as they tend to be keen to learn and familiar about technology, as described in section 5.7. Human capital according to the DFID (2001) 'represents the skills, knowledge, ability to labour and good health that together enable people to pursue different livelihood strategies and achieve their livelihood objectives'.

Due to the high rank given by the different stakeholders to human resources and employment an analysis of this asset was carried out. Estimates of human capital can be reliably isolated on the basis of few variables using temporary and specific quantitative household data and its correlate indicators, to test benefits and define how best to assist in community-based resource management on investments in human capital as an intervention tool (Nguyen & Meyer, 1999).

The effect and interactions of employment and income on human capital factors were tested considering the DFID definition of human capital. The factors considered in the analysis were household gross income, number of household members employed, family size, number of literate household members and household members considered economically active (15-60 years).

Literacy, household size and economically active population are among the factors used to define the human capital of any population (World Bank, 2000). Levels of literacy in Mecoacan are moderately good; in 48.6% of households all the family members read and write. This proportion may be related to that of family size, as 78.5% of household comprise less than seven members and 50% of their members are youngsters. It was found that the proportion for the population considered able to work, named the economically active population segment (age group 15-60 years), is high, as 71.6% of the household have between 2 and 4 members in this age group. The corresponding disposable household income is moderately good for 50.8% of the household, which earned between Pesos$200.00-350.00, 27.8% are below the minimum wage per day Pesos $35.00, corresponding to Tabasco (INEGI, 2000) and 21.4% had a disposable income between Pesos$390.00-3000.00.

The level of household income may be related to the number of income earning members; although the proportion of the economically active population is high, in

87.7% of the household only 1-2 members are involved in formal work. The conditions for this to occur are varied; nonetheless the main reason is that youngsters are studying, and work during school breaks. Elderly members are not involved in paid work or work occasionally, selling house-made food.

Because a significant correlation among the factors was found, it was required to run a principal component test in order to identify the patterns of relationship within the factors (Appendix F: i). Once the number of factors was reduced from five to two (Fig. 99), an independent samples test was carried out to observe the effect of group association on human capital (literacy, household size and economically active population) and livelihood resources (employment and income).

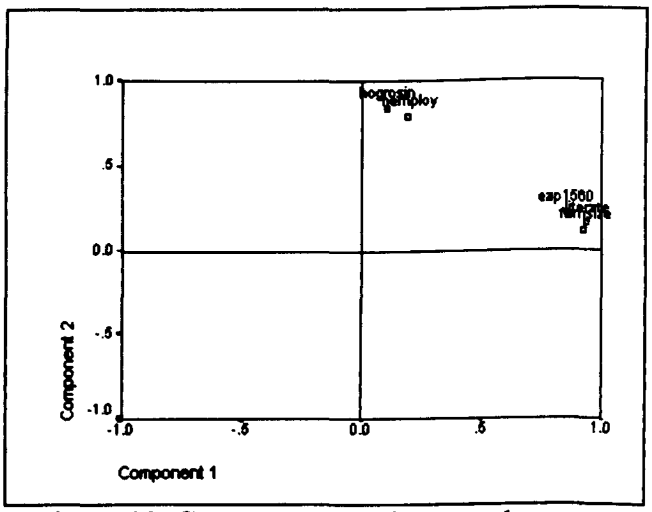


Figure 99. Component plot in rotated space

There were no significant differences between the groups for human capital and livelihood resources factors (equal variances were assumed with a $P>0.05$). This is indicative that the association of fishermen has not a significant effect on the accumulation of human capital [$t=1.483$, $P> 0.05$] and it does not have the expected positive impact on the household access to income and employment [$t = -0.849$, $P> 0.05$] (Appendix F: ii).

5.9 Discussion

5.9.1 Livelihood characteristics

Official statistics show that more than 95% of Tabasco's oyster production comes from aquaculture. However, field visits and references from fishermen indicated that oyster culture is no longer practised and that production is based 100% on fishing activity practised by less than 50% of associated fishermen. Culture sites are abandoned or poorly managed. The same conditions were found for managed oyster banks.

It was observed that for every associated fisherman there are three free fishermen and a similar number of women and children extracting oyster in the same areas. Moreover, a new fishing cooperative was established to organise free fishermen living at the south end of the estuary without the consent of the four cooperatives already established, representing a new source of conflict for resource allocation and use.

No data were available on yield and catch volume in relation to fishing effort. However, associated fishermen stated they learned from their own assessments and experience that stocks in oyster banks were low as the numbers of oyster found were less than 50, when it has should been more than 100 per square meter. It can be inferred from this experience and from the observed distribution of fishermen, the number of hours/days used up, and net income gained that the fishery is overexploited, as these are evidence of too much effort being applied without either improving capture nor income.

The market control exerted by middlemen has offered a little opportunity for added value to fisheries products. These poor market conditions and the lack of regulation have been widely described by government agencies and consultants (Arriaga & Rangel, 1988; De la Lanza & Arredondo, 1990; Sevilla, 1993; GDCI, 1995).

Findings from the analysis suggest that there have been no improvements since the 1980's as similar market conditions prevail, where middlemen are still controlling product distribution and price. Some other aspects have worsened within the cooperatives. The apparent lack of fishing and market regulation appears to be caused by a series of conditions including:

- Power struggles inside fishing cooperatives leading to disorganisation of production
- Lack of interest among members to support the operations of cooperatives due to self-reliance or simply because of indifference
- Lack of communication between cooperatives and federal and state Fishery Agencies
- Regulations corrupted by fishermen and officers: *Vedas* are not observed and fines are arranged "properly" between fishermen and officers
- Cooperative structure dysfunction: Free fishermen were working for cooperatives with membership privileges and members were not working at all for the cooperative, cooperative resources were managed for personal businesses, cooperative facilities were mismanaged, etc
- Market conditions highly controlled by middlemen

The conditions described above have promoted the movement of fishermen from estuary to marine fishing not only because the resources are more abundant, in theory, but also because of perceived higher income and absence of surveillance . Though it was estimated that marine fishermen receive 67% more for their catch than estuarine fishermen, labour conditions established by the *patron* are extremely poor and stressful. From the calculated average income and expenditure, although it can be assumed that marine fishermen receive a better income, they are always in debt as operating costs are equal or even double the total earnings. The local labour force was observed as an underused resource, in the case of women who provide more than 50% of fisheries processing labour.

It was also observed that no processes are carried out for fish carcasses. The remainder of skin, bones and guts are left at the harbours or around households nearby the estuary, polluting the water and soil, as it is not used in other ways (e.g. fertiliser). It was estimated that one fishing team might produce in average of 10 kilos of fish carcass per day. However, the development of vertical and horizontal integration of the fisheries industry is not a current or immediate management goal for the cooperatives or local fisheries agencies, despite development programmes that have stated such medium and long-term objectives (Gob. Edo. Tab., 1995).

Although added value may mean higher income, middlemen hire their own labour outside the fishing communities. The price difference is not significant i.e. for one kilo of whole and gutted fish the price offered was Pesos$1.00 and for gutted and filleted fish the price was Pesos$ 1.50 per kilo, while for whole fish the price per kilo variation was Pesos$ 5.00-35.00. Although some fishermen take the chance and process the catch, most do not process it as it takes more time to reach middlemen and the risk of lower prices is always present. Consumer preference for whole fish is the main reason for the differences in price when compared to fillet and gutted produce.

The case of aquaculture was not found to be different. In spite of the fact that fishermen are skilled in managing culture technology and farm sites, they were not keen to engage in aquaculture production, noting that "it takes too long to obtain a good production and the family has to eat every day". Moreover, prices were not significantly different from those for capture fisheries. Therefore, it is rather doubtful whether aquaculture would be economically attractive to most fishermen as previous experiences showed that revenue would be limited. The observed stakeholder structure and interactions may be indicative of important levels of fictional management of resources. This means that even institutions and structures exists they are not functional and any positive outcome from development and/or resources management programmes are dissipated through an excessive bureaucracy and lack of commitment from all stakeholders.

Furthermore fishermen have to face environmental constraints and conflicts. On the one hand, marine and estuarine fishing is affected constantly by seasonal weather changes with unforeseen consequences on resource availability. Mecoacan fishing communities have also to face environmental impacts caused by the National Oil Industry Petroleos Mexicanos (PEMEX) drilling sites and petrochemical plant, located around the estuary and on the coastline.

The impacts on the oyster fishery have been profound. The accumulation of hydrocarbon compounds in sediments and water column represents a major constraint for fisheries production in Mecoacan as described by Botello and Ponce (1998) and Villanueva and Paez (1998). Although many studies have been carried regarding heavy metals and hydrocarbons pollution in the estuary, none has been proved that this is a highly significant factor reducing oyster production quality (See section 6.3.1). On the other hand, these assumptions have been put out and increased concerns regarding human health have affected consumer preference and reduced market availability for oyster production. As earlier mentioned most production comes from oyster beds and the introduction of products in competitive markets has not been accomplished, as fishermen noted that potential consumers are concerned with heavy metals pollution. There were not found studies on consumer preferences and market for oyster production.

A third significant source of water pollution comes from unmanaged fisheries by-products and the poor sewage treatment network in the area. The impact of those pollution sources has not been comprehensively recorded. However, Rodriguez (1998) carried out a microbiology analysis of oyster from a pilot farm located at the Northeast end of the estuary close to one of the most densely populated Ejidos. The findings showed that though the oyster came from a site, which was assumed to have important impact from population settlements, no traces of *Salmonella* sp, *Vibrio cholerae* or *Aeromonas* sp were found (Appendix G).

In most cases, the economic and employment conditions described above were found to be the main reason for migration out of the state. The movement of local population is towards the United States. Females, and in a few cases males, join fisheries labour teams organised by a local group, to work for processing crab companies located in the coast of North Carolina state. Finally, although fisheries and animal enterprises are the major sources of protein in the area they do not represent an important protein source intake for local people, as they have to sell more than 80% of the production to support what is still then a poor household and livelihood condition.

5.9.2 Fishing cooperative membership: Effects on resources access

Government strategies for development

Mexico has a free market economy dominated by the private sector, with a mixture of modern and outmoded industry and agriculture. During the administration of Carlos Salinas de Gortari (1988-1994) it was proposed that the rural population would be enhanced to the equivalent of first world countries with the implementation of the North American Free Trade Association NAFTA. In order to lessen its dependence on the US, Mexico has pursued additional trade agreements with Latin America countries. A strong export sector helped to cushion the economy's decline in 1995 and led the recovery in 1996-99. Private consumption became the leading driver of growth. However, income distribution is very unequal, with the top 20% of income earners accounting for 55% of income. The number of state-owned enterprises in Mexico has fallen from more than 1,000 in 1982 to fewer than 200 in 1999 (McDonald, 1997, CIA, 2000).

Since the 1990s, macroeconomic programmes have been aimed at controlling inflation, rationalising the state and eliminating subsidies following the neoliberal reforms adopted to fit with trends in the economy globalisation (Chew, 1998). After a new National government was established in July 2000, structural adjustment programmes have come to set new conditions for development. The new economic strategy pursues the complete opening of the economy to private investment in order to integrate Mexico into the world's economy.

More conservative economic policies were introduced in 2000 to meet the current administration's objectives of avoiding another end-of-term economic crisis. While reforms were undoubtedly necessary to correct some of the drawbacks of past approaches, the social costs of the economic adjustments have been very high, especially for the poor. Land and income distribution has become even more regressive. At this stage, only high-income families have benefited from the restructuring of the economy, and the poor have not benefited despite their contributions to exports and internal food supply (CIA, 2000; Guzman & Vera, 2001).

Macroeconomic pressures on coastal communities have increased, transforming them into agents of over exploitation of fragile ecosystems, and placing them in a context of reduced public finances due to budget shortages and therefore not seen as objects of public investment. Furthermore, out of shifts in the livelihoods of rural communities have arisen losses in access to assets, as a result of changes in macroeconomic policies and pressure on natural resources, as discussed by Bebbington (1999).

Community participation in decision-making

Cooperation among individuals is an important factor for the design of institutions that facilitate effective community participation. Nevertheless, intra-village conflicts and inequality may impede collective action, and even if the models of organisation adopted are sound, failures in local cooperation are observed in many cases. Success and failure are not defined by one indicator but by integrated variables. The size of the group, the level of awareness of mutual dependencies, the extent of membership obligations, the level of compliance with these obligations, the appreciation of external assistance and the impacts of informal systems on formal settings are among the key variables (Bardhan, 1993; Molinas 1996).

To a great extent community organisation depends on the social environment in which it is established. Size and membership are closely related and affected by the type and perception of the members towards the need of an organisation and its purpose. The appreciation of an organisation for management and control is often regarded as an important factor in promoting community participation and government involvement in the development of fishery co-management frameworks (Meynell, 1990; Sunderlin & Gorospe, 1997).

The success or failure of cooperative participation in the context of sustainable livelihoods is better explained by the change of people's choices and strategies regarding access to the resource base, sources of income and labour markets. The competitive position of small-scale aquaculture may allow a strategy for alleviating or improving these conditions, but in the face of increasing population, declining fisheries production and scarcity of financial sources, conflicts on access and use of resources requires particular attention regarding the appropriate balance between the roles of government and community in managing resources (Molinas, 1998; Warner & Jones, 1998; Bebbington, 1999; Hoon *et al.*, 2000).

Warner and Jones (1998) discuss the importance of addressing conflict and note that many conflicts that arise in the process are effectively managed through two options: The do nothing scenarios; when it is concluded that the existing mechanisms are likely to be overwhelmed by conflicts there are two subsequent options:

- Organisational restructuring. Determine whether the presence of conflicts will spur reform of existing management systems or encourage the development of new ones
- Weighing the costs and benefits of doing nothing. Determine whether the long-term benefits of do nothing are outweighed by the short-term costs

The do something scenarios, when it is found that a conflict is likely to overwhelm the existing capacities for conflict management or self-reorganisation, or when hope that the conflict sparks wider social reform is impracticable the options fall into five broad categories:

- Force – however, not all parties will be able to use the same force, as it will largely depend upon the power that one party holds
- Withdrawal – the power of withdrawal can be used as threat to force reluctant and sometimes more powerful parties to negotiate in a more consensual fashion. However, disadvantaged groups may also withdraw out of a feeling of helplessness
- Accommodation – when one party values a strong and continuing relationship with one or more of other parties above the attainment of its own goals. In these way the

party may elect to accommodate the other parties, conceding to all or most of their demands through a perception of having gained by way of securing good relations

- Compromise – this means that at least one of the parties perceives that it has had to forgo something
- Consensus- in a consensus approach the synergy of collaborative negotiations is used to widen the basis for decision-making thereby avoiding trade-offs altogether

However, issues such as the social heterogeneity, intra-village conflicts and inequality may impede collective action, and the degree of confidence or trust that individuals have in the likelihood that others will play their part in a cooperative agreement may be low. Latent conflicts, because of their structural nature, can usually only be resolved at the national or regional level through policy or legal reform, education and wealth creation programmes. The competing parties can be encouraged to recognise that they share a mutual self-interest to sustain the resource-base upon which the development depends (Jentof, 1989; Lewis, 1997).

These approaches have been discussed extensively in fisheries co-management, aquaculture development and in the implementation of coastal management frameworks (Ben-Yami & Anderson, 1985; Gubbay, 1989; Black, 1991; Bojos, 1991; Johnson, 1999). Fisheries management responsibility is advantageous where fishermen through community-based organisations have participated in the establishment of regulations, as they have gained a certain degree of autonomy (Jentoft; 1989; Sunderlin and Gorospe, 1997). Lewis (1997) asserts that attention must be paid to other participants when this approach is intended to integrate aquaculture as an income generating activity into coastal communities.

This form of regulation usually takes the form of territorial use rights, as explained by Jentoft (1989). However, the existence of fisheries management greatly depends on the level of organisation of local fishing communities into established structures. Jentoft (*op cit.*) points out that one of the factors regulating cooperative organisations is the composition of the membership, which depends on the appreciation of fishermen of the need for such organisation. Even if an optimum membership size for cooperative organisations to operate has not been defined, smaller cooperative organisations tend to be more successful (Meynell, 1990). People are motivated by the norm of fairness, and are less likely to free ride when cooperating in small groups with similarity of needs, clear boundaries and shared norms and patterns of reciprocity, as described by Bardhan (1993).

In the Mecoacan estuary fishing organisations have a declining membership due to strong migration and mobility, and the lack of influence of the members in decision-making, which work against cooperation. Contact with outsiders and the exit option reduce the effectiveness of social norms raising incentives for short-run opportunism and free riding. However, a number of small cooperatives were organised as the result of a recent split of one of the first cooperatives established in the area. Even though the size of these cooperatives might allow appropriate balances of resource and equity, they appear to have similar tendencies in membership composition as the larger cooperatives, underachieving production goals, and in this way forcing members to establish individual marketing arrangements.

The fishermen are still interested in forming groups and joining the organisations, as they are aware of the benefits of collective activities. However, the interview responses showed that conditions within Mecoacan cooperatives have deteriorated and increasing interest in restructuring the organisations is regarded as a means of integrating employment and income generation alternatives. The reorganisation of cooperatives may be carried out on the base of economic diversification with the creation of fishery centres to promote and support vertical and horizontal integration of fisheries activities (Hotta, 1994; Legaspi, 1994; Pollnac *et al.*, 2001). Fishermen's responses regarding aquaculture practices showed a significant agreement that aquaculture might support improvements of current levels of fisheries production, achieve gains in new markets development, and direct control over the price of cooperative products.

At the same time, the democratic changes experienced in Mexico through the electoral process in 2000, have lead to changing attitudes in fishermen on management and integration, a great expectation of becoming self-sufficient. Thus, the transfer of responsibility for management functions could be expected to introduce an increased democracy in the regulatory process, with improved competence and control of conflicts among members or groups. However, the responsibility for regulation in existing organisations has been regarded as a negative feature by members due to the lack of trust in the administration of cooperative bodies.

Technology feasibility for aquaculture development

In Latin American countries repeated economic crises have resulted in conventional strategies being limited in their ability to promote equitable and sustainable development, as they are pulled increasingly into neoliberal economic models. Although, in some countries these models have appeared to be successful at the macroeconomic level, the introduction of new technologies, privatisation of public services, commercialisation of common property resources, changes in government policies for resources management and the general decline of agricultural produce trade exert pressure on rural communities towards change (Altieri & Masera, 1993; Rigby *et al.*, 2000).

It has been pointed out that the rapid expansion of aquaculture was primarily due to the failure of capture fisheries to supply the growing demand for aquatic products. The development of aquatic farming arose as an income and diversification source for rural communities, rather than a subsistence practice, by integrating aquaculture production with agriculture to produce commodities for import replacement, export and local consumption (Welcomme, 1996; Mohamed & Dodson, 1998; Boyd & Schmittou, 1999; Srinath *et al.*, 2000).

The concept of sustainable aquaculture has been defined based on economic, ecological and social criteria. Issues about its sustainability have been raised regarding its rapid growth, as socio-economic and organisational discrepancies have been major constraints in the implementation of aquaculture practices among rural communities along with poor planning and management, have resulted in a range of economically unsustainable activities (Boyd & Schmittou, 1999; Hugues-dit-ciles, 2000; Srinath, 2000).

Despite all the attention to aquaculture technology practices in Mexico (De la Lanza & Arredondo, 1990) Tabasco has not yet achieved the targeted increases in production and income improvements due to low access and equity conditions. Nor has the introduction of aquaculture increased the role of cooperative organisations in formal control in terms of access to resources, due to the lack of recognition of social constrains affecting this role. Under these conditions past aquaculture programmes have tended to increase conflicts concerning access to benefits from resource management, and risk-spreading strategies for low-income fishermen when they attempt to incorporate aquaculture into their portfolio.

Previous experiences of the disparity in private benefits from common property happened when fish and shrimp on-growing systems were implemented in the estuary leading to a situation in which the members lost from cooperation. These aquaculture systems were implemented as a starting point for improving fisheries production in the area. Fishermen noted that this projects were large financial disasters as they lost all the production after a series of climatic events (class 4 hurricanes), unrealistic financial projections, inadequate technical assistance for training and coordination of farm operations and lack of coordination with the extension officers. This eroded the cooperation agreements and broke down the necessary coordination. From the 30 groups organised for tilapia and shrimp culture in Mecoacan estuary, only one was still operating a shrimp site with an average production of 1 t per ha.

Non-governmental organisations support

The resolution of conflicts also depends on the government's political will to decentralise regulation and policy decision-making, and the strengthening of a mediator agency capable of counteracting tendency to rivalry, oligarchy, and for expropriation by wealthy groups as discussed by Pomeroy and Berkes (1997) and Rivera-Arriaga and Villalobos (2001). The positive level of response regarding the lobbying efforts and involvement of NGOs in community affairs can be related to the increasingly negative judgement of government actions by public opinion. This appreciation of NGOs participation may represent an important factor in developing decentralised management frameworks for common resources as discussed by Deb (1998) and Boyd and Schmittou (1999).

The participation of NGOs, the private sector, technology developers and coastal communities in the pursuit of production and resource use efficiency may enable a proper development environment in the case of aquaculture, to provide a sustainable way to meet current and future needs, recalling that aquaculture should not be considered a panacea for solving shortages in animal protein and income generation (Harrison *et al.*, 1994; Boyd & Schmittou, 1999; Hugues-dit-ciles, 2000; Srinath *et al.*, 2000).

A major challenge is the promotion of productive alternatives that are not only ecologically sound but also economically profitable. The central idea inspiring the work of NGOs is that agricultural research and development should operate on the basis of a *bottom-up* approach, starting with what is there already: local people, their needs and aspirations, their farming knowledge and their autochthonous natural resources. Despite the many advances, bottom-up development efforts in the study area have been met with mixed success. As commented by the NGO fishery agents, a key reason is that local NGOs are attempting to counteract an environment in which their components have little access to political and economic resources and institutional biases prevail against them.

Lewis (1997) states that some difficulties may be faced regarding the participation of NGOs in framework implementation and in the operation of resources management. Although NGOs may overcome the limitations of government fisheries agencies in identifying needs and in having more operational flexibility, in the case of local NGOs in Tabasco the agents commented that they generally lack access in technical research and influence on policy agendas, as a result of existing mutual distrust with government agencies due political affiliations of NGOs, and differences in groups targeting. However, linkages between governmental agencies and non-governmental organisations exist regarding financial support for aquaculture site development. This may represent an opportunity to extend and improve the links for fisheries and resources management.

Linkages between institutions, non-governmental organisations and local implementers need to be implemented through a strong consensus on the need to improve knowledge and information systems, the design and implementation of sound policies and strategies, and the reinforcement of the managerial capacity of the local communities.

5.9.3 Livelihood resources and human capital

Aquaculture has been identified as one of the few profitable and expanding parts of the agricultural sector. During the 1990s, aquaculture contributed with < 15% of total fisheries production and < 1% of agricultural GDP and exports of Mexico (World Bank, 1997). Participatory approaches showed to be helpful in the understanding of the role of aquaculture in rural livelihoods, as opposed to focusing purely on aquaculture as a technical activity and in understanding the attitudes and perceptions of the people involved.

The analyses employed here, while in need of refinement, can be used as conceptual frameworks for a variety of development scenarios. Results suggest actual aquaculture establishment appears to fall within current cultural norms, and it may play an important role in the development of the Mecoacan estuary. However, several social factors may preclude local participation and investment. One of the main problems is that aquaculture producers must compete frequently with more powerful groups for resources and market access. Sustainable aquaculture in the Mecoacan estuary will be difficult to improve if access to resources remains skewed and institutional arrangements (e. g. credit, technical assistance, etc.) and market conditions still favour unregulated free riding, as identified through the stakeholder, seasonal calendar and livelihood indicators analysis.

Although coastal aquaculture may be the only technical alternative for farmland under saline conditions (FAO, 1999), inappropriate land-based aquaculture systems have been developed in the area. In the case of water-based systems the major constraints for the promotion of aquaculture are often not technical (Rodriguez, 1994). In the past, aquaculture practices were promoted without taking into consideration the other needs of the farmer, his family and rural community as a whole. Therefore, a systems approach is required to effectively promote sustainable-rural aquaculture, but a substantial difficulty is the limited local capacity in training, research and development.

Regarding human capital development, Wodon *et al.* (2000) argue that education has an indirect positive effect on household income through employment. Part of this positive effect is due to the education level and the sector of activity of the head of the household. The education level is very low in Mecoacan communities, as only 1% of household heads have completed schooling up to high school. All the heads of household interviewed worked in agriculture related activities, with only 27.7% having a second job in the services sector either working in restaurants or convenience stores (Appendix E).

In most households the second employed adult is usually the spouse or the older child, with 98% working in the agriculture or the services sector. This finding agrees with the state and municipal statistics, which shows that distribution of women employed in this sectors is about 91.8% and 92.5% respectively (INEGI, 2002). Although education may improve income and employment access, there may be a significant impact on social capital as there are few employment opportunities in the Mecoacan area. The main impact is the potential loss of skilled population through migration. Hence, potential help to develop and support social networks aiming at the integration of dispersed and/or disadvantaged groups is reduced if trained and skilled population is not returning to the area due the lack of employment opportunities (Fox, 1996; Molinas, 1998).

It would be expected that the association of fishermen would affect positively the accumulation of human capital, as a broad range of training courses are available from government programmes through cooperatives to improve household access to income and employment. However, the effect on this variable is very low, as shown in the correlation matrix (Appendix F). The lack of effect of fishermen's association on human capital accumulation and access to livelihood resources is indicative that collective aggregation is not producing the expected positive outcome for the communities of Mecoacan. These may be a result of the decreasing membership composition of the cooperatives affecting the appropriation of institutional resources, and the formal modes of regulation through decreased equity, related in turn with the weak horizontal association webs at the local level, as described by Fox (1996).

Although new policies are needed for resources management in the area, they are not enough, as profitability at the household level depends not only on what communities can do, but also on the macro conditions under which the rural production operates, as described by Bebbington (1999). At the macro level there are important obstacles such as the increasing external debt, distribution of resources, appropriate technologies and international forces. These effects may be reduced by the empowerment of local organisations and the effective participation of the rural poor making policies regarding technical change, and economic and social investment, but the effective participation of communities will depend 'on their ability to speak with one voice' as McCay and Jentoft (1996) point out.

However, development approaches have followed the paternalistic fallacy, as described by Wanmali (1999), government agencies have believed that they posses all the knowledge to achieve development objectives and communities should only be the recipients of this knowledge. As noted by respondents, people have not participated in decision making processes regarding resources management, nor is there a clear definition of the roles and responsibilities held by fishing organisations in current sectoral affairs.

It has been reported by the federal government that capacity building promoted for integration of coastal management has been carried out in order to improve management policies for the coastal zone and that there have been several attempts to improve, enhance, and foster the administration of the coastal zone by means of inter-sector political integration for sustainable development. However these efforts have been limited to information and discussion panels regarding taxes and fee systems for administration of beaches on federal marine/terrestrial zones for 13 states including Tabasco (NOAA, 2000). There are no references to other activities or to aquaculture.

Considering the trends for international economic integration, it is impossible to conceive a development strategy that is isolated from the global context. As immediate priorities are more equitable distribution of wealth, securing adequate living conditions, improving the conditions of popular participation in the decision making process and management enhancement of the region's natural resources, a new pattern of growth is needed, which is different from that of the past.

On the issue of free riding, a policy climate that improves the terms of trade for rural production by providing competition to local monopolistic intermediaries may allow fishermen to capture the externalities that a rural-sustainable aquaculture might produce. These may be achieved by a) the vertical diversification of the sector to provide a degree of specialization in the economy, b) the definition of adequate tax policies to charge free riders, c) tradable use or property rights, and/or d) the establishment of a proper subsidies programme for the sector (i.e. aquaculture site improvements, fishery biding network, small-scale processing plants) (Glomm & Lagunoff, 1995; Avault, 1996; Barg *et al.*, 1999). According to Thomas (1996) this provides justification for state intervention to regulate and coordinate the above potential means for improving community's capacity building and reducing opportunity costs.

However, the conditions working for and against sustainability in fisheries and aquaculture are significantly related to economic and social interdependence between fishermen. Free riders face similar problems in accessing resources and in trading fisheries products. Jentoft (1989) states that the crucial question is to get both associated and independent fishermen (free riders) voluntarily to advance their collective interests at the expense of their private ones. Therefore, a major challenge is to create new policies that reduce the changes in social parameters that disperse benefits distribution (Montgomery, 1991).

Bardhan (1993) stated that people sometimes might be able to leave their conflicts behind and settle rules for allocation and monitoring of common resources, enhancing the chances of survival. This is only possible if fishermen find the regulatory scheme legitimate by participating in the decision-making process and getting directly involved in implementing and in enforcing regulations. This may be achieved based on the compromise and consensus approaches (Warner & Jones, 1998) in order to promote capacity building within communities in the context of a participatory intervention strategy through formal and informal organisations (Van der Mheen, 1999). The more the regulations coincide with fishermen definition of problems, the more the regulations will be accepted as legitimate (Jentoft, 1989; Pomeroy & Berkes, 1997).

6.1 Economics issues of Mecoacan fishing cooperatives

6.1.1 Introduction

Fisheries of developing regions typically face over-exploited stocks, a lack of alternative employment outside the fishery and an over-extended fleet. Fishermen without other options will shift from one activity to another regardless of legal conditions and management frameworks to maintain their livelihood. Thus according to Charles and Herrera (1994) 'fishery development policy can be viewed as sustainable only if it enhances, or at least maintains ecosystems, communities, socio-economics and culture, and institutional structures'. These problems coupled with raising human population have justified the development of aquaculture either for food security or to improve income (Hishamunda *et al.*, 1998; Boyd & Schmittou, 1999; Omondi *et al.*, 2001).

The idea of sustainability involves the simultaneous pursuit of ecosystem maintenance, proper distribution of benefits amongst participants in the local and global economy, enhanced socio-cultural welfare of communities and endurance of appropriate institutional structures (Charles & Herrera, 1994). Issues of relevance to the success of attempts to introduce collectively managed aquaculture include the existence of past successful collective activity in fisheries.

Communal management practices are regularly debated. Success or failure of group approaches to aquaculture arises from motivations, inducing groups to form. Problems invariably arise when formal groups are created in expectation of assistance such as loans or grants and because of disputes over rights to the harvest.

Local leadership, management ability and the strength of local services are important in the context of cooperatively managed aquaculture (Harrison, 1996). Ideally, integrated indicators could be developed to integrate ecology, economics and ethics as the fundamental objective of working towards sustainable development. In these terms, sustainable development could be defined as change that can be sustained in terms of commonly agreed principles. As the goal is to sustain ecological processes with clear social end points in mind, there is the need to measure costs and benefits that are not reflected in market prices and to think about what sustainable development means in terms of social systems and cultures, in their relation to ecology and economics by understanding how economies grow and why some fail (Pearce & Nash, 1981; Hundloe, 2000).

With objectives related mainly to household employment and income generation, aquaculture in coastal areas has been an activity undertaken to a large extent by people greatly associated with fishing rather than with agriculture, with significant social implications (Hundloe, 2000). Although aquaculture has a long history in some parts of Asia, straightforward comparisons may be misleading elsewhere. In Mexico, for aquaculture the context is not similar, as political and economic issues have been approached with inappropriate or insensitive projects, reflecting the lack of well-articulated policies and rationales development, project design and management. Disparities may operate both levels at the community and within the household regarding aquaculture, where development does not automatically indicate that benefits are available for all members within a household or a community (Harrison, 1996).

6.1.2 Evaluation of fishermen income and costs

The increase of both human population and more efficient technology are the most serious among many causes for the decline in landings and the over-exploitation of coastal fisheries, thus imposing non-sustainable impacts on those dependent on the fisheries in spite of the productive potential of coastal environments. Approaches to the problem vary from attempts to regulate the fisheries to provide alternative livelihoods and relieve the pressures on the fishery.

However, in many instances these are not working, having failed practically, politically or been subject to negative community-level effects, as fishermen without other options will do anything, legally or illegally to maintain their livelihood when facing shortages of coastal fishery resources. In the case of other serious impacts (e.g. pollution and destructive fishing practices), potential solutions are available to correct problems once there is the political will and community commitment. However, though the causes are known they may not easily be solved (Boyd & Schmittou, 1999; Newkirk, 1996; Warner & Jones, 1998; Yap, 1996).

Market transactions involve production and extraction of goods in response to market prices, which themselves reflect a broad set of economic and social preferences. Estuarine resources, including land, marine life, water and mangroves, are limited in size and have alternatives uses to different sets of users. The ability of resource harvesters to produce for markets depends on property rights to resources, capital, technology and the quality of the environment itself. However, political interests often determine management policies, not strictly by social and environmental interests, and the attendant harvesting of resources may not necessarily result in equity in resource use or environmental sustainability (Welcomme, 1996; Bhatta & Bhat, 1998).

Competing users struggle for dominance over the scarce resources and, depending on their relative political power, influence the policy-making process to seek larger shares in the resource. A host of economic and political factors have contributed to the decline of cooperative fishing and management regimes in Mecoacan. On the one hand, state policies governing estuary use and oyster production process failed to recognise the relationship between the socio-economic well being of coastal communities and estuary ecosystem health (Moguel, 1994).

On the other hand, the terms of cooperative membership have not been observed, as it is required that fishermen should bring all catch/harvest to the organisations, making cooperative investments run into continuing difficulties and losses, combined with continuing depressed markets. Therefore, organisations could not expand their financial bases when employment was decreasing for members, due to a declining market demand particularly for oyster produce (GDCI, 1995) and a reduced flow of product.

The social and economic organisation of the artisanal fishermen is influenced by the exploitation strategy of available resources. The sharing of fish stocks, at the local level, is directly linked to the way resources are accessed with spatial patterns of exploitation of the resources, with intra and inter-community interactions and with the conflicts between community objectives and national goals (McCay & Jentoft, 1998; Terrebone, 1995).

6.1.3 The feasibility of integrating aquaculture

It has been generally proposed that for planning in aquaculture development not only are profit-driven approaches to be considered, but socio-economic and environmental sustainability must also be understood to match aquaculture initiatives to community income and employment requirements (Boyd & Schmittou, 1999; Lee, 1999; Mohamed & Dodson, 1998). However, social objectives are limited in the market context, requiring to set social goals before economic criteria in order to determine how resources are used, what industries people find work in, how food security is met, etc. The use of financial indicators may help decide if a production system is sustainable based on economic criteria (Hundloe, 2000).

One of the common public policy goals of fishery management is to increase the stock of fisheries, which public institutions consider to be over-exploited. The introduction of competitive aquaculture facilitates this goal at the expense of those forced to reduce fishing effort. The common-property nature of the fishery inhibits entry by the aquaculturist when the initial natural fish stock is less than maximum sustainable yield and this may condition the presence of the aquaculturist to be only temporary (Anderson, 1985).

However, in cases where aquaculture is not present, public policies aimed at reducing exploitation of the stock typically force the fishery to become less efficient and the resultant inefficiency leads to an increase in consumer prices. Thus, when competitive aquaculture is present overexploitation of the natural stock is reduced, total supply is increased, efficiency increases and prices may fall (Engle

& Pounds, 1993).

The potential of farming the sea has been touted for many years. However, the target species promoted are mostly high value products: crustacea (shrimp and lobsters), expensive fish (groupers, sea bass, salmon) or molluscs (oysters and mussels). The irony is that most of the species that are landed in current fisheries are not of high value and the demand for low value fish for direct human consumption will continue to increase (Newkirk, 1996).

6.1.4 Aims of the economic analysis of Mecoacan fisheries and aquaculture

The aim of this chapter was to develop a comparative assessment of fishermen in terms of income and costs, and to discuss the potential of integrating aquaculture in their activities through a cost-benefit analysis of current culture practices.

6.2 Fishing income and costs

6.2.1 Financial issues

The physical characteristics of the Mecoacan estuary, including the seaward portion, are such that property rights have never been distributed amongst users, and thus these areas have remained open-access resources. Lands adjacent to the estuary and adjoining rivers are parish and private properties, but these lands are inundated with brackish water during the monsoon every year and most of the owners are small farmers that grow a short range of crops for subsistence. Throughout the year, marine species with higher market prices are sought. Hence, less equipped fishermen seeking to maximise their income have been motivated to harvest as many estuarine resources as possible in response to rising prices of marine fish. On the other hand, the composition of the catches varies seasonally and brackish water species are target species, not for their market value but for their abundance in the estuary.

Economic data was collected through the socio-economic survey used for the livelihood analysis. The sample size was 421 cooperative fishermen and 21 independent fishermen (free riders). Figure 100 summarises the key sources of income by fishery. Other income flows supporting households are shown in Appendix E. Costs on average form approximately 25% of a fisher's gross income. Of these costs, gasoline and maintenance of equipment dominate.

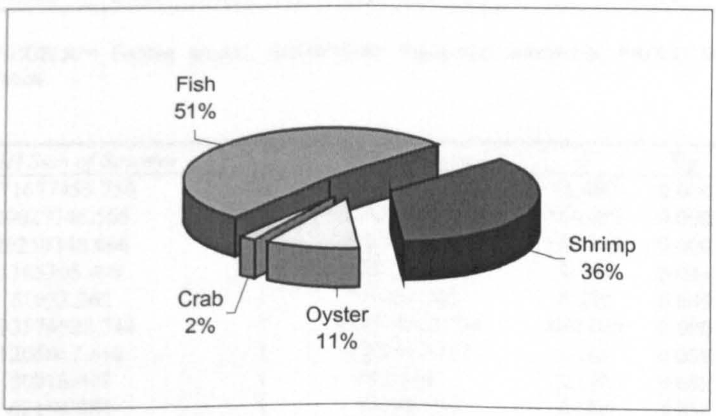


Figure 100. Fishermen distribution of income per specie

The variables selected for the analysis of costs included the number of fishing days, fishing ground, ownership of the fishing equipment, type of propulsion, storing and type of fishing gear (Cast net, gillnet, grab, diving, naza, angling). A regression model (Table 37) was used to determine the marginal costs of fishing per month related to the association of fishermen (cooperative or independent). The variables related to fishing effort and equipment ownership were not significant as most fishermen used cast nets or rods and own the fishing equipment. The main factor in the variable costs is the use of motors and equipment maintenance, both in the dry and wet season. In some instances this was prejudicial financially, as fishermen used fuel but did not capture enough fish to cover the costs.

Table 37. Analysis of the monthly production costs of fishing

Parameter	*B*	*Std. Error*	*t*	*Sig.*	*95% Confidence Interval*	
					Lower Bound	Upper Bound
Intercept	-2,199.781	215.198	-10.222	.000	-2,623.110	-1,776.452
LABOUDAY	166.968	16.269	10.263	.000	134.964	198.972
FISHGROU	116.733	56.996	2.048	.041	4.614	228.852
EQOWNER	14.744	31.457	.469	.640	-47.138	76.625
PROPULS	1,065.873	48.608	21.928	.000	970.253	1,161.493
STORING	150.384	72.176	2.084	.038	8.403	292.365
CASTNET	-27.398	63.997	-.428	.669	-153.290	98.494
GILLNET	-31.131	65.793	-.473	.636	-160.556	98.295
GRAB	-97.660	76.725	-1.273	.204	-248.591	53.271
DIVING	-99.134	61.181	-1.620	.106	-219.488	21.219
NAZANET	142.269	74.414	1.912	.057	-4.115	288.652
ANGLING	40.001	105.291	.380	.704	-167.123	247.125
DUMMY	411.216	151.903	2.707	.007	112.399	710.032

Dependent Variable: COSTS

LABOUDAY= # of labour days, FISHGROU= Fishing ground, EQOWNER= Equipment ownership, PROPULS= Propulsion, DUMMY= Fishermen association

Tests of Between-Subjects Effects

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Corrected Model	271677453.756	12	22639787.813	81.497	0.000
Intercept	29027746.568	1	29027746.568	104.491	0.000
LABOUDAY	29259348.066	1	29259348.066	105.325	0.000
FISHGROU	1165305.499	1	1165305.499	4.195	0.041
EQOWNER	61023.262	1	61023.262	0.220	0.640
PROPULS	133574522.744	1	133574522.744	480.829	0.000
STORING	1206017.112	1	1206017.112	4.341	0.038
CASTNET	50916.417	1	50916.417	0.183	0.669
GILLNET	62194.086	1	62194.086	0.224	0.636
GRAB	450077.861	1	450077.861	1.620	0.204
DIVING	729365.361	1	729365.361	2.626	0.106
NAZANET	1015412.075	1	1015412.075	3.655	0.057
ANGLING	40095.387	1	40095.387	0.144	0.704
DUMMY	2035825.239	1	2035825.239	7.328	0.007
Error	91951875.245	331	277800.227		
Total	671294572.063	344			
Corrected Total	363629329.001	343			

R Squared = 0.747 (Adjusted R Squared = 0.738)

Dependent Variable: COSTS. Exchange rate Pesos$9.30 = US$ 1.00

Accumulation of capital is constrained by highly variable costs and fluctuating catch rates. Though there were no conflicts among fishermen regarding locations, fishing ground selection effect was found to be a significant variable in the regression model. Fishermen operating both in estuary and sea areas tends to increase their costs by Pesos$ 116.73 per month with a marginal cost of at least Pesos$ 4.61 and at most Pesos$ 228.85. Labour costs tend to increase by Pesos$

166.96. Thus, it is difficult to understand on the basis of stated catch value how fishermen make money, mostly because the cost of propulsion tends to increase by Pesos$ 1065.87 per month.

The way fish was preserved was significant. The marginal costs of storing are between Pesos $ 8.40 and Pesos $ 292.36 per month, requiring fishermen to sell catch directly at whatever price is available, so being subject to opportunity cost. The wide range of storing costs is related to catch volume and marketing of produce. Storing is a common practice for marine species and shrimp, and it is employed by fishermen not only to preserve the product but to be able to collect batches of at least one tonne, as requested by middlemen and make the shipment costs worthwhile. Some fishermen family groups have invested in storing facilities to collect the required load. However, most of the fishermen did not have the capital to invest, thus having to take their catch to the facilities of middlemen.

The amounts spent on fuel and other fishing costs have risen more than the general price level for fish, probably evidence that greater effort is being applied, but without increases in catches. The dummy variable used for the association of fishermen to cooperative organisations was found to be significant. The cooperative fishermen tend to increase their costs significantly more than free fishermen by Pesos$ 411.22 with a marginal cost between Pesos$112.39 and $710.03, indicating a considerable uncertainty.

The profits from fishing are extremely variable, as once marketable catches are attained fishermen market fish as quickly as possible to minimise losses due to costs, and to maximise potential benefits. The variables selected to define the income variability were based on capture volume, market price, processing labour input, grading of produce, type of processing, and market channel for fish, shrimp, oyster and crab (Table 38). Though processing is considered a potential means of diversification and improvement of produce quality, it was found insignificant and it did not offer benefits, neither to those who process their catch in any way nor to those who uses family labour to reduce costs of hiring labour for processing.

Table 38. Monthly income analysis of Mecoacan fishermen

Parameter	*B*	*Std. Error*	*t*	*Sig.*	*95% Confidence Interval*	
Parameter					Lower Bound	Upper Bound
Intercept	2,571.686	3,279.592	0.784	0.433	-3,875.655	9,019.027
FISHCAPV	16.158	1.947	8.301	0.000	12.331	19.985
SHRICAPV	23.026	1.408	16.351	0.000	20.258	25.795
OYSCAPV	44.731	4.444	10.066	0.000	35.995	53.467
CRABCAPV	-31.598	35.787	-0.883	0.378	-101.952	38.756
FISHPRICE	122.278	20.148	6.069	0.000	82.669	161.888
SHRIPRICE	26.532	14.158	1.874	0.062	-1.301	54.364
OYSPRICE	45.006	3.789	11.879	0.000	37.557	52.454
CRABPRICE	-8.054	61.082	-0.132	0.895	-128.135	112.028
LABPROC	-939.375	1,016.988	-0.924	0.356	-2,938.669	1,059.919
GRADING	472.852	227.324	2.080	0.038	25.958	919.747
PROCESSING	-3,108.863	2,012.009	-1.545	0.123	-7,064.265	846.540
DISTCHAN	284.474	121.406	2.343	0.020	45.801	523.146
DUMMY	-198.676	985.027	-0.202	0.840	-2,135.137	1,737.786

Dependent Variable: GROSSINC

FISHCAPV=Fish capture volume, SHRICAPV=Shrimp capture volume, OYSCAPV=Oyster capture volume, CRABCAPV=Crab capture volume, LABPROC= Labour invest in processing, DISTCHAN= Distribution channel, DUMMY=Fishermen association

Tests of Between-Subjects Effects

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Corrected Model	12604912781.822	13	969608675.525	55.391	0.000
Intercept	10763453.425	1	10763453.425	0.615	0.433
FISHCAPV	1206051825.623	1	1206051825.623	68.899	0.000
SHRICAPV	4679826867.438	1	4679826867.438	267.346	0.000
OYSCAPV	1773690357.972	1	1773690357.972	101.326	0.000
CRABCAPV	13646263.895	1	13646263.895	0.780	0.378
FISHPRIC	644732099.513	1	644732099.513	36.832	0.000
SHRIPRIC	61476761.144	1	61476761.144	3.512	0.062
OYSPRIC	2469933165.044	1	2469933165.044	141.101	0.000
CRABPRIC	304310.876	1	304310.876	0.017	0.895
LABPROC	14934887.906	1	14934887.906	0.853	0.356
GRADING	75738679.956	1	75738679.956	4.327	0.038
PROCESSING	41792539.650	1	41792539.650	2.387	0.123
DISTCHAN	96107204.872	1	96107204.872	5.490	0.020
DUMMY	712113.938	1	712113.938	0.041	0.840
Error	7019396472.859	401	17504729.359		0.000
Total	40219106508.161	415			
Corrected Total	19624309254.681	414			

R Squared = 0.642 (Adjusted R Squared = 0.631)

Dependent Variable: GROSSINCOME. Exchange rate Pesos$9.30 = US$ 1.00

Profits tend to decline quickly and fishermen lack the flexibility to shift to other income generating pursuits due to their heavy investment debt in fixed capital as encouraged by the middlemen (see later). The regression model showed a significant effect of the distribution channel and grading of produce on income. Produce grading increases fishermen income an average of Pesos$472.85 per month, but there was found a significant marginal effect on income with a variation from Pesos$25.96 to 919.75. The increase according to the distribution channel was found to be at Pesos$284.00 per month, with a variation of Pesos$45.00-$523.15.

Significant effects on income from capture volume of fish, shrimp, and oyster were found. Though catches vary seasonally, the marginal effect found is related to the price fluctuation showed by fish, shrimp and oyster, which significantly constitute the major sources of income regardless of the affiliation status of fishermen. The effect of prices was found to be significant for fish and oyster. Income variations were found to be at least Pesos$ 82.67 and at most $ 161.89 for fish, and Pesos$ 37.56 to $ 52.45 for Oyster. However, the low effect of market prices for shrimp may be an indication of high levels of fishing effort, as fishermen have to capture a large volume to obtain significant gains.

Fishermen have also to cope with rising inflation and with a marked reduction of government intervention in the fishery sector in terms of subsidies and other forms of support including credit, extension and research. Fishery produce has quality problems and fishermen sell it in small quantities. Wholesalers buy in bulk from middlemen out competing attempts by fishing cooperatives to engage in a demanding market with reduced supplies offered by their members.

6.2.2 Effect of market intermediaries

Cooperative work has been almost paralysed since the depletion of oyster production in 1989, for two reasons. Firstly, because there is insufficient support from members to take risks and develop work due to mistrust, and the members' unwillingness to provide collateral to secure a bank loan. Secondly, production from members has been decreasing as they increasingly bring their catch to middlemen (*patrones*).

A small group of fishermen that took advantage of past cooperative leadership, or come from neighbouring states act as middlemen between fishermen and wholesalers. Middlemen have lived in the same area for many years, knew each other well and in many cases are kinsmen. They are generally wealthy and have established strong financial and social ties with wholesalers in Mexico City and Veracruz State, and with Mecoacan fishermen through credits, and thus are able to capture labour by lending money to fishermen to cover fishing costs.

These middlemen collect the catch every day depending on the number of fishermen teams, for storage in nearly facilities providing simple refrigeration, or for direct transportation to markets. A single middleman may work with 10 or more fishing teams. Profits are unstable and unpredictable as payment from middlemen is conditional. Often the middlemen offer short-term credit for a continued operation. Once fishermen establish themselves, produce is brought to middlemen and advances are paid to cover immediate expenses to continue harvesting, in recognition that full payment of product will be sent when fish is sold.

Fishing cooperatives are financially weak in providing sufficient working capital. Problems due to lack of consensus with regard to management practices, profit distribution and resource-organisational issues have lead to ever-changing organisational dynamics, and despite the potential for increasing their income by managing their own production, cooperative administrators seemed to be complacent about the current arrangement that their membership have with middlemen.

However, individual fishermen had become exasperated with this group of middlemen who they felt were exploiting them, as commented "middlemen drop the price whenever they want without authorisation from anyone (officers do not intervene neither cooperatives' administrative bodies) making our effort to increase our income, to pay our debts and accomplish our own operations worthless".

The existence of cooperatives has not resulted in a reduction of external transaction costs, due to increasing opportunism of middlemen in an inefficient market. The large size of cooperatives has led to a lack of trust among members, eventually leading to a disbanding of groups and it seems that the scale of cooperative transactions have result in increased internal costs, leading cooperatives nearly to collapse. Comments on prospects are presented in section 6.4.

6.3 Feasibility of integrating aquaculture in Mecoacan fishing communities.

6.3.1 Background

While the main cause of the historical decline of natural oyster populations in Mecoacan estuary since the 1980s is most likely to have been overharvesting and overdependence on wild seed, Arredondo *et al.* (1993) note that more recent events such as oil spills and parasitic occurrences of *Perkinsus marinus* have essentially reduced natural stocks and made large scale and traditional culture methods unproductive.

However, studies carried out by Villanueva and Paez (1998) and Gold-Bouchot *et al.* (1997) showed the lowest concentrations of different hydrocarbon fractions in oyster are found in the Mecoacan estuary, compared with those for the same species in the northern Gulf of Mexico. The most important impacts were actually from oil industry infrastructure development, through the construction of channels, which have changed the patterns and distribution of salinity (Alvarado-Azpeitia, 1996). The following analysis of aquaculture operations and production, carried out by a small group of fishermen who are members of the largest cooperative in Mecoacan also showed that oyster natural stock and on-farm production recorded sustained levels of production, and health issues were not a major concern.

6.3.2 La Nueva Esperanza

The financial analysis was carried out based on data from an oyster production unit (Fig. 101) ran by La Nueva Esperanza group consisting of six members of Andres Garcia fishing cooperative. This was funded by the Fondo Nacional de Empresas en Solidaridad (FONAES), a government agency created to support rural development during Carlos Salinas-De Gortari administration (1989-1994) and technically assisted and partially funded by the local environmental NGO, Santo Tomas.

Figure 101. Panoramic view of La Nueva Esperanza oyster farm, Mecoacan estuary, Tabasco, Mexico

Initially the group was part of a government development project for shrimp farming, Camaroneros de Punta Brava, which fishermen reported resulted in a financial disaster as they lost approximately 4 tonnes of shrimp with an average value of Pesos$ 120,000.00 (US$ 12 903.23) after a series of climatic events (class 4 hurricanes in 1995), unrealistic financial projections, inadequate technical assistance in coordinating farm operations and lack of coordination with the extension officers. From the 30 groups in this programme La Nueva Esperanza was the only group to pay the credit they were granted through the shrimp project and invested the profits to install and run a small oyster production unit (Rodriguez, 1998).

The farm installation took place at the end of 1997 in an area located at the northeast end of the estuary known as Costa de Montaña, with a total area of 30 ha and an average depth of 1 m. To produce oysters a long line system was selected

(Fig. 102) and initially comprised by 23 tray modules (5 trays per module) and a total density of 400 oyster seed per tray.

Dissolved oxygen and temperature at three different depths, and oyster biometrics were monthly measured. Spat was collected from well-known spat-collecting areas nearby the farm. This operation was carried out once at the initial phase. In-site spat production was recorded and the group did not further require collecting elsewhere, reducing operating costs regarding transportation and labour. 80 modules were allocated for spat production.

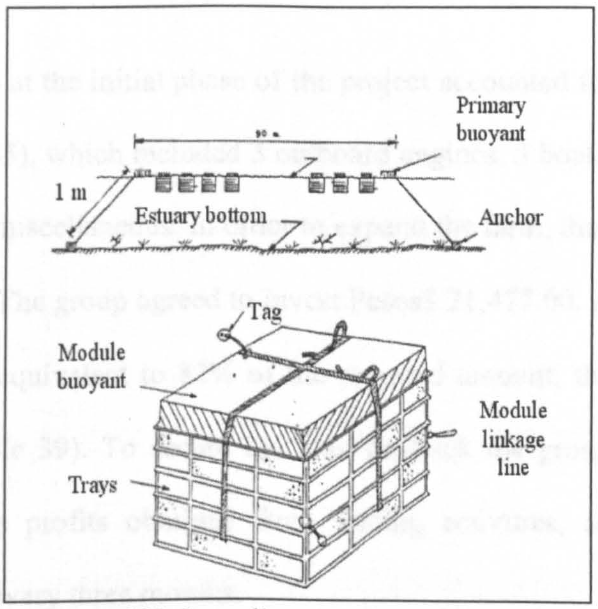


Figure 102. Long line system used in La Nueva Esperanza oyster farm (Rodriguez, 1998)

The group work at the farm consisted of three activities, clearing fouling from modules, redistribution of oyster according size, and night watch. Activities were scheduled for weekly rotation amongst the members of the group and the NGO extensionist (Fig. 103).

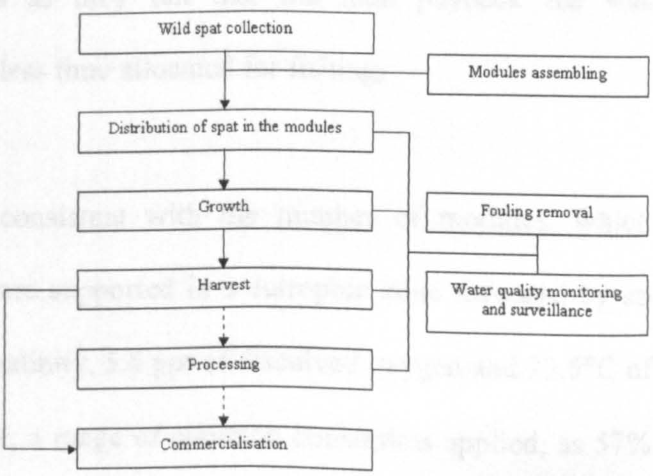


Figure 103. La Nueva Esperanza operations flow-chart

Wages were based on the official minimum wage for the area (Pesos$ 18.00=US dollar$ 1.93) and calculated to specific tasks.

6.3.3 Financial analysis

The total capital assets of the group at the initial phase of the project accounted for Pesos$ 135,914.40 (USD$ 14 614.45), which included 3 outboard engines, 3 boats, 350 modules, fencing material and miscellaneous. In order to expand the farm, they required a Pesos$ 120,389.72 loan. The group agreed to invest Pesos$ 21,477.00. A loan was granted from FONAES[7] equivalent to 82% of the required amount; the rest was funded by the NGO (Table 39). To secure the loan payback the group provided as collateral 50% of the profits obtained from fishing activities, an average value of Pesos$ 26,490.00 every three months.

The oyster system used 5 ha of the total area and the rest was intended for installing cages and enclosures for farming tilapia. However, the group desisted from this as the installation of the oyster system took more time than planned, which concerned the members as they felt that the loan payback fee was compromised because there was less time allocated for fishing.

The growth of the farm was consistent with the number of modules, which increased from 30 to 184 and were supported in a eutrophic zone favoured by an average 19.5 parts per thousand salinity, 5.6 ppt of dissolved oxygen and 23.5°C of temperature (Table 40). However, a range of common constraints applied, as 57% of production was lost at the end of year due the seasonal heavy rain and strong

[7] Fondo Nacional de Empresas en Solidaridad

winds. Despite this the group contacted potential costumers and was able to allocate the produce at an average selling price of Pesos$ 0.90 per shell-on oyster.

Table 39. Capital assets distribution of La Nueva Esperanza farm per year

Items	*Unit price*	*# of Units*	*Total*	*Items*	*Unit price*	*# of Units*	*Total*
Capital costs				Operating costs			
Oxygen meter	21,658.00	1	21,658.00	Gasoline	2.60	1,000 L	2,600.00
Dissection set	325.00	1	325.00	Motor oil	45.00	20 L	900.00
Refractometer	4,420.00	1	4,420.00	Labour	18.00	952	17,136.00
pHmetre	1,250.00	1	1,250.00				
Scale	1,375.00	1	1,375.00				
Fencing material	41.33	450	11,631.14				
Containers	65.00	20	1,300.00	Subtotal			108,461.95
Polystyrene line	74.00	5 kg	370.00	15% Tax			16,269.29
Nets	2.48	3200 m	2,600.00	Total			141,867.24
Knives	30.00	10	300.00				
Laboratory glassware	3,784.00		3,784.00				
Fishing needles	3.00	5	15.00				
Gloves	25.00	20	500.00				

Funding sources: FONAES Pesos$116,038.00; Santo Tomas Pesos$4,351.72; Own capital Pesos$21,477.52.
Currency exchange Pesos$ 9.30 = US Dollar$ 1.00

Most of the potential costumers were restaurant companies in Tabasco, Quintana Roo and Yucatan states and wholesalers in Mexico City and Veracruz. Oyster samples from the farm and from the bottom of the estuary were taken for sanitary analysis in order to certify that produce satisfied market quality standards regarding health issues. When compared with oyster collected from the bottom (natural banks and managed banks), oyster from the long line system did not show sewage pollution or any other parasitic infestation (Appendix G).

Table 40. La Nueva Esperanza oyster farm growth and income: first year production

	9 December 97	*13 January 98*	*January-November 98*
Biometrics			
Weight (gr)	20.66	NA	47.88 SD ± 9.34
Maximum height (mm)	40.00	54.21	63.17 SD ± 6.58
Minimum height (mm)	31.44	42.41	45.60 SD ± 4.53
Wide (mm)	18.18	19.48	22.17 SD ± 1.60
Mortality (%)		2.5	4.87
Total # of production modules	30	44	184
Yield (# of shell-on oyster)	9,6000	14,080	74,400
Total profit Pesos$			6,900.00
Total costs Pesos$	1,126.05	4,762.37	20,705.00
Cost of production (Pesos$ per shell-on oyster)			0.33

NA: Not available. Currency exchange Pesos$ 9.30 = US Dollar$ 1.00

At the end of the first production cycle the total profit gained was Pesos$ 6,900.00 from an expected Pesos$ 99,900.00 profit. Orders were not placed from the companies in Quintana Roo and Yucatan. The group was able to supply produce to the local restaurant market network but in small quantities, an average of 260 shell-on oysters at Pesos$ 0.80 each per transaction. Due to the lack of commercial skills and contacts, market conditions of the area have been overlooked, as the financial proposal did not incorporate considerations to cover proper commercialisation of the produce. Although the group allocated the largest sales in Mexico City, as wholesalers were interested in bulk purchase, continued distribution was not achieved as the costs for leasing transport accounted for more than 50% of net profits making distribution activities and market development unsustainable.

6.3.4 Cost-benefit analysis

A cost-benefit analysis was carried out taking in consideration the most important constraints for local production, the rainy season and marketing operations. The approach considers reallocating the amount the group intended to used for tilapia feed as the initial payment to acquire a vehicle, as transportation and distribution operations costs are high when leasing these services. The production costs and benefits were calculated considering the same loan amount, the farm current level of production set at 74 400 shell-on oyster per cycle and an average market price of Pesos$0.90 per shell-on oyster. This was based on two production cycles, at 4 months per cycle based on production figures in Table 35, and bearing in mind that the last 4 months of the year have a high risk of flooding, and farm operations may be reduced to maintenance of the spat production modules.

The labour force was calculated for 5 people including technical assistance, allowing two members of the group to fish full-time on an alternating basis. Wages were increased from Pesos$ 18.00 to Pesos$ 30.00 per day in order to provide income assurance to members when they are working at the farm.

As the actual discount rate used by the funding agency was not available the CBA was carried out using Weitzman (2001) proposal on gamma discounting that considers that future can be subdivided into five sub-periods. Using within-period marginal discount, the rates for long-term public projects can be set at 4% per annum for *immediate* future (1-5 years), 3% for *near* future (6-25 years), 2% for *medium* future (26-75 years), 1% for *distant* future (76-300 years) and 0% for *far-distant* future (>300 years).

The results of the CBA, allowing only for transportation and distribution showed that the current level of La Nueva Esperanza production is not profitable, as showed by the internal rate of return for a 6 years period calculated (Table 41). In order to maximise profits a CBA considering a 25% increase in farm size was carried out maintaining all the other financial considerations the same. The total number of production modules considered in this analysis was increased from 184 to 230, which the group may still able to manage as the total modules they purchased were 350 to be set in the first year of operations. Under this consideration the farm operations was shown to be profitable attaining the same average market price of Pesos$ 0.90 with an internal rate of return of 39%.

Table 41. Cost-benefit analysis of La Nueva Esperanza farm: 2 cycle culture operations per year

Assets		*Allowing for transportation and distribution*	*Allowing for transportation, distribution and 25% increase of farm size*
Income	Total work force (# of people/ year) [1]	5	5
	Yield (shell-on oyster)	148 800	186 000
	Productivity (shell-on oyster/man-year)	29,760	37,200
	Loan	120,389.72	120,389.72
	Cost of production (Pesos$/shell-on oyster)	0.38	0.30
	Gross income at Pesos$ 0.90/shell-on oyster	133,920.00	167,400.00
	Return per Pesos$ investment	2.60	3.20
	Operating costs	57,000.00	57,000.00
Loan and tax	Depreciation plan ($/year)	105,075.00	105,075.00
	Capital repayments on loan[2]	40,129.90	40,129.90
	Capital repayments on vehicle credit[2]	53,659.44	53,659.44
	Taxable earnings from project	57,018.52	257,898.52
	Tax @ 25%	14,254.63	64,474.63
	Net cash return	42,763.89	193,423.89
	Derived cash flow		
	Contribution (income-expenses)	76,920.00	110,400.00
Less	Own capital expenditure	21,477.52	24,477.52
	Borrowed capital expenditure	120,389.72	120,389.72
	Borrowed capital payback[2]	40,129.90	40,129.90
	Interest payments	18,058.46	18,058.46
	Tax payments	14,254.63	64,474.63
	Vehicle credit repayments[2]	53,659.44	53,659.44
	Net Flows[3]	-2,503.75	148,156.25
	Discounted cash flow	4,274.32	135,904.38
	NPV	-16,542.00	105,468.00
	IRR for 6 years (%)	-1	39

[1]Includes technical assistance. [2]End of year/3 years. [3]Discount rate at 4%. Exchange rate Pesos$9.30=US Dollar$1.00.

6.4 Discussion

6.4.1 Fishing financial and marketing issues

With reference to the description by Charles and Herrera (1994) of fishery development policy sustainability in terms of ecosystem enhancement and community socio-economic maintenance, the analysis of incomes and costs for Mecoacan fishermen, suggests that rural problems have not yet been engaged in progressive policies.

It seems that previous forms of governance have been maintained to shore up power instead of laying the groundwork for viable rural production, as it is clear that some fishermen are competitive while others are not, regardless of whether or not they are associated in cooperatives. Coupled with an unstable and uncertain economy, fishermen are increasingly preoccupied with the future and attempting to find viable livelihoods. Amid their confusion about, and lack of control of the economic changes they are confronting, fishermen are actively struggling to survive and attempting to understand and cope with the changes in the sector.

It has been asserted that the survival of cooperatives has important implications for the sustainable livelihood of fishermen (Jentoft, 1989; Bojos, 1991; Roy, 1999). Firstly, through cooperatives, fishermen could achieve some economies of scale in the purchase of fixed capital and therefore lower the costs of production. Secondly, by cutting out the middlemen, bulk fishery production is likely to increase profits and make cooperative marketing more predictable and stable. This does not mean a call for the return of the protectionist state, as it has been pointed out by Alvarez (1998) and Blejer and Del Castillo (1998) in the analysis of other rural sectors, but rather a progressive state that creates an economic environment that encourages and supports competition as fishermen could look for greater efficiency and better produce quality that will make them economically viable. However, since the application of neoliberal economics policies it appears that the Mexican government approach has been to remove supports and see if any of its rural producers remain standing (McDonald, 1997).

Despite the belief by fishermen that everyone should have the right to harvest anything growing in the water, when asked about past management of estuary resources they considered that property rights could be an alternative to equally distributed access to aquatic and financial resources. This has happened with government agencies coordinating fishing effort in Mecoacan estuary when the first oyster farms were established and natural banks were extended through restocking programmes in the early 1940's.

The fishermen also argued that they could access other fishing alternatives if they were to have a diverse range of financial resources, as has happened to their agrarian ejido (parish) counterparts, who have been extended subsidies through the Programa para el Campo (PROCAMPO) programme initiated in 1993 by Carlos Salinas administration, transformed into the Programa de Educación, Salud y Alimentación (PROGRESA) during Ernesto Zedillo administration (1994-2000), and recently renamed by Vicente Fox administration (2000-2006) as the Oportunidades Human Development Programme. However, other types of government support are available to communities and 26% of interviewees have had access to federal government subsidies such as Fideicomiso Destinado para el

Subsidio de la Tortilla (FIDELIST) to sustain tortilla supply and school breakfast programme from the State government.

It may be assumed that an important implication of cooperative organisations is to stabilise prices and to reduce seasonality of prices paid to fishermen. In this regard, Charles and Herrera (1994) propose that development approaches within the fishery should seek to maximise the benefits flow directly to fishermen through sales to local organisations rather than to outside buyers and measures to increase the harvest added value by improving handling as well as the development of ancillary fishery-related services in the communities. Economic diversification in and outside the fishery sector needs to be implemented to maintain socio-economic and community sustainability in the face of market-orientated policies and as a means to improve the role of fishing cooperatives in marketing. This represents a political demand for institutional reform as a key element in resource allocation through property rights intervention and for understanding its impacts on the incomes of fishermen.

Private property in the case of fisheries, as argued by Charles (1988) and Terrebone (1995) in the form of transferable quotas may lead to optimal resource use when ownership is widely dispersed and entrepreneurs are heterogeneous. However, the heterogeneous composition of entrepreneurs in the Mecoacan estuary may be an important constraint to determine optimal fishery tax policy. Pearce and Nash (1981) suggest that if taxation could represent a management tool it has to be considered amongst the host of political and macroeconomic considerations determining taxes. This approach does not necessarily provide a method of influencing redistribution of income in relation to project selection, as may be the case for fishery quotas. Such measures may incur additional costs by introducing distortions in resource allocation.

As internal and external forces such as markets and credit come to pressure communities, proper development approaches could contribute to creating economies of scale that lead to competitiveness. The cooperatives of Mecoacan have lost competitiveness due to a lack of integration into a market-oriented production, making fishery entrepreneurship a high-risk activity and incapable of producing efficiently in a global market. These conditions may be the result of what McCay and Jentoft (1998) describe as community failure, where social relations are embedded in the economic system instead of the economy being embedded in social relations. In these circumstances, the daily lives of producers become increasingly dominated by money transactions and bureaucratic control, and social relations become basically instrumental and utilitarian.

Market development is one of the basic arguments for the potential of economies of scale to be realised, hence for a smaller number of larger producers to emerge. Credit at a fixed rate needs to be made available for modernisation of cooperative infrastructure, which will encourage cooperatives to take risks and invest in infrastructure modernisation and efficiency and may lead to the diversification of their economic base. The conditions fishermen experience suggest that the hierarchical approach influenced by political decisions as described in the previous chapter have trapped resource managers in programmes that address symptoms rather than causes of basic fish management problems.

On the other hand, if these experiences can be identified as market failure, there is justification for the role of public authorities to intervene. When such failure occurs, Thomas (1996) asserts that it becomes acute and spreads rapidly. Thus, development actions must be sensitive to the rural economy context (Harrison, 1996). In this manner, the state has the choice to foster and support competition rather than simply and inevitably abandon its rural sector.

Thus, information about markets, credit and new techniques are important, indicating that extension needs to be revived in order a) to support those fishermen organisations willing to stay in the fishery sector, b) to allocate resources, c) to develop the concept of social and economic value of resources amongst communities, and d) to organise selling within a predictable market that pays a just price (EIFAC, 1998). This would be assisted through the participation and partnership of national agencies, nongovernmental organisations, and research institutions in terms of structures and staff.

Glomm and Lagunoff (1995) suggested that reductions in income inequality might be attained in regimes with collective property, when such reductions preserve or enhance the degree of specialisation. Specialisation means individuals have claims on goods and services unavailable elsewhere in the economy, as individuals are conferred with veto power in the economy. If the veto power is symmetric in utility terms, then reducing income inequality increases the social stability of regimes with collective property rights. In this manner, Thomas (1996) points out that specialisation has to be sustained in order to avoid both social and economic instability.

There are several instances of diversification of economic base in different countries through sector planning approaches for coastal fisheries management. The analysis of the impacts of the expanded use of capital-intensive technologies has showed that the occupational diversity in coastal zones provides communities with a flexible range of opportunities to respond to changing conditions. Alternative economic activity which would not affect the fishermen's principal activity of fishing, and which also would provide paid work to those women who wish to diversify from traditional domestic work and child-care have been proven to develop well through the re-organisation of fishing organisations into new management frameworks (Charles & Herrera, 1994; Hotta, 1994; Yap, 1996; Britz *et al.*, 2000).

It has also been acknowledged that improvement in management practices might be reached through fishing cooperatives and government jointly devising development plans, as cooperatives may provide self-regulation and coordination (Charles, 1988; Jentoft, 1989; McDonald, 1997; Cyrus & Pelot, 1998) and in such cases, Panayotou (1986) asserts that government intervention is warranted to correct a market failure.

Although state intervention is not the only solution, externalities do not rule out the possibility of private or collective owned production of the resource concerned, as all public goods have the potential for either private appropriation or governmental regulation of access, in the case of collective bodies. Regarding the devolution of regulatory functions to local communities there has been ample discussion on what extent this can help to restore the crucial qualities of collective action (Jentoft, 1989; Pomeroy & Berkes, 1997; Britz *et al.*, 2000).

But it must be pointed out that in the case of rural production, ejidos and cooperatives as collective production units are considered inefficient and unprofitable under new economic policies. This is despite the fact that in Mexico rural production is mainly based on the ejido system where organised groups such as cooperatives and unions posses and exploit resources. In Tabasco 53.2% of the area is subject to the ejido resource ownership system (World Bank, 1997; INEGI, 1998).

6.4.2 Feasibility of aquaculture as an alternative source of income and employment

Coastal aquaculture may represent a source of supplementary employment to small-scale fishermen and reduce potential risks and uncertainty in the formation of another market. However, attention must be paid when implementing alternative economic sources as the use of too much capital and too little labour in areas like Mecoacan with scarce capital and abundant labour may induce wider social and economic disruption.

The option of integrating aquaculture into the Mecoacan fishery system may be significant, but it should be taken as a supplement and not as a complete replacement option. Aquaculture in Mecoacan is a part-time activity. Oyster farms and fishponds are still managed, relying entirely on group/family labour. Therefore, the interest would be to promote aquaculture with those rural producers holding knowledge of the traditional oyster farming, those with fish farming experience and those with the minimal resources for whom aquaculture could represent a significant gain.

From the CBA analysis of La Nueva Esperanza group it would be reasonable to suggest that fishermen would allocate money for aquaculture site improvement, as the activity has proven technically successful, but the lack of environmental and market knowledge is a persistent constraint. As long as the local economy remains stagnant and national macroeconomics programmes have imposed a reduced extension service, the aim would not be to promote a permanent extension activity to support site development and production management.

At the microeconomic level, risk avoidance, rather than profit maximisation, is common in the household decision making process. It has been suggested by several authors that the provision of aquaculture as an alternative source of income may not reduce fishing effort alone, it may provide a long-term solution for raising the incomes of small-scale fishermen (Pomeroy, 1992; Harrison, 1996; Pretto, 1996; Sen *et al.*, 1996). Transfer of appropriate technologies and introduction of sustainable farming systems are major challenges. To a large extent, the successful introduction of aquaculture in fishermen's livelihood portfolios may be measured through quantitative evidence of well-maintained aquaculture sites and data on factors such as the marketing of cultured species.

Examination of the less visible aspects of change requires participatory and qualitative studies, as discussed in the previous chapter. The assessment carried out here through participatory approaches, supported by economic analyses of Mecoacan fishing cooperatives, identified negative factors imposed by an undeveloped market and an evident lack of market skills of fishermen groups involved in aquaculture production.

As a result, adopting aquaculture quickly may be difficult, and conventional high input technological approaches are unlikely to be suitable due to high production costs, unavailability of commercial inputs and credit, and high-risk environmental factors such as floods. Until the relevant issues identified are targeted, high input credit-dependent technologies would be difficult to disseminate widely and any attempt to introduce them in the area could cause increase disparity between those who can and those who cannot get access to credit, as discussed by Ahmed *et al.* (1993).

Freshwater aquaculture is very limited in the area and cannot support large-scale aquaculture initiatives, so mariculture may seem to be a logical activity in the area. However, sustainable aquaculture development can succeed only if all areas of the political sector, society and science accept the concept and work together to implement it. The definition and development of market and consumer issues would be an important factor for production to evolve from subsistence to commercially viable level (Muir, 2001).

Serious constraints still exist, and new technologies may hamper development, as local expertise is not available and its feasibility may depend on economies of scale, which may affect the optimal phasing of investment (Pearce & Nash, 1981; Muir, 1995). However, even if projects are economically feasible there is high risk of failure if the technology is not accessible, as pointed out by Panayotou (1986) and Uwate and Shams (1999). Thus, future projects may need to bring in everything from capital to specialised expertise (Perez, 1998). Other mariculture technologies are not yet available in the area due to the weak relationship between research and the commercial fishery sector.

Prior to aquaculture, capture fishery has been the only source of fish supply, but in many respects, aquatic products are quite close substitutes for each other. A change of supply from one species will have some effect on the other. Whether aquaculture can enter the market depends on its cost and the market price of the species cultured, and only when the revenue is larger than opportunity cost, aquaculture enters the market (Yimin & Beddington, 1996). Where a species comes from both a capture fishery and aquaculture (e.g. shrimp or tilapia) there will be a clear interaction between them and the entry of a competitive aquaculture producer could reduce the price due an increase of the total supply.

Increasing supply from aquaculture will attract consumers from capture fisheries and may act to relieve the capture fishery from the high demand. If technology exists to culture a species with potentially larger profits than normal, aquaculture may enter whether or not the current market demand is greater or less than supply (Pedini, 2000). However, in Mecoacan, fishermen are reluctant to invest in commercial aquaculture, primarily because of the lack of accurate information on technology and production systems, the availability of species suited for potential locations, and the costs and returns of alternative systems.

Muir (1995) suggests that while the size of the system is clearly related to the quantity of physical or environmental resource available at a given location, where these are not directly limiting, development scale is more often associated with the economic and management resources implicit in the organisation and regulatory regimes. In consequence, aquaculture options for the Mecoacan estuary are likely to be:

- Small-scale, with one or more small production units, family or communally run and a spat/seed hatchery output similarly scaled up but also simply run, based on low to moderate input levels and limited external assistance and labour.
- Medium-scale with several small-medium sized production units, which may be commercially run by organised groups like La Nueva Esperanza, with moderate to high input and management levels. Hatchery equivalents may be more specialised offering some external labour.

How the management system selected will work depends greatly on the biophysical situation, the species cultured/managed and the community structure and organisation. Harrison (1996) argues that in Latin America, prospects to undertake aquaculture should be promoted through producers' organisations rather than individuals. Hence, for large-scale organisations such as fishing cooperatives, a commercial orientation is required, associated with more intensive managed systems and using larger scale production facilities, allowing varying degrees of integration. However, these broad descriptions can be misleading and it may be more important to determine the specific and localised mechanisms underlying the characteristics of all the groups operating any aquaculture site in the estuary.

The question of integrating aquaculture into coastal production systems has to do as much with the distribution of benefits as it does to the biophysical factors. Even if some species cannot be cultured, the culture of a close substitute can have similar positive effects on relieving the pressure on the capture fishery (Yimin & Beddington, 1996). It has been argued that in coastal systems, one way of maintaining benefits within a group is through community-based management, in which gains can be achieved over conventional approaches through the improved relationships arising out mutual understanding between stakeholders. This may include cooperative efforts of individual farms, community control of habitat enhancement or management and control of fishing pressures and methods. The choice to produce low or moderately priced products for the local or national market or to produce high valued products for an export market has to be made in considering the sustainability of the whole production system (Nielsen *et al.*, 1996; Newkirk, 1996; Ridler, 1997; Lee, 1999).

Regarding management regimes it has been suggested from the experience of La Nueva Esperanza that partnership for small groups of individuals can be successfully established within current legal frameworks with defined joint aims and responsibilities. Thus, institutionally organised groups with formal structures as in the case of cooperatives may act as central bodies to define strategies and targets, plan and/or bid allocation of resources. Consequently, the activity base of these organisations may be improved to allow a better horizontal integration by coordinating operations in more than one production location, with one or more areas of activity, and management linkages between units, a common approach to expansion and for risk reduction. With vertical integration, units may operate over more than one production stage to improve post-production activities such as transport, handling, processing, marketing, etc.

Although aquaculture has the potential to assist many of the efforts to restore the depleted natural resources of the estuary, signs of economic instability in communities traditionally dependent on estuary resources are more evident, as several groups have lost their livelihood over the last ten to fifteen years due to reduced access or limited entry to resources (Moguel, 1994). On the other hand, the decline of aquaculture practices can be attributed to the fishermen's desire to partake in new economic opportunities opened to them as expected with the introduction of open fishing ten years ago when the State government subsidised the establishment of a local fleet. However, this turned into another development failure due to the lack of training and assistance from the local fishery extension services. The fleet was sold after two years of unprofitable operations to fishermen from neighbouring states.

Thus, the role of aquaculture for economic development of the area should be determined for income generation, potential diversification and utilisation of marginal agriculture land. However, there are institutional weaknesses regarding aquaculture development, mostly related to its low priority for development funds and the lack of no coherent plan, although it is mentioned in strategic plans (Gob. Edo. Tab., 1995).

In the context of administrative reorganisations, the responsibility for aquaculture development has been changing from one ministry to another every few years, and the tendency of having more than one government department responsible for aquaculture development has led to confusion and competition for resources, stimulated by the interest of officers in the fisheries department to maintain a separate extension services. Thus, the lack of coordination has dispersed the responsibilities, and numerous conflicts have arisen. National plans are often no more than project catalogues, due to the common idea of aquaculture as an isolated activity rather than integrated within rural development. No attempts have been made to streamline these different bodies so that comprehensive and holistic management can be developed to coordinate and integrate programmes linked to well defined policies.

These conditions have not favoured the development of government-funded facilities, as the cost of constructing and maintaining the required infrastructure is considered to be prohibitive. The evidence of partially or non-functioning government stations in the area of Mecoacan estuary is statement to the weakness of the strategy. Fishermen believe they should be supplied with subsidised fingerlings but in this context it is impossible to meet expressed demand because of technical difficulties at the government farms and lack of transport. The fact is that people are used to free goods, and demands for loans are prevalent because a history of non-repayment makes them more like grants in the view of fishermen. This in turn inhibits the development of a private aquaculture market (i.e. seed). The majority of fishermen have not developed the independent capacity to run their own production units and thus continue to depend on governmental or non-governmental technical assistance.

Although there are considerable areas of physical and resource potential in Mecoacan, aquaculture has grown at a slower rate than expected due to the imbalanced economy of the country, resulting from recent trade and finance conditions. Most forms of aquaculture are oriented toward domestic markets based on rural aquaculture production for molluscs and freshwater fish (Perez, 1998). Minimum wages are very low, which may benefit operating costs of any aquaculture business, but the motivation to own private business is also very low due limited local market conditions, while export to national and international markets implies higher costs for product conservation and transport.

Anderson (1985) and Ridler (1997) suggest that the present value of net social benefit will depend on how social-welfare gains and losses are distributed over time, and on the magnitude of the discount rate. This requires specification of who enjoys the benefits and who incurs the costs if policy is dictated by trying to maximise the social-welfare value. On the other hand, according to Perman (1996) the optimal path over time of consumption and resource use will depend directly on the discount rate used.

Weitzman (2001) asserts that the disagreement on welfare economics considering the role of government and intergenerational discounting may be resolved when considering the declining social discount rate over time. Based on the above discussion, considering the results from the CBA and the potential large number of aquaculture users in Mecoacan estuary aquaculture may still represent an alternative source of income, and dependency on fisheries resources may be reduced. Similar economic assessments carried out by Vidal-Cornelio and Morales-Romero (1992) for two oyster culture systems in Mecoacan rendered similar results.

One of the more important characteristics of the structure of the aquaculture industry is the degree of economic integration or consolidation. The extent to which this may change is subject to the conditions for development the rise of aquaculture, whether gradual or dramatic. As a new and apparently demanding user of resources this has highlighted in many countries the absence of appropriate planning and development frameworks (Aarset, 1999). Issues such as these require a clear policy overview as well as an informed and responsive system of planning and management, to ensure efficient longer-term development and to protect the environment and the interests of the community.

7. General discussion

7.1 Sustainable coastal aquaculture and resources management

7.1.1 Background

The multi-use conditions in coastal zones require any prospective coastal zone management approach to understand and balance a range of coastal issues such as political, socio-economic and cultural considerations, physical processes, legal frameworks and ecological structures, particularly due to the small scale and artisanal or subsistence economy nature of fisheries (Vallejo 1991; Johnson, 1999).

The contribution of coastal and marine areas to sustainable development has been recognised widely by many coastal states in Latin America. Ecuador, Brazil, Mexico, Costa Rica, Colombia, Argentina, Panama, Peru, Venezuela, Chile and Uruguay have now introduced the concept of sustainability to manage coastal and marine resources while optimising the allocation of uses (Lemay, 1998).

Changes in coastal environments have been increasingly under pressure from potential pollution risks such as port operations, disposal of dredge spoils, ship borne wastes and accidental spills. Coastal communities in both rural and urban settings are rapidly expanding in response to growth in coastal tourism, maritime transport related to port activities, and urbanisation along coastal corridors. The expansion of coastal infrastructure is contributing to the degradation of coastal habitats, and as much as 65% of mangroves have been lost in Mexico in the last 20 years. Mangrove deforestation rates of over 20% over the past 20 years are show in Ecuador, Colombia, Guatemala and El Salvador. In a recent regional assessment, 55% of the entire mangrove coast of Latin America and the Caribbean was classified as either critical or endangered, 30% as vulnerable and only 15% as stable (Lemay, *op cit*).

Mexico has stepped into the pursuit of more integrated coastal management and several programmes and projects have been developed through joint efforts of government agencies, resources users and academic groups (Cervantes-Castro, 1984; Hugues-dit-ciles, 2000; NOAA, 2000). However, these programmes are generally viewed as part of a larger rural development programme (Agüero & Gonzalez, 1997) and not as integrated coastal management programmes per se.

Integrated coastal management is presented here as a broad, multi-purpose endeavour aimed at improving the quality of life of communities dependent on coastal resources. The approach focuses on issues typical of coastal areas through the combination of participatory processes, and techniques such as zoning to evaluate coastal uses and set the premises for improving living conditions, access to resources and the protection of coastal ecosystems.

7.1.2 Organisation of fisheries activities in Mexico

A number of Mexican agencies, including the state, federal and local governments, cooperatives and individual entrepreneurs are involved in fishery activities. The norms for land tenure, ownership of water bodies, exploitation policy, licensing systems and other management issues vary widely. Some states have their own fisheries departments and laws, and are engaged in seed production and distribution and the collection of revenues (SEMARNAP, 1999). At the national level, the

Ministry of Fisheries and the Instituto Nacional de la Pesca INP[8] have been responsible for fisheries development until their inclusion into the former Secretaria del Medio Ambiente, Recursos Naturales y Pesca SEMARNAP[9] in 1995 but have been recently relocated in the Secretaria de Agricultura, Ganaderia, Desarrollo Rural, Pesca y Alimentacion SAGARPA[10].

The new organisation of SEMARNAP under the Secretaria del Medio Ambiente y Recursos Naturales SEMARNAT[11] was established in order to enhance environmental policy implementation and enforcement, and to support institutional capacity building for sustainable development (SEMARNAT, 2002). The headquarters of ministries are all situated in Mexico City. Fisheries officials are posted in the federal delegations located in the states' capitals. In the reorganisation, the Comision Nacional del Agua CNA[12], which is also involved in the process of fisheries development, remained under the new SEMARNAT.

Organisation of fishing groups

Fishing groups are now organized by SAGARPA. The systematic development of lakes and reservoirs through extensive aquaculture was initiated by SEMARNAT in order to increase the number of water bodies managed and to augment the productivity of those already under different management approaches (SEMARNAP, 1999).

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[8] Fisheries National Institute
[9] Ministry of Environment, Natural Resources and Fisheries
[10] Secretaria de Agricultura, Ganaderia, Desarrollo rural, Pesca y Alimentacion
[11] Ministry of Environment and Natural Resources
[12] National Water Commission

Proposals for the organization and management of fishing groups are first sent to the Instituto Nacional de la Pesca for assessment of the existing fisheries stock. The INP decides the type and quantity of gear to be used and mandates the proposal to be evaluated by the Instituto Nacional de Ecologia INE[13] for an environmental impact assessment. Finally, the proposal goes through the Fisheries Management Group in SAGARPA, which issues the necessary permission and licence. The federal delegation coordinates the cooperative organisations and provides assistance in stock management, financial aid and infrastructure development.

7.2 Major constraints for the management of Tabasco coastal area

The discovery of oil in the Gulf of Mexico, and the bonanza it brought in the years 1978-1981, raised hopes of major economic improvements. But despite its oil resources the country has suffered a series of economic crises in the last 15 years. The Government relied entirely on those revenues to finance its internal and external debt costs as 70 percent of all export earnings have been made from the oil industry, and other measures were not tried to help meet the costs (Fraser & Restrepo-Estrada, 1996).

National macroeconomic pressures have also promoted major shifts in livelihood strategies on the rural communities of the Tabasco coastal area, increasing the pressure over natural resources and reducing access to them. Rural fishing villages depend on heavily fished inshore stocks for subsistence, and on mangrove wood for firewood and construction materials. The economic dependence of communities on coastal resources and lands is one of the major challenges of coastal management.

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[13] Ecology National Institute

In the Mecoacan area it was observed that landless people from local communities have settled in deforested and flood prone areas because these are the only lands available to them for settlement as an alternative to migration.

Inadequate institutional capacity reveals itself in the difficulties faced by government institutions to mitigate the adverse effects of development on coastal areas or to resolve conflicts over the allocation of resources under public jurisdiction. As observed in the Mecoacan estuary, the virtual lack of surveillance and enforcement is a widespread institutional problem and one that has left several locations vulnerable to illegal activities.

To date, resource management in the state has mainly comprised a collection of projects, which may or may not support sustainable development opportunities. Real political commitment to the goals of coastal management is still rare, with little evidence in sectoral plans, particularly for fisheries and aquaculture. The lack of coordination among different agencies and social groups has dispersed responsibilities. Because of these conditions aquaculture has been regarded as an isolated activity rather than an integrated activity into rural development.

A particular example of the failure of rural development approaches was recorded in Tabasco when the Plan Chontalpa was launched as one of the largest agro-industrial projects ever implemented in tropical areas. A massive investment in infrastructure was provided for dikes, roads and bridges to settle rural families with all the services they needed. Machinery, credit, inputs, and technical assistance to the farmers were foreseen and 22 new villages accommodated 4 400 families with schools, health clinics and processing plants for basic agricultural produce (Fraser & Restrepo-Estrada, 1996).

Unfortunately the local population never identified with the project as the authorities took all the decisions. Fraser and Restrepo-Estrada (*op cit.*) describe the project as a massive "top-down" intervention without prior consultation or agreement with its beneficiaries, in the belief that this would lead to greater efficiency and better use of capital and technology. The strategy met with serious levels of technology under-utilisation, and inadequate use of wells, irrigation equipment, soils and management of drainage in individual plots. The main consequences of the approach were a continuing process of impoverishment of rural communities living in the area and in even greater disjunction between government agencies and *ejidos* committees.

7.3 Development issues of Mecoacan fishery resources

Fisheries

The fishery sector faces distinct problems in terms of sustainability. In the Mecoacan estuary, fishing is structured around artisanal and small-scale operations based on pelagic species and inshore fisheries, which contribute to the income of rural coastal communities. Federal fishing licenses are issued under fishing acts that allow associated fishermen to exploit all the waters within the jurisdiction of the municipality. However, problems related to the condition of open access, high sensitivity to market prices, the needs for improved management and severe fluctuations in biomass resulting from changes in natural conditions are common to the fisheries of Mecoacan. These have increased because independent fishermen (free riders) are not subject to any regulation. The undeveloped market conditions favoured by local middlemen also imposes a low added value to fisheries produce.

As discussed in section 5.9.1, fishing is a male dominated activity in Mecoacan communities. Although respondents noted that two females were significantly involved in trading fisheries products in and out of the state, the role of women in fishing is limited to processing and in local marketing of produce. Female participation in fishing cooperatives has been partial or insignificant.

It has been suggested that female populations may directly benefit from adopting aquaculture in terms of labour and income, reducing therefore social constraints based on gender participation in fisheries (Ahmed *et al.*, 1993; Lewis, 1997). Although results suggest that current aquaculture activities fall within local cultural norms in the Mecoacan estuary, the participation of women in these activities has also been limited to the assembling of oyster seed collectors and the processing of the harvest. Thus, a significant division of labour by gender was observed.

This suggests that shifts in the livelihoods of Mecoacan fishing communities may occur due to significant changes in the availability of employment for males. These have important implications for patterns of social and economic organisation in local fisheries. Fishermen have moved their activities from estuary to marine fishing due the lesser surveillance from local fisheries authority and perceived higher income. However, they have faced fluctuating and diminishing stocks, substandard and unpredictable incomes, and increased operating costs. Due to these conditions they have had to engage in non-fishing activities (i.e. agriculture, wage labour jobs). The distribution of fishermen according to secondary sources of employment is shown in Appendix E.

Kinship relationships between fishermen and middlemen were observed to be significant in fisheries trading and in getting a job. However, the predetermined shares from the proceeds of catch established by middlemen have been a negative factor making income from fishing less certain, as fishermen may experience prolonged poor catches that prompts a higher dependence on credit offered by middlemen. McGoodwin (1990) states that the social and cultural patterns of this way of life make fishermen continue in a fishery even when it does not provide any significant economic return.

Aquaculture

Although coastal aquaculture is gaining prominence in Mexico, its importance is relatively small when compared to other tropical regions such as Asia (Lemay, 1998). In the case of oyster, farming activities have proved to be a profitable activity in the coastal zone of Tabasco (Rodriguez, 1998) and people are skilled in managing culture technology. However, its potential has not been fully achieved, as aquaculture has not been perceived as an alternative income source. On the one hand, this is due to market prices, which are not significantly different from captured fisheries, which implies that activity shift is strongly related to cash availability in the short term. On the other hand, community involvement in aquaculture practices is low due to the long term of production cycles and restricted market access.

However, the fears of fishermen are comprehensible, as they commented that employment in fishing is often the primary means of ensuring that household needs are met. Although aquaculture might not replace the principal activity of fishing, but become another alternative to improve security, partnership for small groups of individuals may be established to develop small-scale labour-intensive aquaculture as it was observed in La Nueva Esperanza group and suggested by Hugues-Dit-Ciles (2000).

Although, the strong demand for valuable species is still stimulating interest in aquaculture. Its advantages over conventional fishing have been widely recognised as well as an alternative to support fisheries production, a way for improving average income through the creation of employment opportunities outside the fishery sector and a means of reduction in fishing effort (Shang, 1981; Pomeroy, 1992; McManus, 1995; Ye & Beddington, 1996). The practical implications for the development of this approach into integrated coastal resources management are discussed below.

7.4 Policy implications

Coastal areas are the targets of accelerated changes and conflicts with which these are associated. The recognition of these potential impacts has directed attention towards the constraints in implementing integrated coastal zone management. Lemay (1998) asserts that although sectoral policies are designed to achieve legitimate objectives, there are unanticipated and negative side effects on coastal communities, and reforming such conditions may provide a cost-effective tool for promoting coastal sustainability, as it requires the necessary institutional capacity for successful implementation and enforcement.

The analysis of Mecoacan fishing communities has shown that significant opportunities as well as hidden costs have been overlooked by not involving coastal communities into the decision-making process for resource allocation. There has been also an absence of investments to link watershed management with coastal management to reduce impacts from natural processes such as sedimentation, affecting the ecosystem dynamics of the Mecoacan estuary.

A lack of understanding of the coastal zone has also resulted in sector-based approaches to management, which have overlooked the multiple uses of coastal areas and the dynamics of ecosystems. In the absence of clear property rights or management, fisheries resources, coastal lands and mangroves are overused; this has contributed to the displacement of low-income users and even civil unrest (Moguel, 1994). Lemay (1998) points out that these problems are usually accumulative and represent a major challenge to coastal management.

7.5 Practical implications of an ICM approach

It has been discussed in the literature that in a local community context where common reference points can be used and where public and private costs and benefits can be defined, participatory approaches may be allocated for collective decision-making (Montgomery, 1991; Bardhan, 1993; McCay & Jentoft, 1996). These approaches have developed well through the re-organisation of fishing organisations into new management frameworks, as they provide self-regulation and coordination, providing alternative economic activities to fishermen without affecting their principal activity, and involving women who wish to diversify from traditional domestic work (Charles & Herrera, 1994; Hotta, 1994; Yap, 1996; Britz *et al.*, 2000).

According to Panayotou (1986) and Thomas (1996) a policy climate that improves the terms of trade for rural production and the vertical diversification of the sector provides justification for state intervention. In this manner, the state has the choice to foster and support competition rather than simply abandon the sector. However, this does not mean a call for the return of the protectionist state.

Traditional sector approaches have not been entirely effective in maintaining the productive value of Tabasco's coastal areas, as the role of public sector institutions in managing coastal and marine resources has gone through major shifts, and incentives have not yet been introduced to ensure that interventions address sustainability. However, assuming that state intervention is required, the subsequent options of compromise and consensus proposed by Warner and Jones (1998) for the 'do-something' scenarios may represent a valuable strategy to assist in the management of Mecoacan resources, promoting capacity building within fishing organisations by placing coastal development in the context of sustainable integration of resources.

Although state intervention is not the only solution, externalities do not rule out the possibility of private or collective owned production of the resource concerned, as all public goods have the potential for either private appropriation or governmental regulation of access (Jentoft, 1989; Pomeroy & Berkes, 1997; Britz *et al.*, 2000). In the case of collective bodies, improvement in management practices might be reached through fishing cooperatives and government jointly devising development plans (Charles, 1988; Jentoft, 1989; McDonald, 1997; Cyrus & Pelot, 1998)

However, the historical and cultural traditions of Tabasco's coastal zone have been based on the maintenance of the common property condition and the principle of free fishing. Based on this appreciation fishermen stated that anyone has the right to fish wherever they please. This attitude is deeper in independent fishermen (free riders) who are not willing to pay for exclusive access to a resource that may be free elsewhere. Under these conditions Brock *et al.* (2000) discuss that without well-defined property rights, markets will not be established for all goods and services and the result is that incentives will be distorted.

On the other hand, Ferrer (1989) and Brock *et al.* (2000) assert that the owners of the resource, having an interest in its current and future productivity, would be inclined to control fishing effort to manage the resource in a socially efficient way and maximise the net benefits from the resources, because they will themselves bear the cost of mismanagement.

Although territorial rights may be appropriate as an allocation distribution measures for Mecoacan resources, it may prove to be difficult if government support is not available for fostering community-based management and developing alternative income sources (i.e. tourism, value-added produce, direct marketing activities). In the past, estuary resources were managed based on equally distributed access to aquatic and financial resources through cooperatives, as government agencies coordinated fishing effort. However, a host of economic and political factors have contributed to the decline of cooperative management regimes in Mecoacan, as previously discussed.

Christy (1982) asserts that where fixed culture systems are developed, property rights can be established in public areas. Therefore, the conditions that influence the creation and maintenance of localised territorial rights relate to the resource, boundaries, technology used, cultural attitudes, governmental systems and legal institutional frameworks may be present in the Mecoacan estuary. Although ideal conditions will never exist, the possibilities of partially achieving this goal may be sufficient (Table 42).

Table 42. Issues in the development of property/user rights approaches for aquaculture in the Mecoacan estuary

Institutions and organisations	*Levels of management*
Government agencies, NGOs, universities and technology centres	Site allocation, stocking, technical assistance (culture systems, marketing, financial), market regulation (bidding system establishment/support), capacity building and monitoring (communication and negotiation skills training, providing of facilitation/mediation services), improving general conditions of fishing laws (control over free riding)
Local organisations/groups	Stocking, labour, site development, profit distribution, waste management (land-based systems), production planning, consensual negotiations with other groups, development of common visions and goals, knowledge communication
Strategy	
Consultation with stakeholders and partners over strategic research agenda, define processes and mechanisms leading to impact, identify linkages between research and local knowledge to adapt systems to local situations, set up mechanisms for feedback, involve stakeholders in monitoring and evaluation	

Based on the evidence of group-based aquaculture management observed in different locations in the estuary, it may be considered that further studies of the concept of localised territorial rights may be carried out. Christy (1982) stated that such studies should deal with further and more detailed examinations for the conditions permitting the creation of territorial rights, the ways in which the benefits are shared or distributed within communities or groups acquiring the rights and identify the kinds of controls over newly created territorial rights.

It would be reasonable to assume that customary tenure practices in traditional societies would almost certainly regulate aquaculture in some way. For its part, the Federal Fisheries Law of Mexico contains a section dealing specifically with aquaculture in all its various forms (Van Houtte *et al.*, 1989) and Federal regulations exist for the management and culture of oyster (PROFEPA, 1998). The lack of state laws and regulations for aquaculture must then be attributed to other reasons.

The fishermen of Mecoacan considered that property rights could enhance their access to resources. Thus, if a property rights approach is to be considered, the political requirement for institutional reform and the potential impacts on the livelihood resources of fishermen are important elements, as conflicts may be resolved by directing and improving benefits to local organisations through government regulation as discussed by Jentoft (1989), Charles and Herrera (1994), Pomeroy and Berkes (1997) and Britz (2000) on the devolution of regulatory functions to local communities.

Technical experiences in coastal aquaculture in Mecoacan indicate the importance of local organisations. Territorial rights for aquaculture site management may be granted to groups such as La Nueva Esperanza, providing this kind of arrangement for oyster systems and fish cages and enclosures. As asserted by Ferrer (1989) an essential element of community-based ICM is that fishermen who have organised themselves have a better chance of managing their fisheries successfully.

Considering the productive benefits that may be obtained through the establishment of territorial rights, information about markets, credit and new techniques are important. This suggests that extension services have to be revived, but better focused, in order to support those fishermen's organisations willing to stay in the sector and to integrate aquaculture into their activities, as the lack of environmental and market knowledge among fishermen was found to be an important constraint. The aim is not to promote a permanent extension activity but an effective means of coordination, considering that aquaculture must be taken as a starting point and not as a whole new system to support the improvement of coastal communities livelihoods.

The increasing need for ICM is a logical consequence of the rapid socio-economic and environmental changes occurring around the world's coastlines. Whilst the findings of GIS based research may potentially be of both academic and practical interest, they will be of little significance to coastal managers and planners and communities if they cannot easily obtain access to them. The use of multi-criteria evaluation exercises involving all stakeholders is therefore an important factor that must be integrated in the decision-making process to promote sustainable livelihoods and to avoid the disappointing effects of full top-down projects such as the Chontalpa Plan (Bebbington, 1999; Nguyen & Meyer, 1999).

The GIS modelling approach to assess socio-economic issues, environmental factors and resources allocation showed that a general agreement exists among government and NGOs officers while differences among both associated and independent fishermen (free riders) depended significantly on their perspectives and interests in accessing resources. Thus, the provision of coastal resources databases through GIS assessments may enhance the feasibility of an ICM approach to promote an equitable and sustainable allocation of coastal resources, overcome the conflicts associated with sectoral management and preserve the productivity and diversity of coastal ecosystems (Lemay, 1998; Jones *et al.,* 1999). Databases on Tabasco coastal ecosystems are starting to be documented and information from scattered small projects are helping to build local capacity in coastal disciplines, mainly in NGOs and universities (Lopez *et al.*, 1997; Rodriguez, 1998).

The identification of non-conflicting zones through the multi-objective land allocation modelling indicates that the integration of aquaculture with other economic activities is still possible in the coastal zone of Tabasco and potential impacts from the oil industry are low, as most of the suitable areas identified for aquaculture are distant from oil facilities. In terms of potential benefits from the areas identified, estimations showed that tilapia might be more attractive due the number of production cycles that can be obtained in a year representing a more reliable income source.

A potential sectoral strategy for integrated coastal management, including coastal aquaculture development is discussed in the following sections. The strategy outlines the key issues and takes into account the use and demands of resources, which will determine its growth in a sustainable manner.

7.6 Approaches for aquaculture development

7.6.1 Introduction

Expansion in aquaculture production in global and regional terms has resulted in increasing demand for and exploitation of many natural resources. Social and economic constraints may represent an important barrier to improve resource utilisation (Lewis, 1997; Holland & Brown, 1999). Agüero and Gonzalez (1997) state that although coastal management programmes and policies are increasingly incorporating environmental considerations, there is little reference to laws and regulations to facilitate or promote aquaculture activities.

Many of the constraints identified in the Mecoacan estuary for aquaculture development require collaborative work between institutions and organisations, as conflicts over natural resources exists because the rights to use some of these resources are not well defined or enforced.

7.6.2 Institutional and local organisations issues

Broad development projects have been supported and promoted regarding the integration of aquaculture into the economy of the state. However, rather than increasing the role of cooperative organisations as formal control bodies for the access of resources, they have increased the conflict between associated and independent fishermen (free riders). One of the most important conflicts in the area is that of the extended oyster banks shown in Figure 80, as independent fishermen exploit these banks along with associated fishermen without returning oyster shells to natural seed and growth-out areas, which is the principal means for restocking oyster natural banks, as discussed in sections 5.5.1 and 5.91.

Cooperatives represent an excellent case for examining the relationship between perceptions and strategies of fishermen, as they struggle to remain within an economic system they neither understand nor have control over. Increasing interest in restructuring local organisations was regarded by both associated and independent fishermen as an important issue in solving conflicts concerning access to resources, supporting alternatives to generate employment and income through aquaculture, taking advantage of new market development and controlling market prices of fisheries produce. Considering the many stakeholders, appropriate indicators sets could be identified to assess the impact and performance of development policies under the approaches proposed above (Thomas, 1996; Hoon *et al.*, 1999; Roy, 1999).

The linkage created between bottom-up and top-down approaches to resource management and policy reform is one dimension of integrated coastal management frameworks. Described as a two-track approach, this calls for building capacity within central government, coastal communities and local organisations. Jentoft (1989), Lewis (1997) and Lemay (1998) state that the power of this approach lies in creating dialogue that promotes a sense of shared purpose at all levels, as competing parties can be encouraged to recognise the mutual interest to promote and support sustainability of the resource-base.

Key local agencies must recognise that if top-down sustainability approaches are to be promoted they must involve awareness raising and education across all user groups. Recognition of stakeholder participation and needs at the local community level, involving the participation of groups responsible of production and marketing would be required to ensure that needs are adequately represented. Where possible, in the case of conflict-solving frameworks, close liaison between groups, full cost-benefit analysis and transparency in the decision-making process have to be provided as short-term consequences might have unpredictable social and costs impacts on coastal communities (Tibbetts, 1996; EIFAC, 1998).

Regarding bottom-up approaches, the promotion of productive alternatives has met with mixed success. The participation of NGOs, scientists and professionals has been a key factor in the promotion of more integrated approaches. However, the major constraint is that they have been attempting to counteract an environment in which their components have little access to political and economic resources (Halen *et al.*, 1991; Rodriguez, 1998).

Fishermen noted that if any approach to incorporate communities into management would be carried out, the legal coordination and control is significantly dependent on the governmental political will to decentralise decision-making for regulation and policy through the local organisations. The establishment of a mediating agency is an important step, and the effectiveness of this action may be greatly influenced by the local social context, the skill and understanding of human resources and the extent and accurate use of external information for strategic evaluation as discussed by Pomeroy and Berkes (1997), Muir *et al.* (1999), and Rivera-Arriaga & Villalobos (2001).

The *Ejido* (parish land) is still a predominant legal framework for land management in rural coastal areas. One of the obstacles to the reform of land distribution has been the regulation that prohibited the fragmentation of *ejido* land, which prevented rural producers from obtaining and transferring land titles. This law was amended in 1993 to allow the selective distribution of land among farmers, but the process has progressed slowly (Sugunan, 1997). 85% of the households in this study possess a land title, which have enabled them to implement small-scale businesses, as commented in sections 5.2.2 and 5.8.2.

Nevertheless, in terms of traditional management, the ejido-based legal structure for the distribution of land still offers an important opportunity for capacity building on community-based management. The system embraces poor households in the poorer areas, where many of them are subsistence farmers. This traditional system, which goes back to pre-Colombian times, typically has a number of internal committees to deal with matters such as health, women's affairs, drinking water, and other social issues. A group of *ejidos* may join together to form a second-level association known as an *ejidos* union. A union will often provide services to its member *ejidos*, such as supply of farm inputs (Fraser & Restrepo-Estrada, 1996).

These kinds of organisation have not been used to develop integrated coastal management frameworks since the main thrust of government policies and programmes has been the agricultural sector, and fisheries development programmes have focused on relatively large-scale commercial operations which are export oriented (Fraser & Restrepo-Estrada, *op cit.*; Sugunan, 1997; Lemay, 1998).

Lemay (*op cit.*) asserts that coastal management embraces the principles of participation and transparency, which contribute to social equity and good governance for the effective cooperative management of coastal assets, and increase contributions to sustained economic growth. Two major issues have to be tackled in order to promote the development of integrated coastal management approaches in Tabasco's coastal zone: a) application of participatory planning methods and b) a renewed focus on monitoring, supported by an emphasis in decentralisation of decision-making in planning and implementation of resource management programmes.

In order to set the conditions for managing common resources, institutions and organisations must develop a common judgment. Although the ownership of coastal programmes has to reside within several constituencies representing the different sectors depending on coastal resources, generalized norms of reciprocity and trust can be used as initial capacity building amongst stakeholders (Lemay, 1998; Brock *et al.*, 2000).

Networks might serve as an important starting point for creating ownership for larger, more permanent coastal initiatives. Initial institutional arrangements such inter-agency commissions have been made in order to coordinate efforts, with the establishment of the State Fishery and Marine Resources Commission and the Comision Interinstitucional para el Medio Ambiente y Desarrollo CIMADES[14]. These aim at the integration of partnerships with national and local resource management agencies, the private sector, non-governmental organisations and the scientific community, representing an important opportunity to address properly conflicts in the coastal zone. Local organisations from Paraiso, Tenosique and Balancan municipalities, supported by the government development agency Fondo Nacional de Empresas en Solidaridad FONAES[15] and the NGO St. Tomas have become part of the National Fishermen Network since 1994 (Santo Tomas, 1999).

Coastal sciences and local expertise require also to be continuously combined with the notion of good governance to move from open to closed access regimes. Therefore, a key to success will be to demonstrate the ability of good coastal management to yield measurable returns in terms of competitiveness, employment generation and reduction of public costs by establishing formal agreements for cost sharing between local government, private sector associations, NGOs and financing institutions. But it has to be stressed that is important to have all coastal stakeholders genuinely participate in less bureaucratic and more participatory decision-making to set priorities and arrangements for project execution and coordination services.

7.6.3 Human capital development

The strategies being discussed suggest that a range of aspects including social, economic and recreational considerations, biodiversity and the wider aquatic

[14] Inter-institutional Commission of Environment and Development

environment needs to be considered to reduce the negative impacts that previous fishing cooperative administrations in Mecoacan have induced, and to restore confidence in cooperative production. An important issue in this regard is the development of human resources. The human capital analysis indicated that collective aggregation is not producing a positive outcome for the communities of Mecoacan. Further assessment required would be of the effects of key socio-cultural relationships on resources access in order to redirect or expand current efforts.

In the cases of earlier aquaculture activities, the technology did not remain in the local community after introduction, and no resident experts were found or had developed, as local people do not have the capability to improve culture techniques without external assistance. Success in technology transfer requires improvements in communications. These have occurred gradually, but the area still faces a low access to state-of-the-art information and a shortage of local, skilled technicians.

In the area there are schools offering basic fishery and aquaculture-related courses to students at the high school level, and this promises to have long-term positive effects on aquaculture development. The motivation for learning new technology must be stimulated within the community; otherwise the success of technology transfer cannot be warranted.

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[15] National Trust for Solidarity Enterprises

7.6.4 Technology and systems development

The Fisheries Law to foster the growth of the aquaculture sector provides legal security and makes long-term investments possible. The activities supported by the Ministry of Fisheries are focused on relaxing regulations imposed by other government agencies. Under this legal framework, no licences are required by aquaculture producers interested in the development of sea farms or floating cages in inland water bodies (Sugunan, 1997). Land-based systems may be constructed on public land to benefit coastal communities, but attention must be considered in developing farming sites, to reduce impacts on areas of mangrove and other coastal resources on which communities have traditionally relied (Muir *et al.*, 1999).

7.7 Strategy toward an ICM for Tabasco coastal zone

7.7.1 Resource use and projected economic impacts

The interviewees rated fishing as a low-income activity, particularly for those involved in estuary fishing. 22% of the fishermen reported to have a second job to complement their income. While fishing offers an opportunity for short-term development, coastal aquaculture might offer more jobs over a longer period despite its slow development (Britz et al., 2000).

The national per capita consumption of fishery products between 1954-1999 was 1.42-7.97 kg/yr (SEMARNAP, 1999). Increases in consumption are not expected as the rate dropped from 10.87 to 7.97 since 1990. Therefore, potential benefits may be expected in export earning and employment, as more than 80% of fisheries production is addressed to export markets (Chew, 1998). An analysis of aquaculture and culture-based fisheries development is provided, considering existing initiatives for oyster and tilapia culture, and new mariculture technologies (e.g. ornamental fish, mussel shore based farming). Although in aquaculture, as in other resource dependent sectors, complexity in the management and allocation of resources increases as sectors expand (Funge-Smith, 1999, Muir, 2001), various scenarios for aquaculture development can be developed through GIS modelling taking into account estimations for water and resources use, and the potential contributions to regional economic growth.

Significant marginal increases in production can be expected from aquaculture systems. Table 43 shows the resource availability based on the area identified through the GIS modelling, and the options to produce moderately valued products for the local and national market based on the financial assessment of Mecoacan fisheries. On the basis of these scenarios, an average increase of 119 658 t yr^{1} from extensive systems may be feasible with a potential economic contribution of Pesos $ 478.63 million (USDollar $51.5 million). The potential for permanent employment and the development of commercial activities is significant.

Table 43. Projected coastal resource use and economic benefits from aquaculture development in the coastal zone of Tabasco

Issues	*Oyster, Tilapia, ornamental fish, shrimp*	*Tilapia, mussels, oyster, shrimp*
Systems	Extensive ponds/enclosures	Semi-intensive ponds/cages/rafts
Economics	Entrepreneurial/subsistence	Commercial
Productivity t ha^{1} yr^{1} [a]	0.3 – 4.2	6.8 –14.4
Production t ha^{1} yr^{1} [a]	98 542	337 861
Water required m^{3} t^{1} [a]	3,000 – 5,000	6,000 – 11,000
Water usage 10^{8} m^{3} t^{1} yr^{1} [a]	4.92	37.16
Estimated profit US$/year [b,c]	84,767,311	290,633,118
Permanent employment/cycle [c]	8,211	28,155

Suitable area for development identified through the GIS-based modelling 23 462 ha. [a] Based on Muir (2001) [b] 9.33 Pesos = 1 US Dollar (May 2001). [c] Production considerations based on Table 15

Although development directives have been set out for Tabasco's fisheries and aquaculture, development plans have not outlined the mechanisms to make the most of the potential benefits that can be obtained through enhanced production. It may be assumed that the low contribution of fisheries to the state economy compared to that of the oil industry (Table 1) has reduced the importance of the fisheries in coastal communities livelihood and in regional development, making plans and proposals a mere collection of programmes only useful to cover a political agenda.

7.7.3 Organisation and management

Absence or inadequate coastal management in the coastal area of Tabasco have resulted in large-scale exploitation of resources, degradation of the environment and increased impoverishment of rural communities. Based on the potential benefits that might be derived from integrated coastal management, the purpose of this section is to outline a plan to integrate multi-sectoral approaches.

The experiences in developing coastal management plans suggest the need of an integrated multi-sectoral approach (Scura *et al.*, 1992; Yañez-Arancibia, 1999). Multi-sectoral collaboration involving different agencies from state and municipal government, universities, NGOs and communities in ICM planning and implementation may be feasible in practice for Tabasco. However, in order to take place, the state government may need to provide the base structure to integrate other constituencies. The approach would encompass development toward sustainable utilization of resources and environmental conservation, such as:

a) Resources allocation schemes through the resolution of conflicting usages
b) Community-based monitoring to optimise resources availability
c) Integration of economic opportunities to enhance the livelihood of coastal communities.

This means that research and development on coastal issues may be needed to achieve long-term benefits through the integration of coastal resources. Programmes may be combined to moderate certain conflicts, and to make environmental, social and economic policies compatible. The operational effectiveness of this approach may be gained through the improvement of current and the development of linkages between institutions and organisations (Fig. 106). The neutral character of the Inter-institutional Commission of Environment and Development and the State Fisheries and Marine Resources Commission could provide multidisciplinary staff, organisational mandate, and exposure to coastal communities.

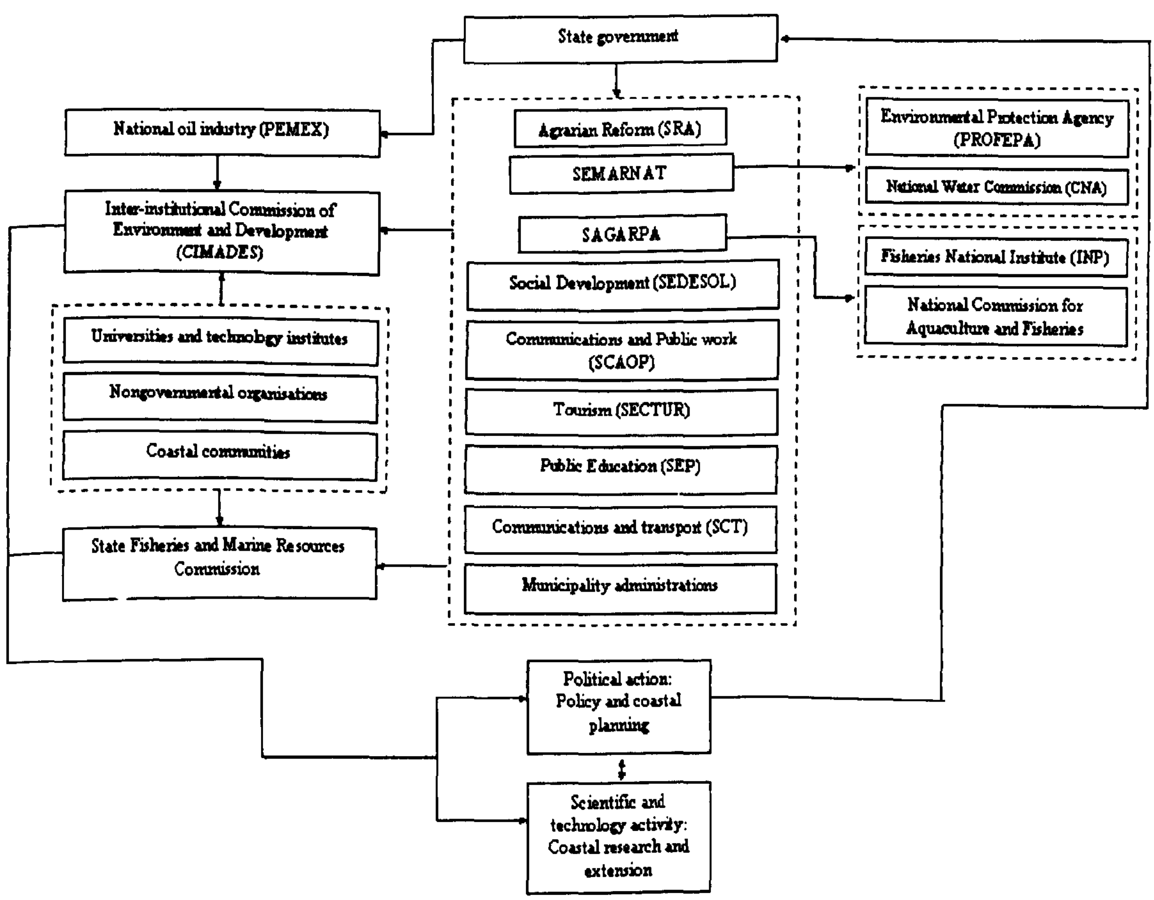

Figure 106. Structure suggested for implementing an ICM in Tabasco state

Elements of the precautionary approach may be applied, such as identification of potential adverse impacts, establishment of contingency plans in the event of adverse impacts, and development of strategies to minimise conflicts and risk between fisheries and other resource users. Figure 107 shows a framework which link programmes to specific conflicts in Tabasco coastal zone.

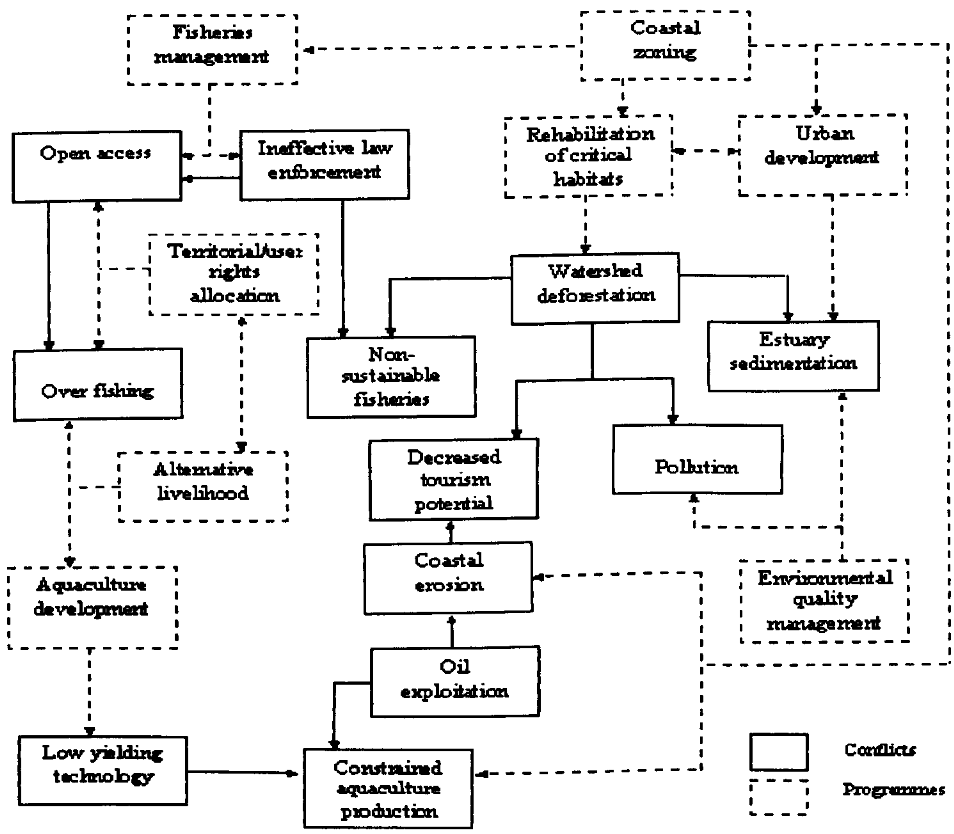

Figure 107. Integrated coastal management framework for Tabasco, Mexico. Developed from Scura *et al.* (1992)

Finally, this case study has highlighted that although conflict over resource access and allocation remain as a major social and economic constraint the conditions to promote a multi-sectoral planning approach are available and the consolidation of previous and new successful approaches represent a significant role in the process of evaluating coastal trends and the effectiveness of management measures including those related to aquaculture development in the coastal zone of Tabasco.

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APPENDIX A

A. Semi-structure questionnaire for the RRA

1. FAMILY STRUCTURE

1.1 How many members does family have? _____

First name	Age	Reads		Education			
		NO	YES	Primary	Secondary	High S.	Graduate

2. EMPLOYMENT

	Who?	Earnings
Agriculture		
Livestock		
Fishing		
Individual sales		
Graduate		
Oil worker		
Handcrafting		
Clerk		
Building worker		
Janitor, maiden or waitress		
Other (__________)		

3. FISHING ACTIVITIES

3.1 Time and days for fishing

Who?	M	T	W	T	F	S	S	Dawn	Morning	Afternoon	Dusk

3.2 Specie and volume capture: (specify volume per week) Fish (______) Shrimp (______) Oyster (________) Crab (_________) Other (______)

3.3 Type of fishing gear and/or art: ______________________________

3.4 Fishing site: ______________________________________

3.5 Time spent to arrive at fishing site: ______________

3.6 Do you use any process to conserve your catch fresh?_______ Which?__________________

3.7 Where do you sale your catch?

Product	Co-operative	Middlemen	Broker	Other	Price
Fish					
Shrimp					
Oyster					
Crab					

3.8 What kind of processing do you practice? Filleting ( ) Crab carving ( ) Oyster carving ( ) Smoking ( ) Gutting ( ), Where do you process your catch?_________ Who does the processing?___________ is there any payment or hiring for processing?________ who hire for processing?____

3.9 Do you select the catch to be processed? _____ You select by size ( ) specie( )

3.10 Are you a co-operative fisherman? _____ (If no go to 3.12)
3.11 Are there female members in the co-operative? ________
3.12 Is there any reason why you are not a co-operative fisherman?

____

3.13 Who is the owner of the equipment and fishing gears and arts? Co-operative ( ) Fisherman ( ) Family ( ) Borrowed ( ) Other (_ ________)
3.14 How much do you spend in equipment and fishing gears and arts maintenance?

____

3.15 Have you been involved in any fisheries or aquaculture programme? ___ Which: Oyster ( ) Shrimp( ) Tilapia ( ) Other ( )

4. FOOD

4.1 How often do you consume the following? D= Dairy A= Almost every day T= Three time a week O= Once a week

Chicken	Fish	Oyster	Meat	Eggs	Tortillas	Rice	Beans	Vegetables	Fruits

5. HOUSING

5.1 Building materials

	Roof	Walls		Floor
Wooden			Earthen	
Concrete			Concrete	
Brick			Tile	
Zinc cover			Earthen/concrete	

5.2 How many rooms: __________
5.3 What kind of water supply: Municipality network ( ) Well ( ) Other (__)
5.4 Is there a sewage system available? _________
5.5 Where is domestic sewage addressed? ________________
5.6 Do you have the electricity service?_______ Do you have a contract?___
5.7 What do you use for cooking? Wood ( ) Gas ( ) Electricity ( )
5.8 Who is the owner of the land you are leaving in?______ Do you own other lands? _____ Do you have land title? _______

6. HEALTH SERVICES

6.1 Where do you receive health service? Health centre ( ) Private physician ( ) Private hospital ( ) medicine man/woman ( ) pharmacy ( )
6.2 Are you registered in the National Health Service? ____ Other:_______________

7. AGRICULTURE AND ANIMAL ENTERPRISES

7.1 Do you practice agriculture: Chilli ( ) Tomato ( ) Corn ( ) Vegetables ( ) spices ( ) Beans ( ) coconut ( ) cocoa ( ) Other ______________
7.7 Do you grow any specie: Chicken ( ) Pig (____) Lamb (______) Cattle (_____) Goats (____)
7.9 What do you use them for: Sale ( ) Family consumption ( ) Other ( )

8. RESOURCES MANAGEMENT

8.1 Which is the most important thing for your livelihood?____________
8.2 Have you participated in fishing or agriculture management programmes?____

9 GENERAL DATA
9.1 Respondent location
Ejido/Ranchería/Villa/Colonia:______________________________
Municipality ____
9.2 Date _______________________________________
9.3 Respondent name ____________________________________
9.4 Sex: Male ( ) Female ( )
9.5 Number of families in the household____________
9.6 Religion ________________________
9.7 Interviewer: Eunice ( )
Miguel Angel ( )
José Manuel ( )

APPENDIX B

Structured questionnaire for the five-factors matrix (multiway factor analysis)

The aim of this questionnaire is to analysis the relationship between fisheries production and aquaculture. Mark the option you may find appropriate. Thanks for your collaboration.

I. SOCIAL ISSUES

1. Fishing organisations should be re-structured:
a) Agree b) Do not know e) Disagree
2. Fisheries sector conditions allow the introduction of aquaculture:
a) Agree b) Do not know e) Disagree
3. Aquaculture is an alternative employment source:
a) Agree b) Do not know e) Disagree

II. PRODUCTION

1. Fisheries sector should proceed to diversification:
a) Agree b) Do not know e) Disagree
2. Aquaculture practices support fisheries volume growth:
a) Agree b) Do not know e) Disagree
3. Aquaculture may introduce fishery products into new markets:
a) Agree b) Do not know e) Disagree

III. TECHNOLOGY

1. The technical assistance available is sufficient:
a) Agree b) Do not know e) Disagree
2. The fishery and aquaculture technology available is suitable:
a) Agree b) Do not know e) Disagree
3. Aquaculture technology may improve production:
a) Agree b) Do not know e) Disagree

IV. RESOURCES MANAGEMENT

1. Communities should participate in resources management programmes preparation and establishment:
a) Agree b) Do not know e) Disagree
2. Coastal resources management by communities is suitable:
a) Agree b) Do not know e) Disagree
3. Coastal communities may manage user or territorial rights:
a) Agree b) Do not know e) Disagree

V. INSTITUCIONAL PARTICIPATION

1. Government agencies are properly represented in coastal areas:
a) Agree b) Do not know e) Disagree
2. Technical assistance matches socio-economic features of fisheries sector:
a) Agree b) Do not know e) Disagree
3. Non governmental organisations play an important role in fisheries management:
a) Agree b) Do not know e) Disagree

APPENDIX C

Questionnaire for weighting assessment for coastal aquaculture and resources management in Tabasco, Mexico.

The aim of this questionnaire is to analysis the relationship between different issues related to fisheries production in the coastal zone including aquaculture practices. Mark 10 to 1 the options according to the concept giving a score of 10 to the one you consider the most important or 1 to the least. Thanks for your collaboration.

Socio-economics issues

Function	Concept	Score
Human resources	Availability of trained and skilled personnel	
Job creation	Employment sources availability for labour intensive activities	
Economic activities	Competition for resources use from different production activities	
Land ownership	Land available for development through parish organisation	
Inputs	Low cost fertiliser and feed sources for aquaculture activities	
Urban areas	Available areas for provision of infrastructure, access to markets and materials	
Existing farms	Area available for aquaculture amenities in the sense of the degree of co-operation generated by adjacent production units	
Farm-gate sales	Access to direct distribution according to levels local of demand	
Income	Potential for expansion of internal markets based on the purchasing power of the consumer	
Energy	Electricity infrastructure available to meet operation processes	

Environmental issues

Function	Concept	Score
Water resources	Water available from different sources (freshwater, brackishwater, seawater and rainfall)	
Soils	Soil characteristics (permeability, texture, structure and plasticity) suitability for land-based aquaculture	
Roads	Distance access from roads where areas of low environment disturbance are found	
Oil industry	Oil facilities areas represent high-risk as the exploitation of petroleum has the potential to cause direct environmental impacts	
Agriculture	Access availability to small scale and seasonal agriculture areas	
Livestock	Access availability to non-grazing lands	
Forestry	Access to non-wood and non-timber areas	
Existing farms	Effects of agglomeration on sharing or competing for resources and infrastructure	
Urban areas	Areas available where pollution from urban centres is low	
Population density	Access availability to areas where impacts from population settlements are low	

APPENDIX D

Semi-structured interview for RHA

Name of fishing co-operative: ______________________________
Location: ____
Number of members:_____________________________
Establishment date:____________________________
Principal fishery: _______________________________
Secondary fishery: ______________________________
Interview #_____
Micro-cassette #__

A. HISTORY

- How was the fishing co-operative organised?
- How many co-operatives were at the time this co-operative was established?
- How the fishery was organised among the co-operatives?
- Was the access to the estuary free or regulated?
- Did this co-operative have any use or territorial rights over the fishery?
- What areas were assigned to this co-operative?
- What areas are used today?
- Who assigned the areas?

B. CO-OPERATIVE STRUCTURE

- What is the organisation structure of the co-operative?
- What are the major activities for co-operative members?
- Have been formed subgroups or work teams at any time?
- What are the co-operative facilities?
- How co-operative's fishing is organised?
- How many members are active?
- Have the co-operative had any trouble regarding fishing/culture site with any other co-operative or fishing group?
- How co-operative's net revenue is distributed?

C. OPERATIONS

- What kind of fishing gears and arts does the co-operative hold?
- What kind of boats?
- How many of those belong to the co-operative?
- How much does the equipment cost including new purchases and maintenance rates?
- What are the average operations costs?
- How many production seasons are available per year?
- What are the most common problems faced due weather conditions and other natural events?
- How many fishing licenses do the co-operative hold?
- Who grants these licenses? What are the requirements to apply for a fishing licences

D. PROCESSING AND MARKETING

- Where the catch is landed and stocked?
- What are the majors processing techniques used?
- Are processing plants available?
- What is the principal market you supply?
- What or who do you sell the production of the co-operative?
- What is the average price?
- Who or what influences price?
- What are the majors marketing problems the co-operative faces?

E. FINANCIAL ISSUES

- Is there any subsidy available? Who or what grants it?
- Do you have or have had access to commercial credit?
- What is the interest rate?
- Have you had financial advice?

F. INSTITUTIONAL ASSISTANCE

- Have you received assistance for any governmental or non-governmental agency? What kind of assistance?
- How do you score the assistance from governmental agencies?
- How do you score the assistance from non-governmental agencies?
- Have you ever been invited to participate in coastal resources management programmes preparation or establishment?

APPENDIX E.

i. Andres Garcia Fishing Cooperative: Household income sources distribution

Household head	Frequency	%	*Spouse*	Frequency	%	*Child1*	Frequency	%	*Child2*	Frequency	%
Fishermen	172	96.63	Fish merchant	4	2.25	Construction worker	1	0.56	Merchant	1	0.56
Agricultural worker	1	0.56	Agricultural worker	12	6.74	Merchant	2	1.12	Career professional	1	0.56
Waitress/waiter	1	0.56	Security guard	1	0.56	Industrial worker	1	0.56	Lorry driver	1	0.56
Merchant	2	1.12	Waitress/waiter	8	4.49	Cook	1	0.56	Total	178	100.00
Career professional	1	0.56	Construction worker	5	2.81	Cleaner	1	0.56			
Total	178	100.00	Merchant	5	2.81	Hotel clerk	1	0.56			
			Clothes making	1	0.56	Career professional	1	0.56			
			Woodworker	2	1.12	House maid	1	0.56			
			Industrial worker	6	3.37	Mechanic	1	0.56			
			Mechanic	1	0.56	Carving industry worker	2	1.12			
			Cook	2	1.12	Coconut oil producer	2	1.12			
			Cleaner	1	0.56	Total	178	100.00			
			Electrician	1	0.56						
			Career professional	3	1.69						
			House maid	1	0.56						
			Coconut oil producer	2	1.12						
			Child minder	1	0.56						
			Fillet processing worker	1	0.56						
			Merchant navy	1	0.56						
			Secretary	2	1.12						
			Total	178	100.00						

ii. Boca de los Angeles Fishing Cooperative: Household income sources distribution

Household head	Frequency	%	*Spouse*	Frequency	%	*Child1*	Frequency	Percent	*Child2*	Frequency	Percent
Fisherman	78	95.12	Fisherman	3	3.66	Fisherman	2	2.44	Fisherman	1	1.22
pAgriculture worker	1	1.22	PAgriculture worker	13	15.85	Convenience store owner	3	3.66	Mechanic	1	1.22
Oil worker	1	1.22	Waiter	1	1.22	Carpenter	1	1.22	Total	82	100.00
Middlemen	2	2.44	Construction worker	2	2.44	Oil worker	1	1.22			
Total	82	100.00	Convenience store owner	4	4.88	Cook	1	1.22			
			Oil worker	2	2.44	Electrician	1	1.22			
			Electrician	1	1.22	House maid	1	1.22			
			House maid	2	2.44	Mechanic	1	1.22			
			Mechanic	1	1.22	Total	82	100.00			
			Crab processing	1	1.22						
			Driver	1	1.22						
			SAGriculture worker	1	1.22						
			Diver	1	1.22						
			Total	82	100.00						

iii. Mecoacan Fishing Cooperative: Household income sources distribution

Household head	Frequency	%	*Spouse*	Frequency	%	*Child1*	Frequency	%	*Child2*	Frequency	%
Fishermen	101	100	Agriculture worker	18	17.82	Agriculture worker	1	0.99	Supermarket	1	0.99
			Commerce	1	0.99	Mechanic	2	1.98	Porter	1	0.99
			Carpenter	1	0.99	Porter	1	0.99	Transport	1	0.99
			Gas station	2	1.98	Deep sea fishing	1	0.99	Nurse	1	0.99
			Mechanic	3	2.97	Cooperative administrator	1	0.99	Total	99	98.02
			Clothes making	2	1.98	Gardener	1	0.99		2	1.98
			Supermarket	1	0.99	Convenience store owner	3	2.97		101	100.00
			Porter	2	1.98	Navy officer	1	0.99			
			Deep sea fishing	1	0.99	Tourism	1	0.99			
			Warehouse worker	1	0.99	Industrial worker	1	0.99			
			Cooperative administrator	2	1.98	House maid	3	2.97			
			Convenience store owner	1	0.99	Preacher	1	0.99			
			Sheriff	1	0.99	Teacher	1	0.99			
			Photographer	1	0.99	Transport	1	0.99			
			Career person	1	0.99	Total	101	100.00			
			Janitor	1	0.99						
			Mechanic	3	2.97						
			Navy officer	2	1.98						
			Nurse	1	0.99						
			Oil worker	1	0.99						
			Industrial worker	1	0.99						
			Secretary	1	0.99						
			Honey distributor	1	0.99						
			Police	2	1.98						
			House maid	2	1.98						
			Coconut producer	1	0.99						
			Agriculture worker	1	0.99						
			Total	100	99.01						

iv. Puente de Ostion Fishing Cooperative: Household income sources distribution

Household head	Frequency	%	*Spouse*	Frequency	%	*Child1*	Frequency	%	*Child2*	Frequency	Percent
Fishermen	33	100	PAgriculture worker	4	12.12	Merchant	2	6.06	Merchant	1	3.03
			Merchant	2	6.06	Oil worker	1	3.03	Oyster processing	1	3.03
			Oil worker	1	3.03	Cleaner	1	3.03	Total	2	6.06
			Career person	2	6.06	Mechanic	1	3.03	System	31	93.94
			House maid	1	3.03	Oyster processing	1	3.03		33	100.00
			Mechanic	1	3.03	Navy officer	1	3.03			
			Crab processing	1	3.03	Total	7	21.21			
			Coconut oil producer	1	3.03	System	26	78.79			
			Oyster processing	1	3.03		33	100.00			
			Total	14	42.42						
			System	19	57.58						
				33	100.00						

v. Independent fishermen (free riders): Household income sources distribution

Household head	Frequency	Percent	*Spouse*	Frequency	Percent	*Child1*	Frequency	Percent	*Child2*	Frequency	Percent
Fishermen	21	100	Fishermen	4	19.05	Fishermen	2	9.52	Fishermen	1	4.76
			Agricultural worker	2	9.52	Agricultural worker	1	4.76	Career professional	1	4.76
			Construction worker	1	4.76	Industrial worker	1	4.76	Total	21	100.00
			Convenience store owner	1	4.76	Career professional	1	4.76			
			Maid	1	4.76	Commercial navy	1	4.76			
			Coconut producer	1	4.76	Total	21	100.00			
			Commercial navy	2	9.52						
			Total	21	100.00						

APPENDIX F

i. Selection of factors affecting Human Capital accumulation in the Mecoacan estuary

Correlation Matrix

		HOGROINC	*NEMPLOY*	*FAMSIZE*	*LITERATE*	*EAP1560*
Correlation	HOGROINC	1.000				
	NEMPLOY	0.382 (0.000)	1.000			
	FAMSIZE	0.210 (0.000)	0.250 (0.000)	1.000		
	LITERATE	0.241 (0.000)	0.293 (0.000)	0.852 (0.000)	1.000	
	EAP1560	0.251 (0.000)	0.317 (0.000)	0.688 (0.000)	0.748 (0.000)	1.000

a Determinant = 8.795E-02. b Sig. (1-tailed)
HOGROINC= Household gross income, NEMPLOY= Number of household members employed, FAMSIZE= Family size, LITERATE= Number of literate household members, Economically active population (15-60 years)

Total Variance Explained

	Initial Eigenvalue			*Extraction Sums of Squared Loadings*			*Rotation Sums of Squared Loadings*		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.813	56.254	56.254	2.813	56.254	56.254	2.496	49.929	49.929
2	1.104	22.080	78.334	1.104	22.080	78.334	1.420	28.405	78.334
3	0.616	12.328	90.662						
4	0.326	6.518	97.180						
5	0.141	2.820	100.000						

Extraction Method: Principal Component Analysis.

Rotated Component Matrix

	Component	
	1	2
LITERATE	0.934	
FAMSIZE	0.922	
EAP1560	0.853	
HOGROINC		0.838
NEMPLOY		0.797

Component Score Coefficient Matrix

	Component	
	1	2
HOGROINC	-0.134	0.653
NEMPLOY	-0.083	0.600
FAMSIZE	0.399	-0.110
LITERATE	0.393	-0.072
EAP1560	0.345	-0.011

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

ii. Association effect on Human capital accumulation in the Mecoacan estuary

Group Statistics

	Association	*N*	*Mean*	*Std. Deviation*	*Std. Error Mean*
Human capital	Associated fishermen	395	1.674408E-02	1.0045383	5.054381E-02
	Independent fishermen	21	-0.3149482	0.8724072	0.1903749
Livelihood resources	Associated fishermen	395	-9.6032119E-03	0.9972179	5.017548E-02
	Independent fishermen	21	0.1806318	1.0598978	0.2312887

Independent Samples Test

	Levene's Test for equality of Variances[1]		*t-test for equality of Means*						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Human capital	0.343	0.558	1.483	414	.139	.3316923	.2236204	-0.1078807	0.7712653
Livelihood resources	0.284	0.594	-0.849	414	.396	-.1902351	.2240188	-0.6305912	0.2501210

[1]Equal variances assumed

APPENDIX G

i.

LABORATORIO REGIONAL DE SALUD PUBLICA
VILLAHERMOSA, TABASCO.

DEPARTAMENTO DE CONTROL MICROBIOLOGICO
LABORATORIO DE MICROBIOLOGIA DE ALIMENTOS

LABORATORIO REGIONAL DE SALUD PUBLICA
VILLAHERMOSA, TABASCO.

CLAVE: 4675

FECHA DE RECEPCION: 2-06-98 día · mes · año

HORA DE RECEPCION:

FECHA DE REPORTE: 7-06-98 día · mes · año

PRODUCTO: Ostión en concha (TIPO Y MARCA) — LOTE — 1 (de Granja en Suspensión) (No. DE MUESTRAS ENVIADAS)

– Laguna Mecoacán, El Bellote (ESTABLECIMIENTO) — S.C.P.P Andrés García S.C.L (PROPIETARIO)

Conocido (DIRECCION) — Ejido "José María Morelos" (LOCALIDAD) — Paraíso (MUNICIPIO) — Tabasco (ESTADO)

Baldomero Wilson Naranjo (NOMBRE DEL VERIFICADOR QUE RECOLECTO LA MUESTRA) — ACTA No.

2 Junio 1998 a las 7:00 A.M. (FECHA Y HORA DE RECOLECCION)

–S.C.P.P Andrés García S.C.L (INSTITUCION O JURISDICCION QUE REFIERE)

FAVOR DE LLENAR A MAQUINA O LETRA DE MOLDE

TIPO DE MUESTREO: ☐ MONITOREO ☒ UNICO

TIPO DE MUESTRA: ☐ LACTICO ☒ CARNICO ☐ OTROS

ANALISIS SOLICITADO: ☒ MICROBIOLOGICO ☒ Vibrio cholerae

OBSERVACIONES:

PARA USO EXCLUSIVO DEL LAB. REG. DE SALUD PUB.

REPORTE DE LABORATORIO

☐ MUESTRA INADECUADA

DETERMINACIONES	RESULTADOS	ESPECIFICACIONES SANITARIAS VALORES MAXIMO. PERMITIDOS NOM-031-SSA1-1993
MESOFILICOS AEROBIOS NOM-092-SSA1-1994 V.P. (X)	Menos de 10 UFC/g	500 000 UFC/g
COLIFORMES TOTALES NOM-113-SSA1-1994 V.P. ( ) NOM-112-SSA1-1994 N.M.P. (X)	13/100 g	Menos de 230/100 g
COLIFORMES FECALES V.P. ( ) N.M.P. (X)	5/100 g	Menos de 230/100 g
MOHOS NOM-111-SSA1-1994 V.P. ( )	XXXXXXXXX	XXXXXXXX
LEVADURAS NOM-111-SSA1-1994 V.P. ( )	XXXXXXXXX	XXXXXXXX
S. Aureus NOM-115-SSA1-1994	XXXXXXXXX	XXXXXXXX
INV. DE Salmonella sp. EN 25g. (X) 30g ( ) NOM-114-SSA1-1994	AUSENTE	AUSENTE
INV. DE Vibrio cholerae	AUSENTE	AUSENTE
INV. DE Aeromonas hydrophila	XXXXXXXXX	XXXXXXXX
OTROS	XXXXXXXXX	XXXXXXXX
	XXXXXXXXX	XXXXXXXX

LOS RESULTADOS AMPARAN UNICAMENTE LA MUESTRA ANALIZADA

ESTE INFORME NO PODRA SER REPRODUCIDO PARCIAL O TOTALMENTE SIN LA PREVIA AUTORIZACION DEL LABORATORIO REGIONAL DE SALUD PUBLICA

OBSERVACIONES:

JEFE DEL DEPTO. / JEFE DEL LAB — ANALISTA ii.

LABORATORIO REGIONAL DE SALUD PUBLICA
VILLAHERMOSA, TABASCO.

DEPARTAMENTO DE CONTROL MICROBIOLOGICO
LABORATORIO DE MICROBIOLOGIA DE ALIMENTOS

LABORATORIO REGIONAL DE SALUD PUBLICA VILLAHERMOSA, TABASCO

CLAVE: 4676
FECHA DE RECEPCION: 2-06-98 (día mes año)
HORA DE RECEPCION: 9:50
FECHA DE REPORTE: 7-06-98 (día mes año)

PRODUCTO: Ostión en Concha (TIPO Y MARCA) 1 (LOTE) (ostión de fondo) (No. DE MUESTRAS ENVIADAS)

Laguna Mecoacan "El Bellote" (ESTABLECIMIENTO) S.C.P.P Andrés García S.C.L (PROPIETARIO)

Conocido (DIRECCION) Ej. José María Morelos (LOCALIDAD) Paraíso (MUNICIPIO) Tabasco (ESTADO)

Baldomero Wilson Naranjo (NOMBRE DEL VERIFICADOR QUE RECOLECTO LA MUESTRA) ACTA No.

2 Junio 98 a las 7:00 A.M (FECHA Y HORA DE RECOLECCION)

S.C.P.P Andrés García" S.C.L (INSTITUCION O JURISDICCION QUE REFIERE)

FAVOR DE LLENAR A MAQUINA O LETRA DE MOLDE

TIPO DE MUESTREO: ☐ MONITOREO ☒ UNICO

TIPO DE MUESTRA: ☐ LACTICO ☒ CARNICO ☐ OTROS

ANALISIS SOLICITADO: ☒ MICROBIOLOGICO ☒ Vibrio cholerae

OBSERVACIONES:

PARA USO EXCLUSIVO DEL LAB. REG. DE SALUD PUB.

REPORTE DE LABORATORIO

☐ MUESTRA INADECUADA

DETERMINACIONES	RESULTADOS	ESPECIFICACIONES SANITARIAS VALORES MAXIMO PERMITIDOS NOM-031-SSA1-1993
MESOFILICOS AEROBIOS NOM-092-SSA1-1994 V.P. (x)	Menos de 10 UFC/g	500 000 UFC/g
V.P. ( ) N.M.P. (x)	46/100 g	Menos de 230/100 g
COLIFORMES FECALES V.P. ( ) N.M.P. (x)	23/100 g	Menos de 230/100 g
MOHOS NOM - III - SSA1 - 1994 V.P. ( )	XXXXXXXXXX	XXXXXXXX
LEVADURAS NOM - III - SSA1 - 1994 V.P. ( )	XXXXXXXXXX	XXXXXXXX
S. aureus NOM - 115 - SSA1 - 1994	XXXXXXXXXX	XXXXXXXX
INV. DE Salmonella sp. EN 25g. (x) 30g ( ) NOM - 114 - SSA1 - 1994	AUSENTE	AUSENTE
INV. DE Vibrio cholerae	Se aisló V. cholerae No O1	AUSENTE
INV. DE Aeromonas hydrophila	XXXXXXXXXX	XXXXXXXX
OTROS	XXXXXXXXXX	XXXXXXXX
	XXXXXXXXXX	XXXXXXXX
	XXXXXXXXXX	XXXXXXXX

LOS RESULTADOS AMPARAN UNICAMENTE LA MUESTRA ANALIZADA

ESTE INFORME NO PODRA SER REPRODUCIDO PARCIAL O TOTALMENTE SIN LA PREVIA AUTORIZACION DEL LABORATORIO REGIONAL DE SALUD PUBLICA.

OBSERVACIONES:

[illegible]
JEFE DEL DEPTO. Vo. Bo. JEFE DEL LAB.

[illegible]
ANALISTA