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presented by

Jorge Iván Euán Avila

has been accepted towards fulfillment
of the requirements for

Doctor of Philosophy degree in Resource Development

Dr. Scott G. Witter
Major professor

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PHYSICAL AND HUMAN DIMENSIONS FOR INTEGRATED COASTAL MANAGEMENT: Assessment of Coastal Changes and Resident Knowledge Base in Coastal Areas of the Yucatán Peninsula.

by

Jorge Iván Euán-Avila

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ABSTRACT

PHYSICAL AND HUMAN DIMENSIONS FOR INTEGRATED COASTAL MANAGEMENT: Assessment of Coastal Changes and Resident Knowledge Base in Coastal Areas of the Yucatán Peninsula.

by

Jorge Iván Euán-Avila

Coastal zones are under severe pressure as a result of multiple human activities. Environmental degradation, coastal ecosystems' importance and resource depletion require alternative policy for long-term sustainable development. This study focuses on physical and human dimensions involved in ecosystem perturbation and management .

This research analyzed data collected with remote sensors to determine land cover changes in tropical mangrove wetlands and their spatial relationships with roads and town developments. It also analyzed data of 139 interviews with residents in the area to assess their knowledge base regarding: (i) the use and non-use values of mangrove wetlands, (ii) attitudes in resource use, (iii) awareness of environmental impacts of urban expansion, solid waste disposal in wetlands, and coastal road networks, and (iv) acceptance of regulation.

Findings indicated: (i) a significant loss of vegetation and soils, (ii) increasing urban growth and (iii) differences between urban and rural residents regarding the use, knowledge and attitudes towards coastal ecosystems and

resources. To receive the future benefits from these ecosystems, specially for those whose daily survival depend upon them requires an integrated management program that accounts for: (i) the size and location of land cover changes in the area, and (ii) the heterogeneity between the urban (Progreso and Prochub) and rural (Chuburná and Chelem) coastal resident knowledge base.

To DIANA, RODRIGO and ANDREA

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Chapter 1

INTRODUCTION

This chapter focuses on the importance of coastal ecosystems, resource depletion and environmental degradation in the coast. It supports the need to devise a correct policy for long-term development and environmental protection. It introduces data requirements for policy planning and implementation and provides a description of the objectives and hypotheses that guided this work. It also shows the opportunities provided by the coastal areas of the State of Yucatán to assess changes in the wetlands and the perceptions of people who live there. Finally, it provides a summary of the major procedures used in this study for data collection and analysis.

1.1 Background

1.1.1 Natural Resources and Coastal Zone Development.

The marine environment, including estuarine coastal areas, is an essential part of the life-support system. Estuarine coastal areas are rich in natural resources, diverse, and dynamic in biological and physical interactions. Estuarine coastal areas are among the most productive ecosystems, the most beautiful landscapes, and highly valued areas for agriculture, fishing, recreation, aquaculture, mineral extraction, and transportation. Resource demands on these areas go back to earliest records of humanity, however the contemporary intense and increasing urban, industrial, and agricultural activities have resulted in excessive resource consumption, mountainous sites of waste, resource use inefficiency, and destabilization of the coastal zone, with economic, social, and environmental implications for present and future generations (Mayor 1991, Chiras 1992, OECD 1993a, Qing-nan 1987). Serious concerns regarding the scarcity of essential fragile resources resulting from this intense development of the coastal zone was evidenced during UNESCO's Coastal Marine (COMAR) meeting for "Coastal System Studies and Sustainable Development" (UNESCO 1992).

Habitat losses, fish and other wildlife population declines, water contamination and land degradation caused by large and dense settlements, ocean-related industries, recreation and tourism, fishing, and inadequate coastal management have been clearly documented in the literature by Pimentel *et al.* (1992), Hawker and Connell (1992), Saenger and Holmes (1992), Dennison *et al.* (1993), Chua Thia Eng *et al.* (1989), Cronin (1992), Butler *et al.* (1993), Pearce (1984), Boto (1992), Ongkosongo (1992), McClees (1993), Arnett (1991), Yañez-Arancibia *et al.* (1992), Swaminathan (1992), Stigliani *et al.* (1993), McCain *et al.* (1992), OECD (1993b), Suman (1994), and others.

Current efforts in management of coastal ecosystems and their resources have not always stopped the impoverishment of the area. Consequently, there is an increasing need to provide adequate information for precautionary and anticipatory management programs. This need is critical at all levels of management to avoid unacceptable environmental damage, maintain necessary natural resources for future generations, and meet the needs of the present population.

1.1.2 Coastal Ecosystems

Mangrove wetlands, seagrasses, lagoons, and other estuarine ecosystems make the coastal zone rich in natural resources, beautiful landscapes, and are ecologically important. In the equatorial region mangrove wetlands play a very important role in controlling coastal hydrodynamics and sediment movements. Mangroves also provide habitat for a wide range of dependent biota from plankton to human communities (Lugo and Snedaker 1974, Odum and Heald 1975, Parsons 1992, Boto 1992).

Unfortunately, mangrove wetlands are severely impacted by human activities in coastal areas (Parson 1992). Increased settlement, aquacultural developments, and nutrient loading are the main causes of their destruction (Benites *et al.* 1992, Boto 1992, Butler *et al.* 1993). In spite of the ecological, aesthetic, and economical values, and their role as an excellent indicator of an ecosystem health, the coastal zones around the world have experienced destruction and governments have difficulties in protecting the mangrove wetland (Ongkosongo 1992, Semesi 1992, Lin and Fan 1992).

The primary reasons given for mangrove wetland destruction include: 1) people's attitudes, 2) low market value of mangrove products, 3) incomplete knowledge about the services provided by the mangroves, 4) property rights, 5) negative externalities, and 6) political and administrative obstacles for their management (Parsons 1992, Hamilton *et al.* 1989, OECD 1993a, Suman 1994). As a result hundreds of hectares of mangrove wetlands are destroyed each year in the world and in the Caribbean and Latin America there are considerable losses in

México, Ecuador, Guatemala, El Salvador, Honduras, and Nicaragua (Boto 1992, Butler *et al.* 1993, Suman 1994).

Caribbean and Latin American coastal areas contain approximately 2,400,000 ha of mangroves, 500,000 ha of which are in México (Suman 1994).

1.1.3 Sustainable Development in Coastal Areas

Sustainable development (SD) is an increasingly important concept for managers, policymakers, politicians, scientists, and the public interested in the development and conservation of the coastal zone. The concept, defined by the World Conservation Strategy in 1980, illustrates their concerns for improving peoples' livelihoods while at the same time maintaining the quality of the environment. The Brundtland Report (1987), defines sustainable development as: "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED 1987, p43).

Several objectives and strategies for sustainable development were recommended by the Conservation World Strategy in 1980, by the Brundtland Report in 1987, and by the Rio de Janeiro Earth Summit Conference in 1992. Common objectives included: 1) using natural resources at rates that do not destroy or severely deplete the natural resource base, 2) preserving biological diversity, and 3) producing wastes according to the assimilative capacity of the environment. Suggested strategies include: 1) comprehensive approaches, 2) community participation, and 3) agency coordination. Axinn (1988) suggests that a comprehensive approach that includes biological, physical, cultural, social, economic, administrative, political, and diplomatic forces; and their relationships, is needed even for simple technological innovation. These forces represent a complex system many times incompletely understood (Axinn 1988). A conceptual model (Figure 1) developed by Rayner *et al.* (1994) to indicate the effects of land use and land cover on global environmental changes shows this complexity. The model links socioeconomic, political and cultural human behavior with land use and land cover and their impacts on global environmental processes. The model spells out the basic drivers, human aspirations and population and the influence of the decision system on soil, water and vegetation.

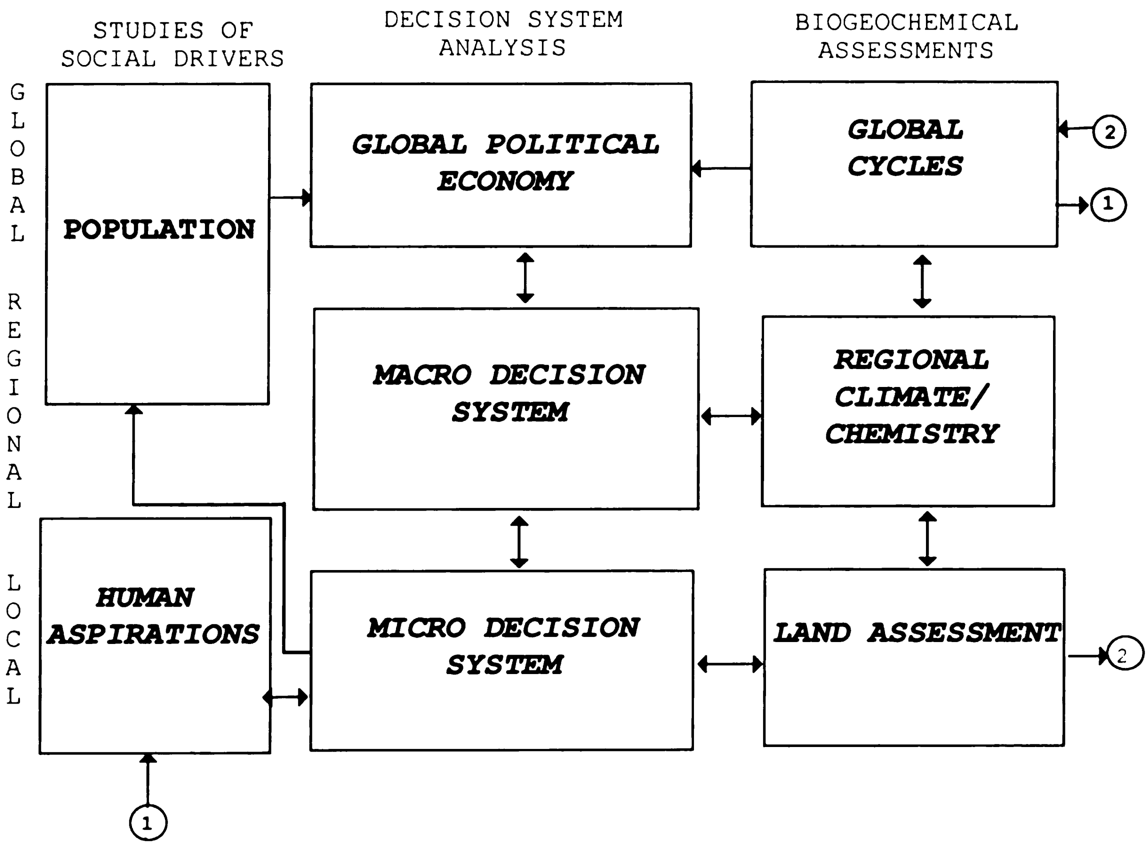

Figure 1 - General land use decision-making model (Rayner et al. 1994)

Difficulties for development and conservation of the ecosystem increase as people's interests, capabilities, and perceptions are included in decision making. Past experience indicates that if all these forces remain misunderstood and unbalanced there is little hope for long-term development and conservation. The dimension in complexity between nature and human society for the purposes of sustainable development is clear in Baba Dioum's (Sénégal) statement:

> "*in the end we will conserve only what we love; we will love only what we understand; and we will understand only what we are taught*" (in Lasserre 1992, p. 38).

1.1.4 Coastal Zone Management Experiences in OECD Countries

In the examination of their experiences, 16 countries in the Organization for Economic Co-operation and Development (OECD) summarize the causes of coastal zone problems in three areas: policy deficiencies, intervention deficiencies, and market failures (OECD 1993a). The problems are the result of: 1) poor policies, poor implementation, and unresolved conflict between or among policies, 2) inadequate data, predictions, and monitoring, 3) lack of agency coordination and demarcation of responsibilities, 4) under-valuation of resources, 5) externalities, 6) lack of long-run cost, and 7) past ignorance and mistakes (OECD 1993a).

Common conclusions from the above indicate that lack of information and insufficient scientific understanding adversely affect the selection of policy instruments for coastal zone management. Studies by the World Bank also show that Instrument selection is influenced by cultural perspectives, environmental perceptions, personal biases (based on life-stage, education, ability, and personality), and political motivations (World Bank 1992). The range of instruments used by 16 OECD studied countries included: zoning, permits, taxes, bonds, limiting discharges, as well as other developmental controls. Instruments, currently used, are heavily oriented towards regulation (*i.e.*, zoning). Improving the availability and usability of information for decision makers, and selecting adequate monitoring programs are fundamental for informed and anticipatory governmental actions (*i.e.*, selection of the right mix of regulatory and economic instruments and extending the types of management instruments).

1.1.5 Coastal Zone Management in Latin America

Problems in Latin America are similar to those experienced by OECD countries. Olsen and Gordon (1992) identified that the major characteristic limiting the initiatives to improve management in coastal areas of Central America is the absence of effective implementation. Among common impediments with OECD countries (*i.e.*, fragmented authority, overlapping jurisdictions, etc.), the short tenure of administrators and technical personnel and the absence of a constituency are major fundamental problems (Olsen and Gordon 1992).

Coastal zone management programs implemented in Latin America use different strategies, instruments and have different levels of development:

1) "The shoreland restrictions" approach implemented in Costa Rica's program for coastal zone management (1977), law 6043, was a response to

public complaints regarding coastal degradation caused by unplanned residential and tourism developments (Sorensen *et al.* 1990). In response to the problems inherent in a national program, Mack *et al.* (1992) indicated that for Law 6043 to be successfully implemented land tenure and land use studies are of priority. Furthermore, that there is a need to identify priority areas and to implement and utilize plans, education and training at a local level.

2) Cuba in 1981, enacted law No. 33 to provide basic principles for environmental protection and the rational use of natural resources in response to natural and anthropogenic impacts. Included in this law is a system of protected areas. The law designated the Ministry of Agriculture (MINAGRI) as the responsible agency in the protection of flora and fauna. More recently (1991), a multidisciplinary group from several Cuban organizations has written a law-decree that focuses on two management belts running parallel to the coast: 1) the coastal zone and 2) the buffer zone (Menéndez *et al.* 1994).

3) Ecuador has explored strategies to implement coastal management programs in the context of third world nations, this means that close attention was given to cultural and government traditions in the design of effective CZM strategies. The program was conducted by the University of Rhode Island as part of the "Coastal Resource Management Project". (Merschrod 1989). More recently and focusing on the mangrove wetland management, Bodero (1994) recommended integrated programs to include: protection, management for multiple users, restoration, ecotourism, education and research.

4) México enacted in 1988 "Ley General del Equilibrio Ecológico y la Protección al Ambiente (LGEEPA)" (SEDESOL 1988b). This general law provided the basis for the management of the natural resources for sustainable development and environmental protection. The Secretariat of the Environment, Natural Resources, and Fisheries (Secretaría del Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP)) is responsible for the formulation and enforcement of the environmental policy. The law provided several instruments such as: ecological order (zoning), promoting development with ecological criteria, environmental impact assessment (EIA), official technical norms (NOM), natural protected areas, research, education and information (Chap. V, LGEEPA). Loa (1996), in relationship to the management and conservation of coastal wetlands, identified several problems in two areas of current legislation: 1) incomplete body of specific laws and regulations and 2) non-enforcement of specific regulations. He said that several factors contribute to a weak enforcement of the regulations such as: non-systematic use of the regulations, partial use of regulations, use of out of date regulations, unclear demarcation of responsibilities, and poorly informed users and the public.

1.1.6 Coastal Zone Management in the State of Yucatán, México

In 1995, the Consejo Estatal de Consultoría Ecología (CECE) identified the need to formulate an integrated management plan in the coast primarily due to: 1) the growing socio-economic role of the coast, 2) the increasing coastal human population (immigration of the rural poor) from agricultural areas, 3) the biodiversity of the area, 4) failure to consider the ecological benefits of the ecosystems , 5) short run benefits and 6) limits imposed by the ground water system (Flores *et al.* 1995). In addition to the management of commercial fisheries, the coast of the State of Yucatán has four protected areas: Rio Lagartos (48,000 ha), Celestún (60,000 ha), Las Bocas de Dzilam (62,000 ha), y El Palmar (50,000 ha). Total protected area is approximately 220,000 ha. Outside of these protected areas important ecological and economic areas exist that must be studied to be considered in an integrated program. Changes in the LGEEPA have given to Mexican states an opportunity to broaden their own local environmental legislation (*e.g.*, The Yucatan Law for Environmental Protection). Current local legislation in the state of Yucatan is under revision and today, a growing awareness exists that local legislation must be changed to provide appropriate and specific indications to meets the needs of the local conditions[1].

1.1.7 Research Needs

The United Nations World Commission on Environment and Development, the U. S. National Science Foundation, and the Social Science Research Council, have emphasized the need for interdisciplinary research efforts to achieve a long-term quality of life and halt environmental impoverishment in the world (Stonich 1992). Research needs include: 1) gaining a better understanding of the biophysical coastal processes, 2) relating human activities to coastal natural resource changes, 3) gaining knowledge regarding local people's interest,

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[1]Minutes of the discussions for modifying the "Ley de Protección al Ambiente del Estado de

attitudes, and behavior in the use and management of the coastal zone, and 4) how to integrate social, biophysical, and economic factors needed for sustainable coastal zone management programs. These research needs are essential given that the United Nations estimates that 2 out of 3 people will live within a strip 60 kilometers wide along the coast by the year 2000 (Swaminathan 1992). This means that 75% of the world's total population will be living on 8% of the earth's surface increasing the pressure on coastal natural resources including fragile ecosystems.

The United Nations conference on Environment and Development in Rio de Janeiro encourages Coastal States to give priority to improving their capacity to collect, analyze, assess and use information for management purposes (United Nations 1992). Developing countries like México face several problems of limited information regarding the state of their natural resources, human activities that affect their natural resources, and human perceptions regarding the use of the natural resources when there is public pressure for increasing their use. In the Yucatán Peninsula mangrove wetlands are being destroyed and threatened by: 1) conversion to urban areas, aquacultural systems, and port infrastructure, 2) unenforced and unregulated use of mangrove wetland products, 3) increasing pollution from industrial and residential sewage and solid wastes, and 4) modification of hydrological regimes because of the construction of roads and ditches (Zizumbo 1986, Benites *et al.* 1992, Valdes 1995). These factors have reduced the mangrove wetlands, polluted the water and affected other dependent

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Yucatán". COPLADE, Merida, Yucatan, February, 1997.

resources in the area. This situation has environmental, and socio-economic implications for the local communities.

In the Yucatán Peninsula mangrove wetlands located in the coastal areas of Campeche, Yucatán, and Quintana Roo, support important commercial **shrimp fisheries** (e.g., *Penaeus duorarum*) and **subsistence fisheries**: (e.g., *Fundus grandissimus*, *Cichlasoma urutalmus*, *Centropomus undecimalis*). In addition mangrove wetland support a high **animal diversity** (e.g., *Phoenicopterus ruber*, *Fragata magnificens*, *Porphyrula martinica*); **protect the coast** from erosions; are a **source of energy**; and are **sink for nutrients** and other substances released from human activities.

The wetlands in the Yucatán Peninsula are among the most important pristine ecosystems in this hemisphere[2]. To face the conservation-development dilemma in the Yucatán Peninsula, information from social, biophysical, and economic dimensions must be available for decision-making. The ecosystem and local human communities need to be properly assessed and incorporated into planning for the long-term benefit of both the ecosystem and the inhabitants of coastal areas of the State of Yucatán. Proposed study area is shown in Figure 2.

[2] Described by Dr. Guy Baldasarre, New York State University (NYSU) during his conference on "Ecology and Wetlands Management" Cinvestav, Mérida, Yucatán, March 1994.

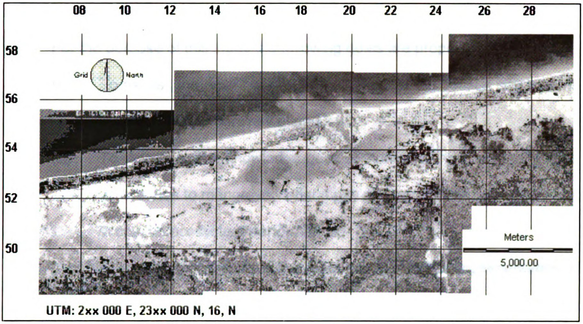


Figure 2 - Study Area in the Yucatán Peninsula

1.2 Purpose of the Study

1.2.1 Problem Statement

Unintegrated environmental and developmental decision-making at the policy planning and management levels influence the actions of all groups in society with implications for the efficiency and sustainability of development (UNCED 1992). Critical to designing and implementing enforceable and effective coastal policy that is economically efficient, socially equitable, responsible, and environmentally sound, is the need to: (1) assess natural resources, (2) relate human activities to coastal natural resource changes, and (3) gain knowledge regarding local people.

1.2.2 Research Goals

For the purpose of this study the following goals are proposed:

(A) To assess the extent of physical changes of the coastal ecosystems including the mangrove wetland.

(B) To determine the knowledge base of individuals that live in the area as it relates to mangrove wetland use and environmental significance in coastal ecosystem performance.

(C) To identify critical factors that influence successful implementation of coastal management plans.

1.2.3 Hypotheses

A better understanding of the natural system must begin with the analysis of the extent and rate of major changes in coastal areas. The land cover is constantly changing due to natural process, infrastructure (roads, urban and industrial areas, piers) and human activities (agriculture, salt extraction). These changes have a profound impact on resources and the environment as well as on human populations living in the coast. In the absence of data for coastal areas of the State of Yucatán, indicating where, when, what and the extent of coastal changes, current data can only suggest that coastal deterioration of the environment is occurring. For these reasons, the following hypothesis (H1) has been proposed:

$H1_0$: There has not been significant changes in the coastal areas of Progreso, Yucatán, México from 1986 to 1990.

$H1_1$: There has been significant changes in the coastal areas of Progreso, Yucatán, México from 1986 to 1990.

In looking at the social system, important drivers for the use of natural resources and environmental protection are the human aspirations (needs and wants) and the public policy. An appreciation and analysis of the knowledge base of residents in coastal areas will assist to devise alternative policies and instrument implementation in a coastal management program. The following hypothesis (H2) has been proposed to guide part of this work:

$H2_0$: Permanent residents from Chicxulub, Chelem, and Progreso and non-permanent residents along the coast are not significantly different from each other in their individual knowledge base related to: 1)the use and environmental significance of the mangrove wetland, and 2) their attitudes for long term resource use and in accepting potential regulatory interventions for their management.

$H2_1$: Permanent residents from Chicxulub, Chelem, and Progreso and non-permanent residents along the coast are significantly different from each other in their individual knowledge base related to: 1) the use and environmental significance of the mangrove wetland, and 2) their attitudes for long term resource use and in accepting potential regulatory interventions for their management.

1.2.4 Objectives

The research objectives are:

(1) To quantify changes in mangrove wetland and dunes from 1986 to 1990 in coastal areas of the municipality of Progreso, Yucatán.

(2) To identify critical converted or impacted mangrove wetland and dune areas.

(3) To identify residential, industrial, commercial and infrastructure developments linked to the physical destruction of the mangrove wetland.

(4) To determine people's knowledge about mangrove wetland uses, and mangrove environmental significance.

(5) To determine people's attitudes to accept regulatory management instruments to protect the mangrove wetlands.

(6) To use a geographic information system to analyze and integrate data from the natural, and social systems.

1.2.5 Methodology Summary

Changes in coastal areas were detected when a change detection analysis was performed using two Landsat Multispectral Scanner (MSS) satellite images taken 4 years apart. Remote sensing (RS) and geographic information systems

(GIS) techniques were used in the analysis of the images. Changes were detected by subtracting and dividing corrected radiometric values from two images and thresholds used to record significant changes. Mangrove wetland cover was calculated from both images. The resulting thematic cartography of the area and changes were employed to quantify losses in the mangrove wetland. These data and results from the change detection analysis were used to test hypothesis H1. Observed changes in mangrove wetland and dune cover was linked to human actions from residential, commercial, industrial and infrastructure developments.

Individual knowledge about mangrove uses and environmental significance was collected using survey data. Attitudes toward long term resource use and the acceptance of management instruments were measured with a self report of the type suggested by Henerson *et. al.*, (1987). Indicators for the variables of interest were integrated in a questionnaire and applied to four sampled groups (*i.e.*, Chuburná, Chelem, Progreso, and Prochub). Data were statistically analyzed to test hypothesis H2. The sample frame was constructed using a GIS to establish the spatial boundaries of the areas. The number and location of the samples was drawn from a stratified aligned design according to the size of the area, economic resources and the time available for the research.

1.2.6 Assumptions

This study was based on five assumptions: 1) that sustainable development of the coastal zone through integrated coastal zone management (ICZM) is desirable; 2) that public and private citizens in coastal areas of Yucatán, México do play key roles in modifying the coastal environment are interested and willing to engage in sustainable management practices, 3) that the national and state governments are interested in promoting and enforcing the policies that promote sustainable management practices; 4) that the study area has many of the problems associated with coastal zone management in Yucatán; and 5) that the results of this study will expand the knowledge base needed to achieve an integrated coastal zone management program in the Yucatán peninsula.

Data collected from interviews, reports, proposals and meetings indicated that ICZM is desirable for the coastal areas of the State of Yucatán. Residents, decision makers, and politicians have all manifested their willingness to participate and promote an integrated approach to solve coastal problems associated with resource use and environmental protection. The studied areas (Chuburná, Chelem, Progreso and Prochub) have also shown that many of the problems associated with the loss and degradation of the mangrove wetland in the Yucatán coast can be attributed in part to: 1) increasing urban developments, 2) road and port infrastructure and 3) solid garbage dumps. These increasing developments are also influenced by the knowledge and attitudes of the residents living there. An appreciation of the differences between these studied towns may assist in defining a better policy for the purpose of coastal management.

Chapter 2

LITERATURE REVIEW

The central focus of this study is to gain knowledge about the state of coastal natural resources, human activities that affect coastal ecosystems, and public knowledge as factors for implementing management instruments in coastal mangrove wetlands. This chapter provides support for: 1) the need to integrate biological, physical, economic, and cultural information for policy design, correction, and/or implementation, 2) the need to gain knowledge about the state of natural resources, human activities, and individuals knowledge and attitudes as key elements for decision making in coastal management, 3) the selection of appropriate tools to collect and analyze data from the natural, and social systems, and 4) the selection of the proposed study area.

2.1 Coastal Zone Management

2.1.1 World Experiences

Resource and environmental management is one of the most important and challenging coastal problems. Contemporary development of the world's coastal areas has resulted in: 1) excessive resource consumption, 2) resource use inefficiency, 3) encroachment and poverty, 4) increasing waste streams, 5) water contamination, 6) soil erosion, 7) loss of biodiversity, 8) reductions in fish and wildlife populations, and 8) degradation and loss of habitats (Pimentel *et al.* 1992, Hawker and Connell 1992, Saenger and Holmes 1992, Dennison *et al.* 1993, Chua Thia Eng *et al.* 1989, Cronin 1992, Butler *et al.* 1993, Pearce 1984, Boto 1992, Ongkosongo 1992, McClees 1993, Arnett 1991, Yañez-Arancibia *et al.*

1992, Swaminathan 1992, Stigliani *et al.* 1993, McCain *et al.* 1992, OECD 1993a, Suman 1994, Moffat and Lindén 1995).

These problems have been attributed by Chua and White to: 1) population growth, 2) poverty, 3) short term economic gains, 4) lack of awareness about management for resource sustainability, 5) lack of understanding of the full economic contributions of coastal resources and 6) absence of governmental support and enforcement (Clark 1992). Similarly, a report from OECD countries identified deficiencies and failures in policy, intervention and the market as the causes of coastal zone management problems. In particular the following problems were highlighted: 1) absence of policies, 2) contradictory policies, 3) improper management strategies, intervention mechanism and instrument deficiencies, 4) lack of adequate information and monitoring, 5) lack of coordination, 6) unclear demarcation of responsibilities, 7) pricing that does not reflect full resource value, 8) externalities, and 9) failure to incorporate long run costs (OECD 1993a).

To correct or at least to mitigate environmental damage and inefficient resource allocation in the coast, there is a need to establish a management policy based on scientific knowledge from both the natural and social systems. Political commitment, community participation and power for implementation are also needed (OECD 1993a). The United Nations Conference on Environment and Development at Rio de Janeiro encouraged coastal states to seriously improve their capacity to collect, analyze, assess and use information for management purposes (United Nations 1992). This was supported by a number of participating countries and the World Bank, who felt that lack of information and insufficient scientific understanding has adversely affected coastal management. In addition to economic and ecological factors, other important management considerations are the cultural perspectives; environmental perceptions; personal biases based on life-stage, education, ability, and personality; and political motivations of all the participants (World Bank 1992).

2.1.2 Comprehensive Approach

A conceptual model developed by Rayner *et al.* (1994) for the study of land use/cover change that relates social drivers, political and economic decision systems, and the environment is used as a framework (Figure 3). The model was selected to describe the human and bio-physical dimensions and their relationships for the purpose of coastal zone management.

Relationships in the model are described by Rayner *et al.* (1994) at three levels: local, regional and global. The model stresses at the local level the importance of human needs, wants, perceptions, attitudes and values in motivating behavior, as well as population as basic drivers for resource use. Feedback loops influence human characteristics according to our understanding of the political and economic decision system (shown in the middle of the diagram) and also by the modified climatic conditions (right hand side of the diagram) (Rayner *et al.* 1994).

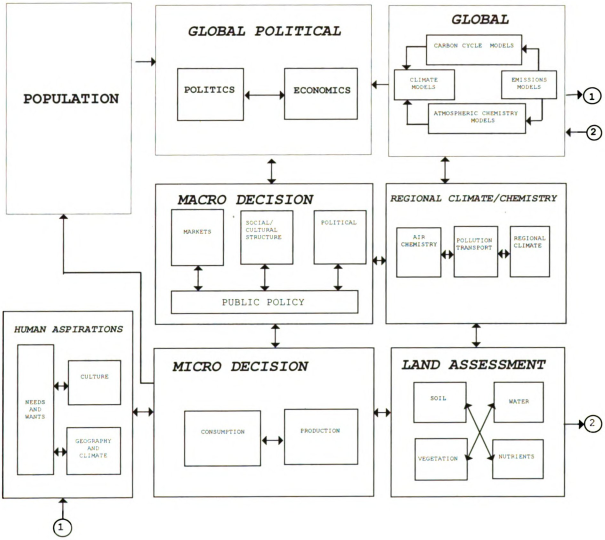


Figure 3 - Conceptual model of land use decision-making (Rayner *et al.* 1994)

The natural system as modeled by the land assessment block, which shows the natural processes and changes due to the influence of the decision system. For the purposes of coastal management the model provides a clear and complete description of the major components of the system and their relationships between man and nature. This model shows the high level of complexity in the system requiring information from several disciplines in order to design a correct and proactive coastal policy to prevent and reduce the negative environmental effects caused by humans. There is also the need for holistic approaches and adequate monitoring programs to better understand the system.

Among others, holistic approaches that have been presented for the purpose of management are: 1) ecosystem management, 2) biodiversity management, 3) ecosystem health, 4) adaptive management, and 5) integrated management. These management schemes share several characteristics: 1) hierarchical context, 2) ecological understanding of the system, 3) data collection, 4) monitoring, 5) adaptive management, 6) interagency cooperation, 7) organizational change, 8) user participation and 9) values (Grumbine 1994).

As suggested by the model major dimensions to be assessed for integrated natural resource management are: a) the natural system and b) the social system.

a) The natural system, represented by land assessment module, indicates the need to collect physical, biological and ecological data about the biophysical processes in order to understand: 1) physical alteration, 2) rates of replacement, 3) maintenance of floral and faunal population levels and sustainable yields, and 4) changes in one resource that have an impact on other resources. This information is critical to relate the impacts of consumption/production decisions on resource changes (OECD 1993a).

This need has been supported by Balkas *et al.* (1993), in his discussion of environmental considerations in CZM in the Izmir Bay in Turkey where a baseline monitoring program and an environmental impact assessment study were conducted. Additional studies were recommended for assessing the assimilative capacity of the bay and preparing environmental impact assessment for the new water treatment system. Also in Norway, the LENKA project was established "as a standardized, efficient, integrating mechanism to provide coastal zone planners with an information base on aquatic capacity to aid in making choices as to the best use of the coastal zone" (Stewart *et al.* 1993, p. 271).

b) The social system, represented by the human aspirations block, shows that the key variables to be considered for natural resource use decisions are: 1) needs, 2) wants, 3) willingness and unwillingness to pay, 4) perceptions, 5) beliefs, 6) attitudes and 7) values. The analysis of cultural variables helps us to understand the transformation of basic needs into goals and values of activities in the decision system that transform the natural environment (Rayner *et al.* 1994).

In the United States (1972) a federal-state program was created for the management and protection of coastal resources called the Coastal Zone Management Act (CZMA). According to Imperial *et al.* (1992), five programs: 1) the Delaware River Basin Commission, 2) the federal river basin commissions, 3) the section 208 area-wide waste treatment planning, 4) the federal coastal zone management program, and 5) the Chesapeake Bay Program have, during the past 25 years represented the best effort in management of the United State of America coastal zone. From these studies several lessons were learned: 1) coastal environmental planning initiatives must have an interested audience, 2) plans and policies must address important public issues, and 3) successful programs included all the relevant actors affected by the plan (Imperial *et al.* 1992).

Clark (1992) suggests that for an Integrated Coastal Zone Management (ICZM) program to succeed interested groups must be involved if new coastal policies and rules are to be supported. It is argued that local communities support sustainable and ecologically sound uses, but this tradition is being lost in modern and overpopulated areas. Clark (1992 p. 60) indicates:

> *"... When people decide to "participate", they as resource users will make the real difference in protected area management. The solution thus lies in helping people to decide to participate in a constructive manner. Once resource users decide to do so and receive the associated benefits, the process will perpetuate itself."*

2.1.3 Policy Implementation and Integration

A common practice when resource use patterns are out of balance or socially undesirable is to use non-market institutions (Emel and Peet 1989). Current public policies for coastal management are based on strategies and methods that help to organize natural resource use and environmental conservation. Coastal states in developed and developing countries have adopted a comprehensive and integrated approach for policy development and implementation called integrated coastal zone management (ICZM) or integrated coastal area management (ICAM) (Imperial *et al.* 1992, OECD 1993a, Boelaert-Suominen and Cullinan 1994, Sorensen *et al.* 1992, Flores *et al.* 1995). ICZM is one of the several systems that attempt to control development that negatively impacts resources and the environment (Clark 1992). ICZM, in response to ineffectiveness of sectoral approaches, considers the functioning of the coastal system as a whole with implications and challenges to current legal perspectives and mechanism implemented for the management of the coast.

In 1994 during the workshop on integrated coastal management at the Bedford Institute of Oceanography, Biliana Cicin-Sain, University of Delaware and Editor of the Ocean & Coastal Management Journal, described the meaning of Integrated Management. She addressed the several dimensions of integration in the context of the ocean and the coast: 1) among sectors, 2) between coastal land and coastal waters, 3) among levels of government, 4) between nations, and 5) among disciplines. She said that integration in this context is a continuous process that moves from less-integrated to more-integrated situations as they pass from fragmented approaches, communication, coordination, harmonization, and integration (IOC Seminar on Integrated Coastal Management 1995)

She also stressed the need to identify factors and incentives to facilitate integration and described how local and national perspectives and knowledge are different. She said that the local community concentrates on economic well-being, infrastructure needs and quality of life and the locals know best the local needs and have the best information and understanding of the area. The national perspective, on the other hand, is concerned with the need to provide orientation to lower levels and uniform approaches for the entire nation (IOC Seminar on Integrated Coastal Management 1995). This suggest that appropriate approaches must consider the local social, economic and cultural conditions.

To implement coastal zone management policies, two categories of instruments are of the greatest importance today: regulatory and economic. Regulatory instruments attempt to regulate process and products by limiting discharges or restricting activities in time and space. Land use zoning is a regulatory instrument used to designate dominant uses at the regional level and specific land uses at the local level. At the local level, zoning specifies residential, industrial, commercial, recreational, reserves and parks areas. Zoning, well implemented, may contribute to reduced urban expansion, aesthetic controls, separation of incompatible activities, and protection of important natural areas (OECD 1993a). Disadvantages are lack of flexibility and in the economic and environmental inefficiencies that can result in suboptimal allocation of land uses.

Economic instruments, on the other hand, attempt to stimulate desired actions with the use of financial stimuli including: charges, subsidies, market creation, and financial enforcement incentives. Economic instruments can be cost effective and easy to modify, but they are often incapable of fully incorporating environmental values (OECD 1993a). Effective management of the coast requires knowledge about public preferences regarding management alternatives and must be incorporated by decision makers. Knowledge of public beliefs and preferences are required for new management models to select an appropriate mix of regulatory and economic policies.

Additional instruments to promote ICZM objectives discussed by Boelaert-Suominen and Cullinan (1994) are: exclusion zones, public ownership, expropriation and acquisition , environmental impact assessment, environmental compensation and recognition of traditional and/or indigenous rights.

2.2 Coastal Zone Management in Latin America

2.2.1 Regional Efforts

Countries in Latin America have reached different levels in Coastal Zone Management (CZM). For example, the "shoreland restrictions" approach, implemented in Costa Rica's program (Law on the Marine and Terrestrial Zone 6043, 1977), divides the coastal zone in two areas: the public zone (50 meters inland from the high tide mark) and the restricted zone (additional 150 meters) (Sorensen *et al.* 1990, Mack *et. al.* 1992). This law attempts to assure public access and regulate development in the marine terrestrial zone. Law 6043 excludes from the restricted zone important areas such as estuaries and mangrove wetlands. In spite of the dynamic character of this Law, 200 meters of the coast may not be sufficient to control deforestation, pollution, and environmentally unsound uses (Mack *et al.* 1992). Honduras has nine protected areas on its coasts, only one of the areas currently has a management plan (Oyuela 1994). Two increasing industries in Honduras are mariculture and tourism. Mariculture has consumed more than 5,000 hectares of coastal areas to install shrimp ponds. The development of ponds, wood to fuel salt ovens, and domestic consumption have resulted in the destruction of mangroves and loss of access to traditional fishing grounds. Even with the institutional framework and agency efforts to control human activities along the coast weaknesses in reviewing applications, granting permission, training personnel in resource management, monitoring, and fostering public education still exist (Foer 1992).

In Panama, public lands on the coast extend from the high tide to 200m inland (Código Agrario de 1962, artículo No. 116). Executive Decree #39 (1966, articles 8 and 34) prohibits the destruction of trees that regulate the flow of water, prevent erosion, and protect unique species located within 30m of river banks, lagoons, and lakes respectively. Forest Law No.1 enacted in 1994 requires a license for wood harvesting and building aquacultural ponds in mangrove wetlands. Law No. 21 (1980) regulates pollution from boats with fines up to $200,000 for spilling toxic substances. Unfortunately, these laws are unknown to the public and, many times by the officials charged with their enforcement. Osorio (1994) concludes that it is unclear when mangroves are included in the current laws, sometimes it is necessary to deduce it. Because of these and other difficulties, a strategy for coastal management was recommended in 1992. Part of the management needs were: 1) to define critical habitats; determine adequate measures to preserve ecological process, ecosystems and biodiversity; 2) to design strategies to establish a coastal tourism industry which causes the least possible disturbance to the environment while maximizing the social benefit; 3) develop a set of legal standards for coastal buildings; and 4) public education (Vasconez 1991).

Ecuador uses a strategy based on "Working Groups" developed by the University of Rhode Island as part of their "Coastal Resource Management Project". This approach combines flexibility and informality in procedures, and facilitates maximum participation and at the same time avoids institutional rigidity. Cultural and governance traditions in Ecuador are different from first world traditions and are considered crucial to the design of effective coastal zone management strategies (Merschrod 1989).

2.2.2 Mexico's Environmental and Natural Resource Policy and Law

In the Mexican constitution, article 27 indicates that the property of the land and water belong, originally, to the nation, which has the right to transfer them to individuals to become private property. The Constitution indicates that public and private property has to be regulated because of public interest. This is in the interest of an equitable distribution of the wealth from natural resources, resource conservation, balanced development, and improvement in the life styles of the rural and urban population (Constitución Política de los Estados Unidos Mexicanos 1995).

Laws and regulations related to article 27 of the Mexican constitution with relevance to the management of the coast are dispersed in the following laws: 1) Ley de Aguas Nacionales (National Water Law), 2) Ley de Pesca (Fishing Law), 3) Ley de Caza (Hunting Law), 4) Ley Forestal (Forest Law), 5) Ley Minera (Mining Law), 6) Ley Federal del Mar (Federal Marine Law), 7) Ley de Conservación del Suelo y Agua (Soil conservation and Water Law), 8) Ley General de Asentamientos Humanos, (Human Settlement General Law), 9) Ley

General de Bienes Nacionales (National Property General Law) , 10) Ley de Planeación (Planing Law), 11) Ley sobre Metrología y Normalización (Metrology and Normalization Law), y 12) Ley General de Equilibrio Ecológico y la Protección al Ambiente (General Law for Ecological Equilibrium and Environmental Protection).

In 1988, the law "Ley General del Equilibrio Ecológico y la Protección del Ambiente (LGEEPA)" was enacted (SEDESOL 1988b). This Law provided the basis:

"I. To define the principles for a general ecological policy and regulate the instruments for its application.
II. To pursue an ecological order.
III. To preserve, rehabilitate and improve the environment.
IV. To protect the natural areas and the aquatic and land flora and fauna.
V. To guide a rational use of the natural elements where economic benefits and ecological equilibrium be compatible.
VI. To prevent and control water, air, and soil contamination.
VII. To coordinate the participation of the federal government, states, and municipalities.
VIII. To coordinate the participation among the federal public administration entities and offices and society" (Translated from LGEEPA, 1988).

In addition to other factors, a more intense use of the natural resources is anticipated in México with the elimination of trade barriers included in international agreements such as the North American Free Trade Agreement (NAFTA). NAFTA will place considerable attention on the need for environmental protection. LGEEPA should play an important role in the long term management of the natural resources via environmental protection. In 1992, the Secretaría de Desarrollo Social (SEDESOL) was created, replacing the former Secretaría de Desarrollo Urbano y Ecología (SEDUE). SEDESOL, the new created agency, was charged with the formulation and enforcement of the Mexican environmental policy. In 1995, a new secretariat was created, Secretaría del Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP). It replaced Secretaría de Pesca (SEPESCA) and assumed the functions of SEDESOL.

Following LGEEPA Mexican states have enacted their own local environmental legislation (i.e., The Yucatan Law for Environmental Protection). Current local legislation in the state of Yucatan is based on generalities of LGEEPA, however a growing awareness exist that local legislation must be changed to provide specific and focused legislation that meets the needs of the local conditions[1].

Even with this body of laws and agencies, current problems have been identified in the following two areas: 1) incomplete body of specific laws and regulations and 2) non-enforcement of specific regulations (Loa 1996). Factors that contribute to a weak enforcement of regulation are: 1) discretionary use (officials make the decisions that they consider convenient), 2) official does not know the regulation, 3) out of date regulation use, 3) unclear demarcation of responsibilities, 4) lack of public education, and 5) public does not know regulation (Loa 1996).

[1]Minutes of the discussions for modifying the "Ley de Protección al Ambiente del Estado de Yucatán". COPLADE, Mérida, Yucatán, 1997.

2.2.3 Project of Ecological Order in Mexico

A project for an ecological order called proyecto de ordenamiento ecologico (POE) was included in LGEEPA. POE provides the basis for land use planning in the country including coastal areas. Ecological order was defined by this law as: *"The planning process directed to evaluate and program the land use and the management of the natural resources through out the nation and also over the zones through which the nation exerts its sovereignty and jurisdiction to preserve and rehabilitate ecological equilibrium and protect the environment"* (Translated from LGEEPA 1988, Art 3th-XX, p37).

Projects have been conducted under guidelines provided in the "Manual de Ordenamiento Ecológico del Territorio" (SEDUE 1992). This guide introduces the criteria for integrating ecological and socio-economic studies to create a model for an ecological order. At national level the Secretaría de Desarrollo Social (SEDESOL) and the Instituto de Geografía de la UNAM published the results of a National Project for a General Ecological Order under this criterion. At the regional level four out of ten projects were concluded in 1991 emphasizing the coastal zone located in Coatzacoalcos, Veracruz; Salina Cruz, Oaxaca; Jalisco; and Rio Panuco, Veracruz. Currently more than six projects in the coastal zone are underway in the states of Baja California, Tamaulipas, Sonora, Oaxaca, and Guerrero (SEDESOL 1993a). Reports regarding the success or failure of these projects are scarce and thus knowledge that may facilitate project acceptance for future efforts does not exist. In general, there is a lack of information about economic and cultural factors that either support or detract from traditional physical and biological interventions. In the State of Yucatan a growing awareness exist that a POE can be a useful planning tool and that the state and municipalities must provide the funds to initiate the implementation of an ecological project (ICZM) in the coast.

2.3 Ecosystems and Human Communities in the Coast

2.3.1 Mangrove Wetlands Fragility

Of primary interest to coastal management is the conservation of critical habitats. This point is especially important in developing countries because people in poverty depend on many products from the natural coastal ecosystems for food, fuel, and construction materials. A critical habitat in the coast is the mangrove wetland. Mangroves are salt tolerant plants that range from small shrubs to tall trees. They developed in intertidal coastlines in low-wave energy environments. The substrate is typically muddy, saline, acidic, and anaerobic. Mangroves play an important role in controlling coastal hydrodynamics and sediment movements that result in shoreline stabilization. The extraction of nutrients by the mangroves and the ability of the soil to hold toxins and metals helps in the maintenance of the water quality. Mangroves also provide habitat for a wide range of dependent biota from plankton to human communities (Lugo and Snedaker 1974, Odum and Heald 1975, Parsons 1992, and Boto 1992). See Figure 4.

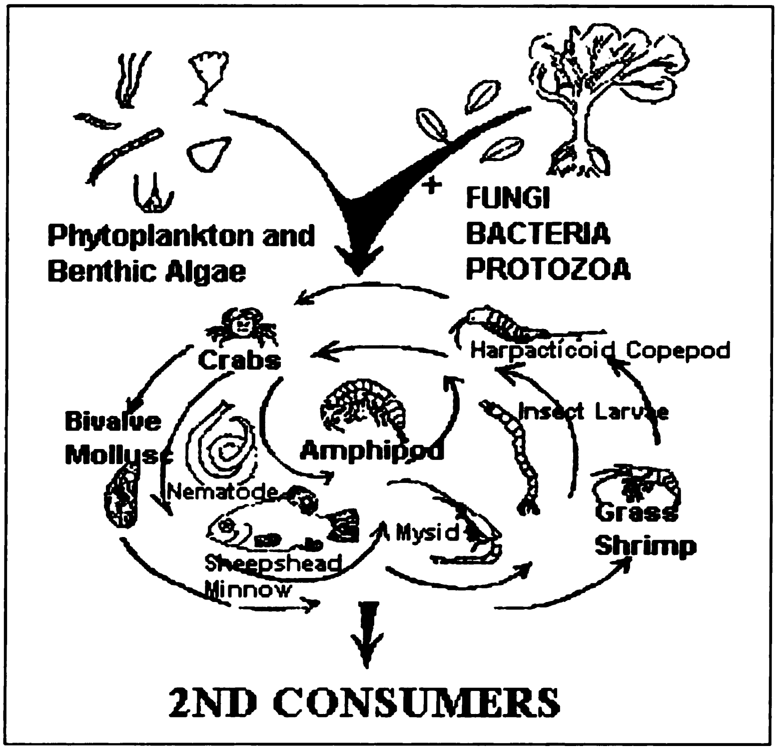


Figure 4 - Major contribution of mangrove detritus (From Odum 1970 in Mitsch and Gosselink 1993)

Unfortunately, mangrove wetlands are most severely impacted by human activities in coastal areas (Parsons 1992). The potential use of mangrove ecosystems for urban development, agriculture, aquaculture, port infrastructure, waste treatment area, and energy production are a serious menace to their conservation. Mangrove clearing by increased settlement and aquacultural developments, and pollution from sewage are the main causes of destruction of the mangroves (Benites *et al.* 1992, Boto 1992, Butler *et al.* 1993). Even though it is well known that they have important ecological, aesthetic, and economical values and a role as an excellent indicator of the health of the coastal ecosystems; the coastal zones in Pakistan, China, Indonesia, East Africa, Australia, Ecuador and other places have still experienced significant destruction and difficulties in protecting the mangrove forest (Ongkosongo 1992, Semesi 1992, Lin and Fan 1992).

Mangrove wetlands in Mexico cover approximately 4900 km^2 (Loa 1994). The State of Yucatán has a surface area of 630 km^2 of mangroves (13% of the nation) and is the forth largest area after Nayarit with 1,342 km^2, Campeche with 804 km^2, and Sinaloa with 705 km^2 (Loa 1994). There are 4 mangrove species in the Yucatán Peninsula: 1) *Rhizophora mangle* also called red mangrove or "xtapche'" by the local Maya people, 2) *Avicennia germinans* or black mangrove also called "taabche'" by the locals, 3) *Laguncularia racemosa* or white mangrove called by the locals as "sak-olhom", and 4) *Conocarpus erectus* or buttonwood or "canche'" (Morales 1992, Sanchez 1994). Relative distribution of mangrove species in the Yucatán is shown in Figure 5.

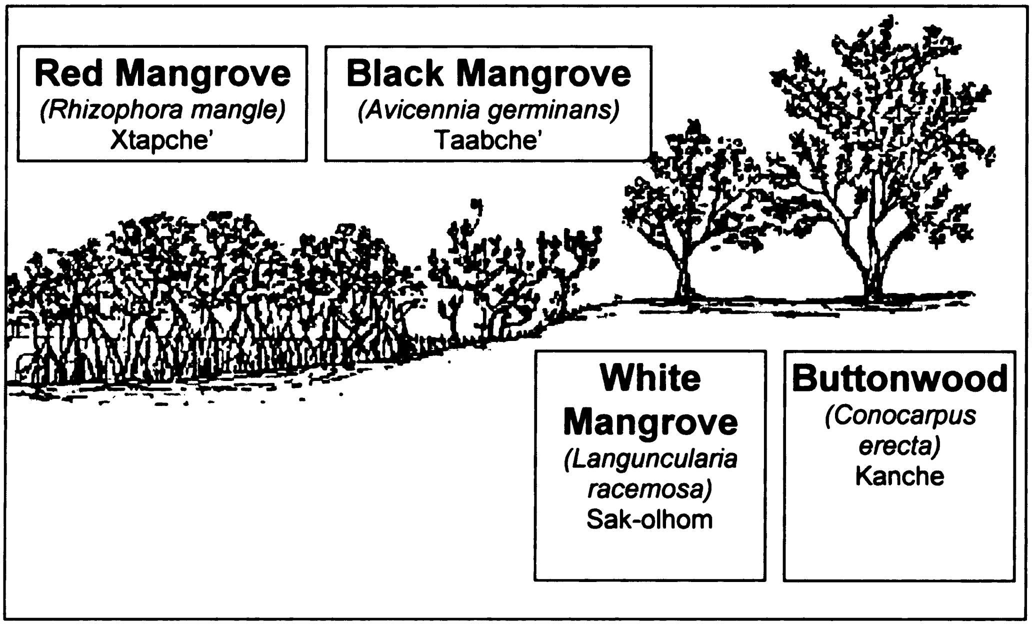


Figure 5 - Mangrove species zonation in the Yucatán Peninsula (After Morales 1992)

Mangrove wetlands in the coastal areas of the Yucatán have been destroyed and impoverished by the road network, increasing filling for residential and industrial developments, urban sewage, mangrove harvesting for construction and energy production, solid waste, and maintenance of port infrastructure, channels, vessels and oil pipes (Zizumbo 1989, Valdés 1995).

2.3.2 Changes Affecting Mangroves

There is evidence that the mangrove forest changes its boundaries as part of its natural evolution. Mangroves are considered stable as long as they occupy the same area and unstable if their boundaries are advancing or retreating (Bird and Barson 1982). Changes in the mangrove structure and species composition impact species productivity. Human activities that change the conditions of the mangrove ecosystem appear to directly alter the natural mangrove evolution to levels that may result in undesirable vegetation changes including mortality. Critical parameters that have been identified and reported in the literature (Bird and Barson 1982) that affect the mangrove system are:

1) Salinity. Damage has been reported in places were mangroves were cut for boat landings, building harbors, or allowing runoff to escape from manmade canals. Variation in salinity may be affected by interrupting the frequency of inundation by the seawater, and changes in the pattern of freshwater inflow. Fresh water inflow can occur by stream flows or groundwater flows.

2) Sea level. There is evidence that the rise of the sea level promotes the regression of the mangroves to landward with recolonization of the immediate hinterland.

3) Sediment supply. Mangrove dieback is reported from places where accumulation of sand eroded from other places and carried by drainage channels has buried pneumatophores.

4) Nutrient Pollution. Sewage effluent, aquaculture ponds, and agriculture runoff are the major sources of nutrient input. Boto (1992) mentions that 300 Kg N and 30 Kg P per hectare annually should be capable of being processed by the mangrove forest. However he assumes that very high concentration of ammonium would be toxic to dependent biota and substantial amounts of organic nutrients will lead to extreme eutrophication, which is detrimental to the associated fauna.

5) Oil spills. It is known that mangroves die if oil reaches the roots. Experiments with young mangroves showed that high concentrations above 1250 to 12,500 ppm did have effects on black and white mangroves (Thorhaug 1992).

6) Clearing and Reclamation. Much of the reduction of mangrove areas is reclamation of land for housing, aquaculture, solar salt production, agriculture and industry. In addition to the direct effect of landfilling for reclamation purposes, other adjacent areas may be sensitive to this change.

2.3.3 Coastal Land Use and Control

As population grows, the amount of land has become scarce and in the absence of proper land use planning many natural populations and their environments have been negatively impacted. Pressure on land has caused many coastal countries to strengthen land use planning and regulation with the purpose of protecting the welfare of present and future generations. However, implementing land use controls requires that people understand and accept required trade-offs as benefiting all. Opposition to land use planning are often associated with perceptions regarding property rights and the real estate markets. To the individual motivated by profit, free markets may lead to the highest and best use of land. This behavior is not necessarily safe for the environment or desirable to the public. Others feel that in the future land will be treated more as a public resource than a commodity Mokma (1994).

House *et al.* (1976), have proposed several instruments for shaping land use: 1) ownership, 2) regulation, 3) taxation, 4) subsidies, 5) incentives, 6) investments, 7) information, 8) education, and 9) persuasion. The problem is how to select the most appropriate set of instruments for a particular case. To deal with this problem, the cause and effect relationship between land use and the environment must be understood. This necessitate that we be able to predict the likely environmental consequences related to each different land use alternative.

2.4. Data Collection and Analysis

2.4.1 Natural System

2.4.1.1 Environmental Impact Assessment

Identification and evaluation of the environmental impacts of development in the coastal zone are essential if sustainable mitigative measures and recommendations regarding project design and operation, land use planning and other management interventions are to be implemented. Environmental Impacts (*i.e.*, changes in the attributes of the environment) are largely determined by the way resources are used (Schultink 1993). Environmental Impact Assessment (EIA) is a process that provides indicators of the likely consequences of current and proposed actions. Spatial and temporal changes of environmental parameters that occur as consequences of a particular activity are called an impact (Wathern 1988). In general EIA is used as a tool for: impact identification, prediction, interpretation, communication, and in designing monitoring schemes (Wathern 1988).

Schultink (1992) provides examples of major actions potentially affecting the resource base (Table 1). These actions, in the coastal zone, may result as a consequence of development projects from urban, commercial, industrial, and agricultural developments, such as: 1) building homes, 2) motor road and airport construction, 3) construction of water ways and marinas, 4) marine product manufacturing, 5) disposal facilities, 6) salt extraction, 7) aquaculture ponds, 8) fishing, 9) hunting, and 10) wood extraction.

Table 1 - Examples of major actions on the Environment (Schultink 1992).

1	Modification of Ecosystem functions, properties and boundaries
2	Land transformation and change
3	Resource extraction and depletion
4	Resource utilization and processing
5	Resource alteration and conservation
6	Resource renewal and redevelopment
7	Introduction and storage of hazardous materials

EAIs are required by Multinational Development Banks for sanctioning and liberating funds for development projects and mandatory in many countries, including México according to LGEEPA (1988).

Table 2, list the output components of an EIA called Environmental Impact Statement (EIS) (Devuyst 1993, pag. 152).

Table 2 - Components of an Environmental Impact Statement (Devuyst 1993)

1. Description of the development: the purpose(s) of the development should be described as should the physical characteristics, scale, and design. Quantities of materials needed during construction and operation should be included and, where appropriate, a description of the production processes.
2. Site description: the on-site land requirements of the development should be described and the duration of each land use.
3. Residuals: the type and quantities of residual and/or waste matter and energy created should be estimated, the expected rate of production given, and the proposed disposal routes to the environment described.
4. Environment description: the likely geographical extent of the affected environment should be described.
5. Baseline Conditions: a description of the affected environment as it is currently, and as it could be expected to develop if the project were not to proceed, should be presented.
6. Definitions of impacts: potential impacts of the development on the environment should be investigated and described. Impacts should be broadly defined to cover all potential effects on the environment and should be determined as the predicted deviation from the baseline state.
7. Identification of impacts: methods should be used which are capable of identifying all significant impacts.
8. Prediction of impact magnitude: the likely impacts of the development on that environment should be described in exact terms wherever possible.
9. Assessment of impact significance: the expected significance that the projected impacts will have for society should be estimated. The sources of quality standards plus its rationale, assumptions and value judgments used in assessing significance should be fully described.
10. Alternatives: alternatives to the proposed project should be considered. The alternatives should be outlined, the environmental implications of each presented, and the reasons for their rejection briefly discussed.
11. Mitigation measures: all significant adverse impacts should be considered for mitigation. Evidence should be presented to show that proposed mitigation measures will be effective (Lee et al., 1990).
12. Monitoring: the predictions included in the EIS and the effect of the proposed mitigation measures could be evaluated when a permit for the project has been issued. A plan which describes the best way to monitor the project could already be proposed in the EIS.
13. Annex: interesting additional information, external sources etc., should be presented at the end of the document in an annex.

Environmental impact identification can be conducted with the use of checklists, matrix methods, networks, overlays, and simulation (Wathern 1988, Devuyst 1993). Checklists are simple lists to collect impacts associated with a project activities. These simple **lists** do not provide: 1) interactions between effects, 2) the most significant impacts, and 3) the likelihood of occurrence. Matrices introduced by Leopold (1971) are the most popular method. **Matrices** relate development actions with environmental components and can be used to measure and interpret impacts. Such matrices focus on direct impacts, not the cumulative impacts. **Networks** are graphs relating actions with secondary and higher-order impacts, which can result from an initial impact. **Overlays** are suitable for the consideration of spatial distribution and intensity of individual impacts. In this case, layers can be overlaid with the use of geographic information systems (GIS) commands to determine amongst others: 1) total impacts, 2) select locations with specific criteria, 3) compute areas, 4) change weighting values, and 5) add new impact type layers. Computer **simulation** is another tool that allows analysts to use a GIS model to test several scenarios and compute likely outcomes from the real system (Wathern 1988).

The above tools utilize physical models, experimental methods, and mathematical models to measure and predict the extent and nature of impacts. An additional method without predictive capabilities is the **valuational method**. It is used to compare alternative locations on the basis of the value of the environmental services that will be damaged by the proposed project (Wathern 1988).

2.4.1.2 Data Types and Methods

Policy design and implementation requires a good understanding of the condition of the natural resources and environmental impacts of human activities on natural systems. This task involves: 1) the detection, distribution, and quantification of physical changes, 2) evaluation of the quality of the natural system, 3) quantifying present and future rate of resource use, and 4) quantifying current and future waste generated in the region and other regions discharged in the coastal zone. Land use and land cover patterns are required to detect changes during the impact analysis. Land cover is defined as the type of feature present on the surface of the earth, and land use as the types of human activities associated with a specific piece of land (Lillesand and Kiefer 1987).

Most of the data is collected from large areas and multiple ecosystems where the use of traditional survey methods does not provide enough synoptivity. Remote sensing techniques (RS), geographical information system (GIS), and global positioning system (GPS) offer improved capabilities to be used in detecting landscape changes. A GIS is one of the recommended tools for integration and analysis of the pre-classified spatial data and to produce zoning maps (Thackway and Cresswell 1992, Welch and Remillard 1992). GIS oriented analysis provides flexibility and alternative solutions and it is convenient for a wide range of applications, including conservation assessment, planning and management. GIS also offers greater versatility because the data base can be cheaply analyzed numerous times to produce alternative maps (Thackway and Cresswell 1992).

A data base that includes land use and land cover types can be built with the use of remote sensing techniques. Remote sensing involves photographs or digital images taken by satellites or airborne sensors of the Earth's surface. The analysis of the images provides information about the objects, areas of interest and various phenomena. Digital image interpretation and GIS provide the tools for the analysis of remotely sensed imagery (RSI). Land cover information can be directly interpreted from remote sensors, however, information about human activities cannot always be taken from them.

Digital image processing through computers is a common way to analyze remotely sensed imagery. The various types of computer assisted operation for this task involve: 1) image rectification and restoration, 2) image enhancement, 3) image classification, and 4) data merging (Lillesand and Kiefer 1987). Image rectification and restoration (preprocessing) includes geometric and radiometric procedures to correct distorted or degraded images caused by atmospheric conditions, platform and sensor changes, and GIS requirements. Image enhancement procedures display images usually for visual interpretation. Image classification involves quantitative techniques for automatic feature identification. Procedures that involve the interpreter's knowledge to train the classifier are called supervised, others are called unsupervised. Statistical analysis of multiple bands is used in classification processes. Data merging procedures combine remotely sensed data with other data sources (Lillesand and Kiefer 1987).

2.4.1.3 Coastal Classification and Detection

From a comprehensive approach, the management and conservation of the mangroves under ICZM requires an adequate description of the coastal zone including: 1) mangrove forest, 2) open waters, 3) barrier island, 4) urban areas, 5) agricultural developments, and 6) industrial developments. Necessary information for these categories includes: 1) geographic location and extent, 2) composition, 3) production, 4) condition, 5) trend, and if possible 6) rates of change. The Coastal Change Analysis Program (C-CAP) that is part of the Estuarine Habitat Program (EHP) of NOAA Coastal Ocean Program (COP), has developed a C-CAP system classification for three major coastal components: wetlands, submerged vegetation, and uplands (Dobson *et al.* 1995).

This classification system is used in: 1) inventories and 2) monitoring changes in coastal areas. Three major components are called superclasses and were divided into classes and subclasses reflecting ecological relationships and classes that can be discriminated from data provided by satellite image, aerial photography, and field data (Table 3).

To collect data for classification and monitoring of the coastal zone, the use of level II United States Geological Survey (USGS) is suggested for land use/land cover classification. For level II, small scale photography, Landsat TM (30 m), and SPOT (20 m) imagery were recommended (Lillesand and Kiefer 1986). For other landscape features, Jensen and Toll (1982) successfully used Landsat MSS band 5 to study residential land-use developments. MSS band 5 (600-700 nm) is also used to separate vegetated and nonvegetated surfaces (Jensen and Toll, 1982). To study changes in the urban areas, Jensen and Toll

(1982), in addition to band 5 raw data, used MSS band 5 for texture analysis to improve change detection accuracy in residential land-use development.

Table 3 - C-CAP Coastal Land-Cover Classification System (Dobson *et al.* 1995)

C-CAP Coastal Land-Cover Classification System Superclasses & Classes
1.0 Upland
1.1 Developed Land
1.2 Cultivated Land
1.3 Grassland
1.4 Woody Land
1.5 Bare Land
2.0 Wetland
2.1 Marine/Estuarine Rocky Shore
2.2 Marine/Estuarine Unconsolidated Shore
2.3 Marine/Estuarine Emergent Wetland
2.4 Estuarine Woody Wetland
2.5 Riverine Unconsolidated Shore
2.6 Lacustrine Unconsolidated Shore
2.7 Palustrine Unconsolidated Shore
2.8 Palustrine Emergent Wetland
2.9 Palustrine Woody Wetland
3.0 Water and Submerged Vegetation
3.1 Water
3.2 Marine/ Estuarine Reef
3.3 Marine/ Estuarine Aquatic Bed
3.4 Riverine Aquatic Bed
3.5 Lacustrine Aquatic Bed
3.6 Palustrine Aquatic Bed

Source: Dobson et al. 1995: NOAA Coastal Change Analysis Program (C-CAP). NOAA Tech. Rep. NMFS 123

For mapping coastal vegetation, Loubersac and Slimani (1985) suggest that dense *Rhizophora* forest can be delimited using vegetation indices. Visible (MSS band 5) and infrared (MSS band 7) are preferred spectral bands to calculate vegetation indices (Green *et al.* 1994). These electromagnetic bands are selected because chlorophyll is a compound that highly absorbs energy from blue (400-500 nm) and red (600-700 nm) bands in the electromagnetic spectrum with low percent reflectance. Another characteristic is that internal leaf structure responds to near-infrared (NIR) band (700-1350 nm) by increasing NIR percentage of reflectance as leaf layers increase. Thus, NIR percentage of reflectance is typically bigger than visible bands for vegetated areas.

A simple vegetation index that uses this property is calculated by subtracting the visible channel from the infrared channel. This vegetation index gives high values for vegetation because of the relatively high near-infrared reflectance and low visible reflectance. In contrast, water and clouds give negative values because visible reflectance is greater than the near-infrared reflectance, and rock and bare soil areas result in vegetation indices close to zero since they have similar values in both bands (Lillesand and Kiefer 1987). Vegetation indices can be computed using MSS Landsat images using band 5 (600-700 nm) and band 7 (800-1100 nm) data. Proposed vegetation indices suggested by Lillesand and Kiefer (1987) are:

(a) Difference index as given by:

$$VI = \mathrm{Band}(7) - \mathrm{Band}(5) \qquad (1)$$

where values of $VI > 0$ are taken as vegetated areas, $VI = 0$ rock and bare soil, and $VI < 0$ clouds, snow, and water.

(b) Normalized Difference Vegetation Index (NDVI) as given by :

$$\mathrm{NDVI} = \frac{\mathrm{Band}_7 - \mathrm{Band}_5}{\mathrm{Band}_7 + \mathrm{Band}_5} \qquad (2)$$

The normalized index is sometimes preferred since it compensates for changes in the illumination, surface slope, and other factors.

2.4.1.4 Change Detection Procedures

To discriminate land cover changes between two dates, a change detection analysis is usually conducted with the use of maps, photographs, and satellite images. Change detection is performed by a combination of techniques that include: image differencing, image ratioing, and change vector analysis. For these techniques, geometric and radiometric corrections are needed. Geometric corrections are accomplished to register the images, this means that pixels (i.e., elements (i,j) of the image array) in both images with the same row (i) and column (j), must refer to the same place on the ground. Radiometric distortions caused by degradation of the sensor, platform changes, and changes in light conditions should be corrected by algorithms that take into account, sensor calibration, changes in the orbit, sun seasonal variations, and haze (Dobson *et al.* 1995, Eastman *et al.* 1991).

In addition to raw images for change detection, images can be transformed for better analysis using vegetation indices, principal components, regression, texture images, or classified images. Suggested manipulations are:

(a) Image Differencing as given by:

$$D = (\text{Band}_5(t_1) - \text{Band}_5(t_2)) / +127 \tag{3}$$

and values of D > 127 are considered as clearing, D = 127 no forest change, and D < 127 regrowth.

(b) Ratioing as given by:

$$R = \text{Band}_7(t_1) / \text{Band}_7(t_2) \tag{4}$$

and R is normalized to fit 8 bits and ± N standard deviations from the mean are used to separate change from no-change pixels

(c) Standardized Principal Components (Fung and LeDrew, 1988). The index as given by:

$$D = SPC_3(t_1) - SPC_3(t_2) \tag{5}$$

and SPC_3 is the third principal component and it is a measure of the greenness. To separate change from no-change pixels, ± N standard deviation from the mean can be used.

(d) Ratio Image Differencing as given by:

$$R_1 = \left(\frac{\text{Band}_7(t_1) - \text{Band}_5(t_1)}{\text{band}_7(t_1) + \text{band}_5(t_1)} + 1\right) * 127 \tag{6}$$

$$R_2 = \left(\frac{Band_7(t_2) - Band_5(t_2)}{band_7(t_2) + band_5(t_2)} + 1\right) * 127 \tag{7}$$

$$R = R_1 - R_2 \tag{8}$$

Equation (6 and 7) are highly correlated with the amount of green biomass and equation (8) is useful in the estimation of green biomass change between different dates.

(e) Vegetative Index Difference (Nelson, 1983) as given by:

$$VID = \frac{Band_7(t_1)}{Band_5(t_1)} - \frac{Band_7(t_2)}{Band_5(t_2)} + C \tag{9}$$

C is a constant to produce a non-negative real image. Nelson (1983) in a single and multi-band analysis found that this index produces the highest accuracy against differencing and ratioing procedures similar to those described in cases (a) and (b).

(f) Linear Regression as given by:

$$\text{Predicted Band}_7(t_2) = a + b * Band_7(t_1) \tag{10}$$

A linear relationship is assumed to exist between the two images. The linear relationship that result from regressing one image against the other is used to create a predicted image in t_2. Predicted and true images are subtracted according the procedure in case (a).

(g) Post-Classification comparison. This is a method that involves independent classifications for dates t_1 and t_2, and verification of corresponding pixels (*i.e.*, no-change = pixels with same number category, change = pixels with different number category). In this method, the accuracy of the change detection is the product of multiplying the accuracy (measured on a scale from 0 to 1) of each classification.

(h) Change Vector Analysis. Multispectral images involve more than one band. Bands from time t_1 image are used to fix one point in a multidimensional space and bands from time t_2 image are used to fix a second point. The magnitude of the Euclidean distance between these two points is calculated and represents a measure of difference or change. In addition, direction of change can be computed when two bands are involved. Direction can provide additional information.

(i) Texture Analysis. Interpreters use texture to distinguish features with similar reflectance. Spatial Gray-Level Dependence (SGLD) matrices are common sources of features. Popular features are: energy, entropy, correlation, inertia, and local homogeneity. Images created with the SGLD approach can be subtracted for change detection (Ballard and Brown 1982).

2.4.1.5 Field Sampling and Thresholds

A common need in these procedures involves the use of a threshold to decide change from a no change situation. As noted in the literature, there is not a unique or effective way to set a threshold. One approach assumes that residuals have a normal distribution, therefore a threshold can be chosen based on statistical confidence intervals. For example, a 95% confidence interval suggests ± 1.96 s.d. from the mean to fix the area of no-change, in this case 2.5% of the points in both tails of the distribution is taken as the true change. This approach does not always provide the best results. Fung and LeDrew (1988) found, using six indices that as the number of standard deviations increases the accuracy of the indices increases until they reach a maximum and afterwards they decrease.

Unfortunately, to find this maximum value for indices, field data must be collected and multiple confidence intervals tested to find the best threshold. Fung and Ledrew (1988) suggest that the Kappa index of agreement is the best way to select the threshold between change and no change areas using ground truth data. The Kappa index measures the difference between observed agreement and the agreement that might occur by chance. A simplified Kappa index is defined as follows:

$$k = \frac{p_0 - p_e}{1 - p_e} \tag{11}$$

$$\text{where} \quad p_0 = \sum_{i=1}^{c} p_{ii} \quad \text{and} \quad p_e = \sum_{i=1}^{c} p_i \, p_i$$

p_0 = the proportion of units which agree
p_c = is the proportion of units for expected chance agreement and
c = the number of classes used.

It is assumed that error matrices are products of appropriate sampling design and an adequate number of samples (Congalton 1983). The proposed sampling scheme by Rosenfield *et al.* (1982) mentioned that for each category the number of samples is taken according the cumulative binomial probability with the assumption that a preliminary percent of the accuracy can be estimated (p_0). The maximum error tolerated (E) and a confident level (alpha) are also involved in the computation of sample size (n). Table 4 shows values for (n) at 95% confidence level (alpha = 0.05) and E = 10%.

Table 4 - Sample size from Rosenfield *et al.* (1982)

Po	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85
n	60	57	60	52	45	40	30	19

2.4.1.6 Mapping and Precision

In the case of quantitative data where radiation values are the basic data, maps should be submitted with statistical results that justify threshold selection and estimation of the propagation error due to image manipulation with GIS operations. Error matrices and their Kappa coefficients that result from several thresholds must be evaluated. The highest Kappa value is the criteria for threshold selection. Kappa is a measure of the change detection precision. GIS data transformation creates changes in the thematic classification precision. The intersection of two layers (e.g., and operations) has precision equal to the product of the proportion of the points correctly classified (PCC) from each layer.

In the case of qualitative data where values of radiation were transformed into categories, the standard form used to report the differences between two images is a crossclassification table. Crossclassification is an *n* by *n* array where columns and rows are labeled with the categories. Diagonal values in the array are the number of pixels with no change, and off-diagonal values are the number of pixels with change. Inspection of the array provides quantitative data about the changes which have occurred in the study area. Statistics used include Chi Square, Cramer's V correlation coefficient, and the Kappa Index of Agreement.

2.4.2 Social Systems

Basic precepts for wildlife management were introduced by Aldo Leopold in 1933, but it is in the last 25 years that the human dimension has emerged in contemporary wildlife management. Today, efforts are conducted to integrate the human dimensions with biological dimensions as a way to present sound solutions in management programs (Decker *et al.* 1992).

Decision makers need to know people's responses both short and long-term regarding the effects of current or projected actions. Proactive decision makers need to anticipate and calculate the reactions that their proposals will produce on people. In general, data from the socio-cultural dimension will enhance policy selection and implementation of strategies for resource management (Payton 1990, Decker *et al.* 1992). Relevant data for the purpose of natural resource management includes: 1) traditional uses, 2) preferences by type of project, 3) short vs. long term economic returns, 4) preferences by project location, 5) environmental knowledge, 6) organization, 7) aspirations, 8) potential response to management programs, 9) competing groups, 10) attitudes, and 12) values. Assessment of the individual knowledge base and attitudes of people (i.e., fishermen, students, industrial workers, tourist, etc.) will provide information about the realistic success in the design, implementation and future results of management plans.

2.4.2.1 Knowledge Base

In coastal areas where the mangrove wetland is the primary ecosystem, public knowledge critical to the management of the area include: knowledge concerning the direct and indirect mangrove products and use; threats to mangroves; mangrove ecological benefits; economic and cultural values; and attitudes.

1) Resource use and ecological functions. Data about mangrove wetland products are in general divided in: 1) mangrove wetland direct products and 2) mangrove indirect products. Principal direct and indirect products and their uses are shown in Tables 5 and 6. More information about direct and indirect products can be found in (Suman 1994, Dugan 1992, Hamilton and Snedaker 1984).

Table 5 - Mangrove Direct Products

Category	Use
1. Wood for energy production	Cooking or heating, smoking fish, and burning bricks
2. Wood for construction	Beams and poles for houses, boat-building materials, fence post, furniture, and toys
3. Fishing	Poles for fish traps, fishing floats, tannins for net preservation, and fish attracting shelters.
4. Agriculture	Fodder, and green manure
5. Food and Drugs	Tea, condiments, and medicines

Table 6 - Mangroves Indirect Products

Category	Use
1. Finfish	Food, fertilizer, and bait
2. Mammals	Food, fur, observation, and sport Hunting
3. Crustaceans	Food, fertilizer, and bait
4. Reptiles	Food, skin, observation, and sport hunting
5. Mollusks	Food, fertilizer, bait, and shells
6. Insects	Food, honey, wax
7. Birds	Food, feathers, observation, and sport hunting
8. Recreation	Swimming, walking, sailing

In addition to residents knowledge about direct and indirect mangrove products use, it is important to understand how much residents know about the ways mangrove wetlands are transformed (by direct and/or indirect actions) with effects that reduce or eliminate its natural production. Table 7, shows some of the mangrove wetland conversion frequently reported in the literature.

Table 7 - Mangrove Wetland Conversions

Category	Category
1. Residential use	7. Marine infrastructure
2. Roads	8. Disposal of Solid waste
3. Pipes	9. Salt pond developments
4. Parking lots	10. Oil industry
5. Aquacultural ponds	11. Sewage
6. Agriculture	12. Recreational and tourism facilities

Less tangible for residents are the environmental benefits provided by the mangrove wetland. Dugan (1992) and Hamilton *et al.* (1989) provided a good description of the mangroves environmental benefits. A summary is provided in Table 8.

Table 8 - Mangrove Environmental Services

Category
1. Production of organic matter and feeding nursery
2. Protection of shore erosion
3. Protection from hurricanes and storms
4. Habitat for nesting of birds
5. Spawning area and protective cover
6. Removal of nutrients, heavy metals, and other substances from the water
7. Transportation by water
8. Retention basin for flood waters
9. Export of Nutrients

2) Long-Term Resource Use. Information about people's feelings, beliefs and values related to resource conservation and protection of critical processes in coastal ecosystems is needed. Kellert (1980) studied attitudes toward animals creating a taxonomic division of **cultural values**: naturalistic, ecologistic, humanistic, moralistic, scientistic, aesthetic, utilitarian, dominististic, negativistic, and neutralistic. In addition to cultural values, economic values other than **use** such as **option**, **bequest**, and **existence** have been recommended to be introduced in natural resource management (Randall 1987, Hamilton *et al* . 1989, Barbier 1994).

Also important are beliefs regarding the consequences of human activities on vegetation, wildlife, and fish that may adversely affect the mangrove wetland. For example: 1) **conversion** (urban expansion, port Infrastructure, aquaculture development, salt ponds, road expansion) 2) **residuals** (domestic and Industrial solid wastes, untreated domestic and industrial sewage, oil spills), and 3) rates of **resource consumption** (trees, fish, birds, mammals).

Another important factor is the acceptance of regulation for controlling resource use and environmental protection. Controls may involve the protection of nursery areas and creation and protection of corridors where almost all human activities would be banned. For activities such as fishing, hunting, and wood harvesting, the following control may be required: obtaining hunting permits, limiting or rotating the number of fishing grounds, the establishment of seasons, etc. For urban and industrial activities, the controls required include: controls for home construction, roads and port infrastructure (marinas), as well as regulation for solid garbage and sewage is used.

2.4.2.2 Data Collection Methods

To collect data from the human dimension and test proposed hypotheses, it is necessary, as Singleton *et al.* (1993) suggest, to define the concepts outlined in the hypotheses, operationalize these concepts into variables, select proper indicators for further analysis, and select the best approach to generate information. Singleton *et al.* (1993), examined three of the various approaches to operationalization: 1) verbal reports, 2) observation, and 3) archival records. Verbal reports or self-reports provide simple and generally accurate measures of background variables, as well as subjective experience (Singleton *et al.* 1993). To measure complex concepts, two or more responses are combined to create an index or scale. Indices simplify the analysis and increase precision.

Henerson *et al.* (1987) have suggested the following instruments to measure attitudes: 1) Self reports, which include interviews, surveys, polls, questionnaires and attitude rating scales, logs, journals, and diaries; 2) reports of others, which include interviews, questionnaires, logs, journals, reports, and observation procedures; 3) sociometric procedures, which include peer rating, and social choice techniques; and 4) records, which include counselor files, and attendance records.

Self-reports are procedures for asking people to provide information (oral or written) about age, gender, education and their own attitudes. Attitude assessment with the use of self report procedures are the most direct approach. It has been recommended that when the people understand the questions asked of them and have sufficient self-awareness to provide the necessary information, that they will answer honestly and tend not deliberately, to falsify their responses (Henerson *et al.* 1987). Reports of others, refer to a procedure in which a person (the observer) is informed about the behavior and attitudes of others. This is useful when people are unlikely to provide accurate information. Two main concerns in this approach are provided by Henerson *et al.* (1987): 1) the bias introduced by the observer (lack of objectivity) and 2) the completeness of the information.

Sociometric procedures are in general used for asking people to provide information about the social structure or pattern of a group (i.e., Who are the group leaders?). Finally, archival records refer to the analysis of existing recorded data such as statistical records, public and private documents, and mass communication.

2.4.2.3 Population and Sampling

As Singleton *et al.* (1993) suggest, defining the target population requires keeping in mind the scope of the desired generalization and the practical needs to draw the sample. Generalization can be made regarding individuals, groups, or organizations with geographic (target area) and time referents and appropriated samples that involve economic and technical feasibility. To operationalize research on a given population a sampling frame must be defined. A nonspatial sampling frame is the set of all cases defined by either listing all cases or providing a membership rule. A spatial sampling frame might be a map where sample units are identified using a coordinate system (McGrew and Monroe 1993)

To capture population heterogeneity requires a careful procedure to make sure that population variation is represented adequately in the sample. The quality of the sample is related to the sampling design. Samples are drawn using probability and non-probability procedures. Probability procedures are preferred over non-probability sampling design to avoid bias in the selection of cases and because it allows the use of probability to measure the accuracy of the sample. Under probability sampling, random selection is required at some point in the process. Simple random sampling, stratified random sampling, and cluster sampling are methods that involve the use of random selection.

The size of the sample is affected by several factors: heterogeneity, desired precision, type of sampling design, available resources, and the number of breakdowns (Singleton *et al.* 1993). Heterogeneity indicates that more cases are required for the sample. Statistical measures, such as the standard deviation (σ), provide an indication about the data heterogeneity. In computing the sample size the standard deviation or a close approximation is required.

Samples with geographical location are of special interest for management. Spatial sampling can be conducted in several ways including: point sampling, line sampling and area sampling. Point sampling may involve the following sampling strategies: systematic, random, proportional and disproportional stratified, and clusters. Selected types of hybrid point sampling provided by McGrew and Monroe (1993) include: stratified systematic unaligned, disproportional stratified systematic aligned, cluster systematic, and disproportional stratified cluster.

2.4.2.4 Data Analysis

Techniques used in the analysis are usually selected according the type of the data collected: nominal, ordinal, interval, or ratio level (Craft 1990). As mentioned by Singleton *et al.* (1993), the analysis of these univariate measures helps to find the most appropriate variables, collapse categories, and determine the shape of frequency distributions. When hypotheses involve more than single variables, bivariate analysis provides tools to assess relationships or associations between two variables. Contingency tables, cross-tabulation, and cross-classification are tables for the analysis of variables with few categories, usually nominal and ordinal scale measures. The test of statistical significance that allows the conclusion that evidence of statistical association exists, is the *chi-square* (χ^2) (Bhattacharyya and Johnson 1977, Craft 1990). The strength of statistical association between the two sets of measures is computed with the use of Cramer's contingency coefficient, Parson's coefficient of mean square contingency, or Parson's phi coefficient in 2x2 table. Large values of these indexes indicate a strong association (*i.e.*, < .10 weak, .11 to .25 weak to moderate, .26 to .40 moderate, .41 to .50 moderate to strong, over .50 to strong (Craft 1990)).

For interval and ratio scale measurement, regression analysis is used to determine the best mathematical equation that describes relationship. Linear regression fits a straight-line to the data and provides an index r^2 that represents the portion of the dependent variable variability explained by the linear relation with the independent variable. Small values of r^2 indicate that a straight-line does not fit well for the data. Some nonlinear models can be tested with the use of linear regression using their linearized transformations.

To explore more complex relationships such as causation with more than one causal variable, models are tested with multivariate analysis. Multivariate analysis with nominal and ordinal data and contingency tables uses a technique called *elaboration*. Interval and ratio level measurements use a multiple-regression analysis, similar to the simple linear regression model. In this case, Pearson's R^2 is the index that reports the proportion of the variation in the y (dependent) variable explained by x_1, x_2, .., x_n (independent) variables in the analysis.

2.4.3 The Study Area

2.4.3.1 Boundaries

The coastal zone is that region on the earth where land and fresh water reach salty ocean waters. The coastal zone or simply the 'coast' is also called the land-sea interface. According to OECD (1993a), the interface is characterized by two axes: the long-shore axis and the on/off-shore axis. The former runs parallel to the shore axis and the later is perpendicular to the shore line. It is especially difficult to define the boundaries for the on/off axis. This axis can include, for the inland definition, entire watersheds to a small strip of shoreline, and for the seaward limit can extend as far as the 200 nautical miles limit.

The boundary problem arises since the coastal zone is diverse in the number of the ecological systems present in the area such as: marshes, mudflats, shallow open waters, mud and sand bottom, beaches, and dunes. Each of these systems consist of interrelated populations of plants and animals, and flows of water, nutrients and other materials. These ecosystems may exist on various scales and complexity and vary from region to region. These ecological systems, although different, are linked together to form an interdependent system where the activities or changes in one system influence the functioning of the others. These ecosystems are also influenced when the ocean and nutrient materials flushed from the land move to this area.

For these reasons, the boundaries for a study area should be defined based upon an ecosystem approach according to the objectives of management. This approach, when applied to the on/off-shore axis should cover part of the hinterland and include aquatic ecosystem and portions of tributaries (OECD 1993a).

It is suggested by Clark (1992) that the bounded area must be divided in management sub-units called tiers, each unit is characterized by resources, issues and jurisdictions. A four tier approach could be: 1) Marine and coastal areas, 2) transitional area, 3) shorelands, and 4) uplands.

2.4.3.2 Opportunities in the Yucatán Peninsula

Coastal areas in the State of Yucatán provide opportunities to test and study the proposed hypotheses. Outside the protected areas, mangrove wetlands in the coastal areas of Chuburná, Chelem, and Progreso also contribute to the support of: 1) commercial **shrimp fisheries** (e.g., *Penaeus duorarum, Penaeus aztecus,* and *Penaeus brasiliensis*), 2) **subsistence fisheries**: (e.g., *Fundus grandissimus*, *Cichlasoma urutalmus*, *Centropomus undecimalis*, *Lutjanus griseus*, *Lutjanus analis*, *Pogonias cromis*, *Bardiella ronchus*, *Cynoscion arenarius*, *Cynoscion nebulosus*, *Scomberomorus maculatus*, *Lutjanus Synagris*, *Ocyurus Chrysurus*, *Peprilus paru*, *Caranx hippos*, *Xancus angulatus*, *Melongena corona* and others), 3) **animal diversity** including birds (e.g., *Fragata magnificens*, *Porphyrula martinica*, *Jacana spinosa*, *Fulica americana*, *Himantopus mexicanus*, *Gallinago gallinago*, *Calidris minutilla*, *Pandiion haliaetus*, *Buteogallus anthracinus*, *Eudocimus albus*, *Ajaia ajaja*, *Casmerodiius albus*, *Butorides striatus*, *bubulcus ibis*, *Phoenicopterus ruber*, and many other), 4) **protect the coast** from erosion, and human settlements from hurricane and storms, 5) are a **source of energy** (wood and other organic materials); and 6) are **sink for nutrients** and other substances released from human activities in the area.

Mangrove ecosystems in this area are threatened by intentional landfills, improper road constructions, gas pipes, industrial developments, maintenance of port and urban infrastructure, industrial and residential solid wastes, and improper sewage treatment (Zizumbo 1989, Valdés 1995). Threats to mangroves due to previously described human activities originate from urban developments. A selected area in the state of Yucatan provides the opportunity to study a coastal community in a fragile ecosystem with pressures for environmental protection, economic development and population growth. The area includes three towns at different stages of economic development (Chuburná, Chelem and Progreso) mixed with a popular vacation area. Chuburná is an small rural town where residents heavily dependent on the coastal natural resources (small scale fishing, hunting, wood for energy production). Chelem is a rural town bigger than Chuburná. Residents also depend on coastal resources (small scale and mechanized/industrial fishing activities), however, the industrial plant located in Progreso and Mérida (fish processing and maquila) and services required by non-permanent residents along the year (demand increases during the months of July and August) provide alternatives for jobs. Progreso, the larger and more urban area, offer job opportunities in the commercial fishing industry, transportation, construction, and services. Progreso has many restaurants and hotels, state offices including the Mexican navy, the lighthouse and a pier to receive large vessels. This area, also provides the opportunity to study a large non-permanent group of residents that use the area during several holiday periods throughout the year. Full occupation occur during the months of July and August when schools have a long vacation period. To protect the environment and resources in this area, the mangrove ecosystem and local human communities need to be properly assessed and incorporated into planning for the long-term benefit of both, the mangrove wetlands and inhabitants of coastal areas of the State of Yucatán. The selected study area is shown in Figure 1, Chapter 1.

Chapter 3

RESEARCH DESIGN

This chapter provides a complete description of the procedures used in this work to: 1) determine and compare changes in the mangrove wetland over time, 2) link environmental changes to cultural features over specific distances, 3) assess the individual's knowledge base related to mangrove use and conservation, and 4) assess the acceptance of current and proposed general controls for regulation. It shows hypothesis operationalization, survey design, sampling design, criteria for accepting or rejecting the hypotheses, and proposed statistical analysis.

3.1 General Approach

As suggested by Rayner et al. 1994, an assessment of the natural and social systems is the first step. Natural coastal areas that have been damaged or converted by human activities were identified using synoptic data provided by remote sensors. A Change Detection Analysis (CDA) was conducted using photographs and MSS satellite images taken from the same geographical area. Remote sensing techniques were used in quantifying changes in the mangrove wetland and adjacent land with the production of land cover maps. Data from this analysis were used to identify major changes, link cultural features to changed areas, and assist the sampling design for assessing the social system.

In assessing the social system, a pilot study was conducted to prepare an intensive survey in three semi-homogeneous strata to collect from local residents data about: 1) use, 2) conversion, 3) ecological knowledge and 4) attitudes toward resource use and regulation. A preliminary questionnaire was designed and tested in the study area and a pre-tested questionnaire was applied using a spatially stratified sampling design. The sampling process was based on photographs and GIS tools to select sampled areas. A total of 139 interviews were conducted and the data collected was captured and statistically analyzed with a software package.

3.2 Analysis of the Natural System

The natural system was studied under the hypothesis H1 that stated: *"There have not been significant changes in the coastal areas of Progreso, Yucatán, Mexico from 1986 to 1990."* Hypothesis was tested under an EIA approach utilizing a change detection analysis (CDA), photographs, maps and MSS satellite images.

3.2.1 Boundaries and Location

The boundaries for the study area were defined based upon an ecosystem approach (Clark 1992). The on/off-shore axis (perpendicular to the shore) included the transitional areas and shorelands tiers. The transitional area was defined as the edge of the sea, which is intertidal and included coastal lowlands subject to flooding during seastorms as well as intertidal mangroves, tideflats and beaches. Also, the shoreland tier was defined as: lands adjacent to the transitional area which generate significant impacts on coastal resources such as the urban, recreational and industrial areas that usually disrupt the edge zone and generate pollution. The longshore axis (parallel to the shore) included the coastal lagoon in the area.

The extension of these axes provided the limits for sampling, data collection, and analysis. The selected area has coordinates 89° 35' - 89° 50' West and 21° 11' - 21° 18' North. The main geographic characteristics of the area include: 1) coastal barrier, 2) coastal lagoon, and 3) the mangrove wetland (see Figure 6)

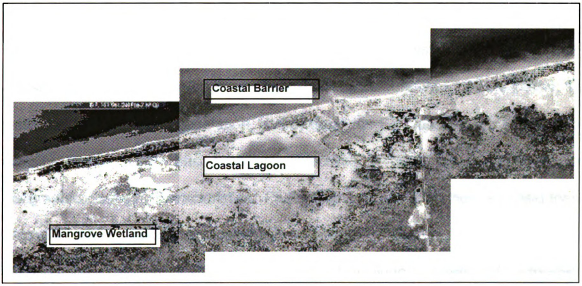


Figure 6 - Geographic characteristics of the studied area: 1) coastal Barrier, 2) coastal Lagoon, and 3) mangrove Wetland.

Three coastal towns are located on the area: 1) Chuburná, 2) Chelem, and 3) Progreso, as well as a large stripe of vacation homes 4) Prochub. Towns are located in the municipality of Progreso. This area is the fifth most populated area in the state of Yucatán with 18, 945 males and 18,861 females for a total of 37,806 permanent residents ($INEGI_1$ 1990).

3.2.2 Land Cover Classification

Land cover of coastal areas was classified using the system proposed in the Coastal Change Analysis Program (C-CAP) developed by NOAA Coastal Ocean Program (Dobson *et al.* 1995). C-CAP was selected because the several characteristics considered during its development: 1) detecting coastal upland and wetland land cover, 2) monitoring changes in the coastal region, 3) calibration among regions and scenes, 4) regional ecological modeling, 5) using remotely sensed data, and 6) using geographic information systems. The C-CAP classification system involved three major coastal components for classification: 1) wetlands, 2) submerged vegetation, and 3) uplands. Six classes were selected to classify coastal areas based on the objectives of this study and the main geographical coastal characteristics. Photographs, previous studies, and field trips helped to select proposed subclasses as follows:

1) Upland/Developed Land. This category included areas of intensive anthropogenic use such as: "cities; towns; villages, strip developments along highways; transportation, power, and communications facilities; and areas such as those occupied by mills, shopping centers, industrial and commercial complexes, and institutions that may, in some instances, be isolated from urban areas" (Anderson *et al.* 1976 in Dobson *et al. 1995*). This category was selected

because it represents the greatest threat to the mangrove wetland and dunes in the coastal area of Progreso.

2) Upland/Woody Land/Deciduous/Scrub-Shrub. Includes all upland areas having a predominance of shrub (plants < 6m in height) that lose their leaves or needles at the beginning of the dry season. This category of tropical upland vegetation was selected because their destruction increases run-off and sedimentation that affect the mangrove wetland.

3) Upland/Bare Land. Categories include " Dry Salt Flats; Beaches, Sandy Areas other than beaches; Bare exposed Rock; Strip Mines, Quarries; Gravel Pits; Transitional Areas; and Mixed Barren Land" (Dobson et al., 1995). This category was selected because once mangroves are cleared and filled, then the area develops similar characteristics to upland/bare land.

4) Estuarine Woody Wetland/Evergreen/Scrub-Shrub. This category includes areas with at least 67 % shrub that remain green throughout the year. Areas are located in semi-enclosed tidal wetlands in which marine water is diluted by freshwater runoff from the land. This low-energy area favors plants and animals, such as mangroves (*Rhizophora mangle, Avicenia Germinans*) and oysters. This is the most important category because mangroves have ecological, economical and cultural values for society as described in chapter 2. Their loss has implications for water quality conservation, fish production and protection, wood production, and as a habitat for many birds and mammals.

5) Marine/Estuarine Unconsolidated Shore/mud-organic. Include areas with 75% unconsolidated substrate (stones, boulders or bedrock), 25% pioneering vegetation, and temporarily flooded. Subclasses provided by Cowardin et al.

(1979) are: cobble-gravel, sand, and mud. The reason that this category is so important is because it is no longer accepted that mangroves are "land builders". Mangroves usually follow the land building as a consequence of currents and tidal energies (Mitchs and Gosselink 1993). Lugo (1980) indicated that mangroves contribute to land building only after the soil has been established (Mitchs and Gosselink 1993). This class also has implications in detecting mangrove clearing and mortality, since hurricanes, droughts and human-influenced changes (modification of hydrology, dredging, and sedimentation) cause mangrove destruction.

6) Marine/Estuarine Water. Refers to permanent flooded areas that are sufficiently deep so that they do not support emergent vegetation. This is the seaward mangrove boundary where marine and estuarine waters are frequently the routes by which mangroves are reached for wood extraction. Mangroves are also cleared for boat landing, and afterwards the area appears as open water.

More details about the original definition of these classes can be found in Dobson et al. (1995).

A coastal profile of the Yucatan coastal area is also used to indicate the relevance of selected classes: 1) marine system, 2) coastal barrier, 3) mangrove wetland and lagoon, and 4) uplands (see Figure 7).

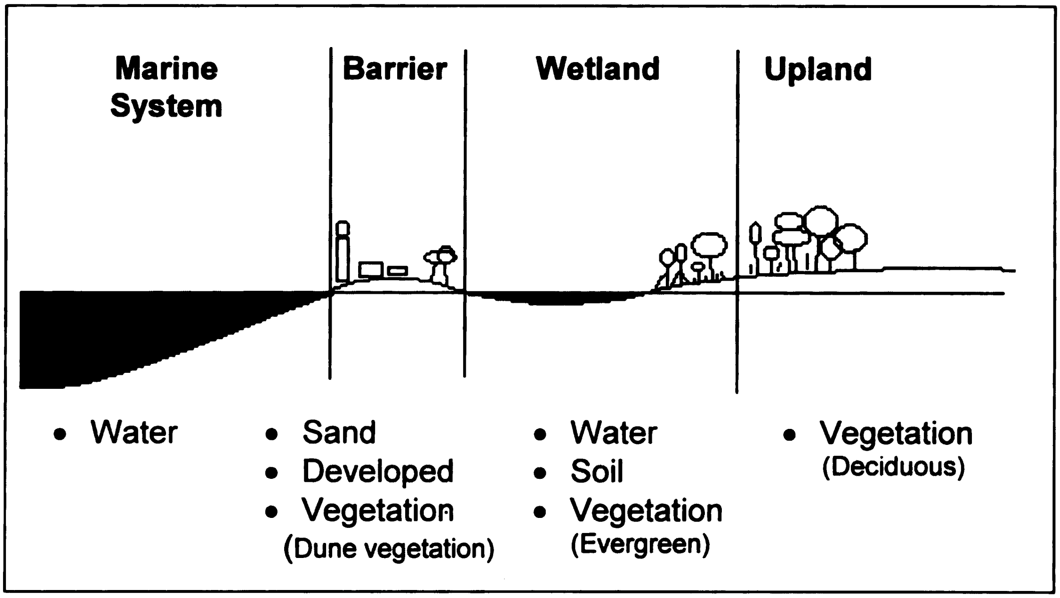


Figure 7 - Zonal classification and categories of Progreso coastal areas.

3.2.3 Change Detection

A multiple-date change detection method using a binary mask (Dobson *et al.* 1995) was used for the analysis of two MSS satellite images taken from the same geographical area with four years lag and seasonally close. The procedure involved the following stages:

1) Geometric corrections were performed on the images so that corresponding pixels refer to the same place on the ground (coregistry). The following steps were conducted:

- Two Landsat multispectral images (MSS) taken in February, 1986 and April, 1990 were used. Images corresponded to dry season.
- Resampling was used to create a multi-raster project to construct a set of coregistered raster images. Six points were used for coregistry.

- Images were georeferenced using six control points. Their geographical position were recorded by the use of a GPS. A 1st order polynomial function was selected.

2) Radiometric distortion caused by degradation of the sensor and light conditions was corrected according the following steps:

- Moran's I index of autocorrelation was computed for independent variable (X = February 1986) for bands 4,5,6 and 7 at several distances or lags.
- Images were radiometrically corrected to eliminate differences in calibration of the sensors, atmospheric conditions, and solar elevation with regression. A new set of corrected images were produced using linear equations from regression.

3) Change was determined by computing the magnitude of a change vector in a multidimensional space created by a multispectral image and added (logical OR) to the magnitude of a vegetation index difference. The procedure involved the following steps:

- Change vector analysis. Bands 5 and 7 were used to compute the magnitude of the change vector.
- Distance = $\text{sqrt}((\text{band5}\ (t_2) - \text{band5}\ (t_1))^2 + (\text{band7}(t_2)\text{-band7}(t_1))^2)$
- Thresholding. Cumulative frequency distribution of the distance was used to select several thresholds to create binary masks that indicated potential sites of change.
- Vegetation difference index. A vegetation index was created with bands 7 and 5:

$$DIV= (band7 (t_2) / band5 (t_2) - (band7(t_1)/band5(t_1) + C$$

- Tresholding. Cumulative frequency distribution of the difference was used to select several thresholds to create binary masks that indicated potential sites of change.
- Change Binary mask. One threshold value was selected from each method to create two binary masks. Binary mask were added (logical OR) to produce a total binary mask for changes in the area. Changes were limited to uplands, and wetlands. Deep water was masked out as well as the areas covered by clouds.

4) Classification of changed areas was conducted following a standard supervised classification.

- The C-CAP Coastal Land Classification System was used to convert spectral clusters into information classes already described.
- Training sites. At least five training sites were selected per class to extract statistical information for classifiers. Photographs and field data were used to select the areas. Resulting spectral signatures were analyzed with the inspection of the histogram. Extreme values in both sides of the histogram were eliminated to adjust minimum and maximum values. Training sites inside the area of change were eliminated.
- Minimum distance classifier. A minimum distance classifier was used for classification. No limit was imposed on the distance and standard deviation values were used to compare distances.
- No field inspections were conducted to assess the quality of the classification.

5) Change analysis was conducted overlaying a binary mask on classified images.

- The binary mask was overlaid on classified images for date1 and date2.
- A "from-to" matrix was computed to determine changes in the area.

3.2.4 Linking Environmental Changes with Development

The following developments were selected to explore their relationship with changes on environmental attributes based on distance: 1) urban areas, which have been developed for permanent residences, commercial and industrial purposes; and 2) the coastal road network.

Relationship between development and ambient environmental quality were established over one component: land. From many possible attributes, total land cover changes, vegetation losses, new developed land and unconsolidated soil losses were used. Proximity maps to selected cultural developments were overlaid on these land cover changes.

A town proximity map (*i.e.*, the Euclidean distance between each cell and the nearest town feature) was created starting at the main squares of Chuburná, Chelem, Yucalpetén, and Progreso. Isolines to the target features were created using an interval of 3 pixels (1 pixel = 60 m). A number of 30 intervals of 180 m (3 pixels of 60 m) were selected. A road proximity map was also constructed with 30 intervals of 180 m for major roads in the area. Proximity maps were overlaid on total coastal changes, vegetation loss, new developed land and unconsolidated soil. The number of changes per distance interval was computed and plotted to determine their relationships.

3.2.5 Criteria for Rejection of the Null Hypothesis H1

Significant changes, as it was stated for hypothesis (H1), means that the 1990 mangrove wetland individual category proportions are not significantly different from 1980 proportions. This step is to test two binomial proportions, the null hypothesis Ho: $p_1 = p_2$ vs. the alternative H_1: $p_1 \neq p_2$. To compute the proportions p_1 and p_2, for all individual classes, the number of marginal pixels per class were divided by the total number of changed pixel n the "from-to" matrix.

The statistic $Z= (p_1-p_2)/ (\sqrt{}(p_2*(1- p_2)/n)$ was used. The overall hypothesis will be rejected if evergreen (**eg**) or dune vegetation (**dv**) or both land cover categories are rejected (**eg**($date_1$) <> **eg**($date_2$), **dv**($date_1$ <> **dv**($date_2$)) for the two study dates

3.3 Analysis of the Social System

3.3.1 Resource Use and Ecosystem Environmental Services

Second hypothesis states: "*Permanent residents from Chubumá, Chelem, and Progreso and non-permanent residents along the coast are not significantly different from each other in their individual knowledge base related to: 1)the use and environmental significance of the mangrove wetland, and 2) their attitudes for long term resource use and in accepting potential regulatory interventions for their management* ". Elements of survey and causal-comparative research were used. A structured approach was selected for testing the proposed hypothesis. A questionnaire was developed for data collection with open and closed-ended questions with two response formats: 1) multiple choice and 2) agreement scale.

Hypothesis H2 part 1, was subdivided into three parts to operationalized the concepts (Appendix A). Parts were restated as is shown below:

$H2a_0$: No differences exist across residents from Chuburná, Chelem, Progreso and non-permanent residents in their knowledge about the mangroves direct use

$H2b_0$: No differences exist across residents from Chuburná, Chelem, Progreso and non-permanent residents in their knowledge about the mangroves indirect use

$H2c_0$: No difference exists across residents from Chuburná, Chelem, Progreso and non-permanent residents in their knowledge about the environmental services provided by the mangrove wetland.

3.3.1.1 Mangrove Use and Environmental Significance Concepts

The individual knowledge base was defined as the knowledge that residents and temporary residents living in the study area have about the mangrove wetland uses and ecological functions. To determine the state of the public's knowledge about mangrove wetlands, data were collected in four categories: 1) mangrove wetland direct products, 2) mangrove indirect products, 3) mangrove wetland conversion, and 4) mangrove ecological functions. Proposed direct and indirect products, and ecological benefits of the mangrove wetland were taken from Hamilton and Snedaker's (1984) as reported in Hamilton *et al.* (1989) and by Dugan (1992).

a) Mangrove Direct Products

The following mangrove direct product use categories were selected and included in the questionnaire (see Table 9) because of the importance of mangrove wood to rural economies and critical to the poor who depend upon it.

Table 9 - Mangrove direct products included in the survey and the name of the variables

Category	Variable	Use
1. Wood for energy production	**firewood**	Cooking or heating, smoking fish, and burning bricks
2. Wood for construction	**conwood**	Beams and poles for houses, boat-building materials, fence post, furniture, and toys
3. Fishing Arts	**artwood**	Poles for fish traps, fishing floats, tannins for net preservation, and fish attracting shelters.
4. Agriculture	**agricul**	Fodder, and green manure
5. Food and Drugs	**foodru**	Tea, condiments, and medicines

b) Mangrove indirect Products

The following categories in Table 10 were selected and included in the questionnaire because mangrove indirect products (fisheries and hunting) are in many rural communities the only alternative to include protein as part of the daily food. Mangroves also support in the area 14 bird species with value to sport hunters that during the months of January and February have its higher activity (Batllori 1995). For the Gulf of Mexico, 90% of the capture (US$700 millions/year) is attributed to mangrove dependent species (Dugan 1992).

Table - 10 Mangrove indirect products included in the survey and the name of the variables

Category	Variable	Use
1. Finfish	**finfish**	Food, fertilizer, and bait
2. Mammals	**mamma**	Food, fur, observation, and sport hunting
3. Crustaceans	**crust**	Food, fertilizer, and bait
4. Reptiles	**repti**	Food, skin, observation, and sport hunting
5. Mollusks	**mollu**	Food, fertilizer, bait, and shells
6. Insects	**insect**	Food, honey, wax
7. Birds	**birds**	Food, feathers, observation, and sport hunting
8. Recreation	**recrea**	Swimming, walking, sailing

c) Environmental Significance

In addition to the benefits from direct and indirect products, mangroves have functions and attributes with environmental significance unknown to the users and coastal residents. This situation contributes to low valuation and appreciation of the mangroves with negative consequences for their sustainable use and conservation. The environmental significance to residents was tested with the functions (ecological services) and attributes shown in Table 11.

Table 11 - Mangroves ecological services included in the survey and the name of the variables

Category	Variable
1. Production of organic matter and feeding nursery	**promat**
2. Protection of shore erosion	**soilpro**
3. Protection from hurricanes and storms	**hurpro**
4. Habitat for nesting of birds	**nesit**
5. Spawning area and protective cover	**nurs**
6. Removal of nutrients, heavy metals, and other substances from the water.	**clewa**

d) Mangrove Wetland Conversion

Mangrove wetlands are transformed (filling and drying or removing trees) to make it suitable for other uses. Resident knowledge about changes (**change**) in the area and rate of change (**rchan**) were collected to assist the change detection analysis. Possible categories for conversion were included in the questionnaire to be used as a guide (see Table 12).

Table 12 - Mangrove wetland conversions included in the survey and the name of the variables

Category	Category
1. Residential use	7. Marine infrastructure
2. Roads	8. Disposal of Solid waste
3. Pipes	9. Salt pond developments
4. Parking lots	10. Oil industry
5. Aquacultural ponds	11. Sewage
6. Agriculture	12. Recreational and tourism facilities

3.3.1.2 Instrument Design for Use and Environmental significance

To collect data for testing hypothesis H2, three sections were included in the questionnaire according the categories and needs described above for: 1) mangrove wetland use (direct and indirect products), 2) mangrove wetland conversion, and 3) mangrove ecological functions. The questionnaire included 6 sections: 1) mangrove wetland use, 2) mangrove wetland conversion, 3) attitudes toward sustainable resource use, 4) land use, 5) perceptions towards menaces, 5) Environmental benefits, 7) general information, and 8) final comments.

Mangrove Wetland Use

In section 1 of the questionnaire a picture was to show respondents the studied area (photo No. 1). The image included the Chelem lagoon, the surrounding mangrove wetland, and the uplands where Chuburná, Chelem, and Progreso are located. A list of names were collected in Q1 in order to identify how residents referred to the study area and the associated vegetation. **Q1: Would you like to tell us the name you use to designate the area that is shown inside the RED circle in PHOTO #1?.** Using a second picture (photo #2) trees that live partially submerged in water where showed to the respondents. Names were registered in question 2. **Q2: Would you like to tell us the name you use to designate those trees shown inside the RED circle in PHOTO #2?** To know if residents use the mangrove wetland and their products, **Q3: Do you make use of any part of these trees such as the wood, roots, flowers, leaves or any other part of the tree?** Respondents were told that based on previous discussions with members of the community, some possible uses of these trees were identified and that we would like to know more about them. **Q4: Please indicate from the following list your current uses and add other uses people make of these trees**. Add any others uses not represented on the lists. Question format is shown in Figure 8.

	Own Use	Others Use
1. Wood for energy production	( ) Q4.1.a	( ) Q4.1b
Additional information was collected for specific use such as:		
Cooking or heating	( )	( )
Smoking fish	( )	( )
burning bricks.......................	( )	( )
Other	( )	( )
2. Wood for construction	( ) Q4.2a	( ) Q4.2.b
3. Fishing Arts construction	( ) Q4.3a	( ) Q4.3.b
4. Agriculture	( ) Q4.4a	( ) Q4.4.b
5. Food and Drugs	( ) Q4.5a	( ) Q4.5.b

Figure 8 - Mangrove wetland use format question

Surveyors also asked, **Q5: Do you know of any other trees harvested in this area (photo #1) that people make use of?** and **Q6: Can you mention the names of those trees?**

To determine what indirect products are used, **Q7: What other benefits have you received from this area (Photo #1) in practicing hunting, fishing, swimming, bird watching or any other activity?** An example of the question format is shown in Figure 9.

	Own Use	Others Use
1. Finfish	( ) Q7.1a	( ) Q7.1.b
Additional information was collected for specific use such as:		
Food............................	( )	( )
Fertilizer.......................	( )	( )
Bait..............................	( )	( )
Other	( )	( )
2. Mammals	( ) Q7.2a	( ) Q7.2.b
3. Crustaceans	( ) Q7.3a	( ) Q7.3.b
4. Reptiles	( ) Q7.4a	( ) Q7.4.b
5. Mollusks	( ) Q7.5a	( ) Q7.5.b
6. Insects	( ) Q7.6a	( ) Q7.6.b
7. Birds	( ) Q7.7a	( ) Q7.7.b
8. Recreation	( ) Q7.8a	( ) Q7.8.b

Figure 9 - Mangrove indirect product format question

Mangrove Wetland Conversion

Three questions were used to collect data for comparison in section 2 of the questionnaire. **Q8: Do you think that important changes in the land use or cover have occurred in the area shown in Photo #1?**, **Q9: How fast do you think these changes are occurring? (0 to 5), (5 to 15), or (more than 15 years)** and **Q10: Can you tell us the current use(s) of the changed area(s)?** Figure 10 shows question format.

Residential use .... ( )	Salt pond developments .... ( )
Road constructions .... ( )	Storage areas .... ( )
Pipe Introductions .... ( )	Oil Industry .... ( )
Parking lots .... ( )	Fish industry ....( )
Aquacultural ponds .... ( )	Sewage ....( )
Agriculture .... ( )	Recreational and tourism facilities ....( )
Marine infrastructure...................................( )	Other ....( )
Solid waste disposal .... ( )	

Figure 10 - Mangrove wetland conversion format question

Environmental Services.

Section 6 of the questionnaire was developed to measure to what extent residents knew about the environmental benefits provided by the mangrove wetland. Six out of thirteen services mentioned in Hamilton et al. (1989) were used. **Q14: Below we have a list of environmental services provided by mangrove wetland. For each one, please check those that you know**. Figure 11 shows the question format.

1. Mangroves are a source of food for many small animals that live in the swamp. These small animals are also food for other creatures.	( )	( )	Q14.1
2. Mangrove protect the soil. Without these plants tides would erode the soil.	( )	( )	Q14.2
3. Mangrove trunks and branches protect other plants and animals from hurricanes and storms.	( )	( )	Q14.3
4. Mangrove branches are the place where birds construct their nests to reproduce, protect, and grow.	( )	( )	Q14.4
5. Calm waters close to mangrove roots are the place where fish and crustaceans reproduce, protect, and grow.	( )	( )	Q14.5
6. Mangrove roots and soil help to keep water clean. They trap substances mixed in the water.	( )	( )	Q14.6

Figure 11 - Mangrove environmental services format question

3.3.1.3 Criteria for Rejection of the Null Hypothesis H2a, H2b, and H2c

To test difference ***across*** towns (Chuburná, Chelem, Progreso and Prochub) and ***across*** coastal stripes (beach, inner and wetland), proportions were calculated for all variables needed to test the null hypothesis of homogeneity ($H2_0$: $p_1=p_2=p_3=p_4$). The test statistics were given by χ^2.

The following tables, Table 13, 14 and 15 show variable name, explanation, derivation and type that were used in the contingency tables to test H2a, H2b and H2c.

Table 13 - Mangrove direct products variables, explanation, derivation, and type.

Variable Name	Explanation	Derivation	Type
firewood	Respondent currently uses or has known others use wood for energy production	firewood=1 if Q4.1A OR Q4.1B IS "YES" ELSE firewood=2	NOMINAL
conwood	Respondent currently uses or has known others use wood for home constructions	conswood=1 IF Q4.2A OR Q4.2B IS "YES" ELSE conswood=2	NOMINAL
artwood	Respondent currently uses or has known others use wood for fishing gear constructions	artwood=1 IF Q4.3A OR Q4.3B IS "YES" ELSE artwood=2	NOMINAL

Table 14 - Mangrove indirect products variables, explanation, derivation, and type.

Variable Name	Explanation	Derivation	Type
finfish	Respondent currently captures finfish or has known others capture in the area	finfish=1 if Q7.1A OR Q7.1B IS "YES" ELSE finfish=2	NOMINAL
crust	Respondent currently captures crustaceans or has known others capture in the area	crusta=1 IF Q7.3A OR Q7.3B IS "YES" ELSE crusta=2	NOMINAL
mollu	Respondent currently captures mollusks or has known others capture in the area	mollus=1 IF Q7.5A OR Q7.5B IS "YES" ELSE mollus=2	NOMINAL
birds	Respondent currently hunts birds or has known others hunt in the area	birds=1 IF Q7.7A OR Q7.7B IS "YES" ELSE birds=2	NOMINAL
mamma	Respondent currently hunts mammals or has known others use the area for hunting	mamma=1 IF Q7.2A OR Q7.2B IS "YES" ELSE birds=2	NOMINAL
recrea	Respondent currently uses or has known others use the area for recreational purposes	recrea=1 IF Q7.8A OR Q7.8B IS "YES" ELSE recrea=2	NOMINAL

Table 15 - Mangrove environmental services variables, explanation, derivation, and type

Variable Name	Explanation	Derivation	Type
promat	Respondent has known about mangrove food production for small fish.	answer to Q14.1	NOMINAL
soilpro	Respondent has known about the protection mangrove provides to soil.	answer to Q14.2	NOMINAL
hurpro	Respondent has known about the protection mangrove provides during storms.	answer to Q14.3	NOMINAL
nesit	Respondent has known about the mangrove as a place for bird nesting and reproduction.	answer to Q14.4	NOMINAL
nurs	Respondent has known about mangrove roots as a fish nursery and a place for fish reproduction.	answer to Q14.5	NOMINAL
clewa	Respondent has known about mangrove role for water quality.	answer to Q14.6	NOMINAL

3.3.2 Regulatory Interventions

Hypothesis H2 section 2, was subdivided into three parts and were restated as is shown below:

$H2d_0$: No differences exist across residents from Chuburná, Chelem, Progreso and non-permanent residents for their attitudes towards long term resource use.

$H2e_0$: No difference exist across residents from Chuburná, Chelem, Progreso and non-permanent residents in their awareness regarding threats to mangrove wetland.

$H2f_0$: No difference exist across residents from Chuburná, Chelem, Progreso, and non-permanent residents to accept mangrove wetland regulation.

To test the acceptance of regulatory interventions, data were collected in three categories: 1) attitudes towards long terms resource use, 2) awareness towards potential threats that will increase conversion and pollution, and 3) acceptance towards regulation.

3.3.2.1 Attitudes Toward Long Term Resource Use

Information about people's feelings, beliefs and values related to resource conservation and protection of critical processes in coastal ecosystems, was collected with an agreement scale type questionnaire. The survey included questions to measure attitudes towards animals proposed by Kellert (1980): **moralistic**, **naturalistic**, **ecologistic**, **utilitarian**, and **negativistic**. In addition to these cultural values, we also included questions to test other values such as: **existence**, **option**, as well as for **intergenerational equity**.

3.3.2.2. Awareness Regarding Threats to Mangroves

From current human activities in the area, mangrove wetland can be affected by conversion, residuals from residential, commercial and industrial activities and rates of resource consumption. Selected categories and corresponding types are listed in Table 16.

Table 16 - Mangrove potential threats included in the survey

Category	Type
1. Land use	• Urban expansion • Port Infrastructure • Aquaculture Development • Roads expansion
2. Waste	• Domestic and Industrial solid wastes • Untreated domestic and industrial sewage • Industrial and Vessels/pipes oil spills
3. Resources consumption	• Trees • Fish • Hunting Birds and Mammals

3.3.2.3 Acceptance of Regulation

As mentioned in Chapter 2, many coastal areas are environmentally sensitive and some of them, such as the mangrove wetlands, are considered critical to rural communities and to biodiversity conservation. To explore to what extent regulation can be enforced and accepted by residents in the area, hypothetical regulation was proposed to **protect nursery areas** and **corridors** where commercial or recreational human activities would be banned. For current extractive activities such as fishing, hunting, and tree cutting the need for the following regulation was proposed: **permits**, **limiting or rotating the number of fishing grounds**, or the **establishment of seasons**. In urban activities, the following proposals were used: controlling new **home construction**, **roads and port infrastructure (marinas)** as well as regulation for **solid garbage disposal and sewage**.

3.3.2.4 Instrument Design for Long Term Resource Use

Attitudes Toward Resource Use

An initial list of 60 sentences were developed for section 3 of the questionnaire. The list was given to three judges (i.e., mangrove and reef experts) to see which questions clearly contribute or do not contribute to long term coastal resource use. After several discussions with the judges, 33 questions were removed. During the training period difficulties were observed in keeping respondent interest and respondents also had difficulties in understanding some of the questions. Therefore an additional 13 sentences were removed from the questionnaire. **Q11: We want you to rate the following sentences using the next options: Agree (3), neutral (2), Disagree (1), and (0) for avoiding the question**. The following sentences in Figure 12 were used:

1.	We have a moral obligation to protect the fish and the wildlife	( ) ( ) ( )
2.	It cause me satisfaction to see the wetland and its wildlife	( ) ( ) ( )
3.	Sewage discharged into the wetland affects the fish	( ) ( ) ( )
4.	Regardless of how much we exploit resources nature will always .... continue to provide enough for our needs	( ) ( ) ( )
5.	More wetland vegetation means more fish	( ) ( ) ( )
6.	We need to conserve the wetland to be studied	( ) ( ) ( )
7.	Wetlands only produce dangerous animals to people	( ) ( ) ( )
8.	Wetlands may not exist in the future. Therefore, I must exploit .... them as much as possible now.	( ) ( ) ( )
9.	Wetlands conservation is needed because may be in the future .... we will find valuable things in it	( ) ( ) ( )
10.	I do not have an obligation to conserve the wetlands for others	( ) ( ) ( )
11.	The reason that wetlands will exist in the future is sufficient .... important for me to participate in conservation.	( ) ( ) ( )
12.	Anything people do on their property will not create problems .... for others	( ) ( ) ( )
13.	I would sacrifice something to uphold the purpose of wetland conservation	( ) ( ) ( )
14.	Wetland meetings are a waste of time	( ) ( ) ( )

Figure 12 - Attitudes towards mangrove resource use format question

Land Use Regulation

Questions in section 4 of the questionnaire were developed to determine if residents were willing to accept more regulations for using the wetland and conservation. **Q12: Thinking about the area shown in PHOTO #1, would you like to tell us your answer for the next questions (Yes, Undecided, No)?** Figure 13 shows the format used in the questionnaire.

1. Are you willing to accept /enforce the law to control some .... ( ) ( ) ( )
   activities to protect land, vegetation, wildlife, and water in this area?
2. This law may demand more control on homes, roads, and boat .... ( ) ( ) ( )
   landing constructions. Is this acceptable?
3. This law may prohibit the use of wetlands for dumping. .... ( ) ( ) ( )
   Is this acceptable?
4. This law may prohibit the cutting of living trees. .... ( ) ( ) ( )
   Is this acceptable ?
5. This law may prohibit hunting during some seasons and ....( ) ( ) ( )
   require a hunting license. Is this acceptable?
6. This law may close fishing grounds, regulate fishing arts, ... ( ) ( ) ( )
   and require a permit . Is this acceptable?
7. This law may control the number of boats and trips. Is this acceptable ?......... ( ) ( ) ( )
8. Do you support the creation of protected areas where, construction, ... ( ) ( ) ( )
   hunting, and fishing would be completely banned?

Figure 13 - Land use regulation format question

Awareness of Current Menaces

Questions in section 5 included: 1) increasing developments that may get off part of the wetland, 2) waste management in the urban, commercial and industrial area, and 3) extraction of natural populations. Q13: **From the following list please tell us which ones you consider a current threat to mangrove wetlands (plants and animals).** Figure 14 shows the format used for this section in the questionnaire.

1.	Is it the actual size of the urban area of Chuburná, Chelem, and Progreso?	( )	( )
2.	Is it the number of port facilities?	( )	( )
3.	Is it the type of road construction ?	( )	( )
4	Is it solid garbage?	( )	( )
5.	Is it sewage ?	( )	( )
6.	Is it oil pipes and vessels leaks	( )	( )
7.	Is it the wood rate extraction ?	( )	( )
8.	Is it the commercial and subsistence fisheries	( )	( )
9.	Is it Hunting	( )	( )

Figure 14 - Awareness of current menaces to mangrove wetland format question

General Information

General information was collected from the respondents in section 7. Q15: **the birth date (mm/dd/yy)**, Q16: **sex (M=male/F=female)**, Q17: **marital status (married/not married)**, Q18: **job type**, Q19: **the number of years living in the area or using the area**, and Q20: **the number of years in school.**

Final Comments

At the end of the questionnaire, section 8, respondents were thanked for participating and offered the opportunity to make suggestions or comments about the interview. Q21: **We appreciate the time that you have set aside for this interview and I am happy to make a note of any of your suggestions related to this interview.**

3.3.2.5 Criteria for Rejecting of the Null Hypothesis H2d, H2e, and H2f

To test differences ***across*** residents, proportions of each of the variables per strata were calculated to test the null hypothesis of homogeneity (H2d, H2e, H2f: $p_1=p_2=p_3=p_4$). The test statistics is given by χ^2. The following tables, Table 17, 18, and 19 list the names, explanations, derivations and types of variables that were used for testing H2d for long term resource use, H2e to accept/enforce regulation, and H2f for awareness toward current mangrove wetland threats.

Table 17 - Long term resource use variables, explanation, derivation, and type.

Variable Name	Explanation	Derivation	Type
moral	Respondent believes we have a moral obligation to protect the wetland	response to Q11.1	NOMINAL
natura	Respondent experiences satisfaction when he is in contact with the wetland	response to Q11.2	NOMINAL
ecol1	Respondent accepts that sewage affect life in the wetlands	response to Q11.3	NOMINAL
ecol2	Respondent recognizes limits in nature	response to Q11.4	NOMINAL
ecol3	Respondent relates vegetation with animals.	response to Q11.5	NOMINAL
scien	Respondent accepts the need of conservation for mangroves be studied	response to Q11.6	NOMINAL
negat	Respondent believes that only dangerous creatures live in the wetland	response to Q11.7	NOMINAL
short	Respondent preference is for short time	response to Q11.8	NOMINAL
option	Respondent accepts conservation for mangroves because of their possible future uses	response to Q11.9	NOMINAL
equity	Respondent accepts his obligation to protect the mangroves for others	response to Q11.10	NOMINAL
exist	Respondent participates in conservation with the only reason mangroves will exist in the future	response to Q11.11	NOMINAL
extern	Respondent accepts that some actions can create negative externalities	response to Q11.12	NOMINAL
willi	Respondent is willing to sacrifice something for wetland conservation	response to Q11.13	NOMINAL
parti	Respondent say that participation in wetland conservation is not waste of time	response to Q11.14	NOMINAL

Table 18 - Acceptance/enforcement of regulation variables, explanation, derivation, and type.

Variable Name	Explanation	Derivation	Type
Igral	Respondent accepts regulation as a way to protect natural resources	response to Q12.1	NOMINAL
Icons	Respondent accepts regulation as a way to control urban development, roads, and boat landing areas	response to Q12.2	NOMINAL
Icont	Respondent accepts regulation as a way to regulate discharges in the wetland	response to Q12.3	NOMINAL
Iwood	Respondent accepts regulation for wood extraction	response to Q12.4	NOMINAL
Ifish	Respondent accepts regulation for fishing	response to Q12.5	NOMINAL
Ihunt	Respondent accepts regulation for hunting	response to Q12.6	NOMINAL
Ireserv	Respondent accepts regulation to maintain core areas where conversion and extractive activities would be banned.	response to Q12.8	NOMINAL

Table 19 - Awareness toward mangroves threats variables, explanation, derivation, and type

Variable Name	Explanation	Derivation	Type
urgro	Urban growth is currently a threat for the mangrove wetland	response to Q13.1	NOMINAL
porin	Port infrastructure is currently a threat for the mangrove wetland	response to Q13.2	NOMINAL
roads	The road network is currently a threat for the mangrove wetland	response to Q13.3	NOMINAL
garba	Garbage is currently a threat for the mangrove wetland	response to Q13.4	NOMINAL
trewa	Untreated sewage is currently a threat for the mangrove wetland	response to Q13.5	NOMINAL
oilspi	Oil spills are currently a threat for the mangrove wetland	response to Q13.6	NOMINAL
woode	Wood extraction is currently a threat for the mangrove wetland	response to Q13.7	NOMINAL
fishe	Fishing effort is currently a threat for the mangrove wetland	response to Q13.8	NOMINAL
hunte	Hunting is currently a threat for the mangrove wetland	response to Q13.9	NOMINAL

3.4 Sampling Design

3.4.1 Population

The target population was defined as all permanent and temporary residents in the coastal area of Yucatán from Chuburná to Progreso. Target population included all adult males and females (>18 years) living in the area from February 1996 to August of 1996. The target area was defined as a set of 5 locations: 1) residential homes in Chuburná, 2) residential homes in Chelem, 3) residential homes in Progreso, 4) vacation homes from Chuburná to Chelem

(Prochub a) and 5) vacation homes from Chelem to Yucalpetén, Progreso (Prochub b).

To delineate the spatial boundaries for the sampling frame, several pictures were generated using photographs and city maps. Vacation homes were all included in one non contiguous semi-homogenous stratum (A), and towns were divided in three semi-homogenous stratums (A, B and C) that run parallel to the coast. Coastal area segmentation was decided according to the spatial distribution of permanent residents and an appreciation of their socio-economic conditions. Residents in stripe A are integrated in neighborhoods with a better economic condition than those living in B and C. Stripe B characterizes all resident that live in the inner part of the towns where stores, schools, and in general services are located. Stripe C characterizes residents that live in difficult and poor conditions close to or inside the wetland. Figures 15, 16, 17, 18, and 19 shown these stripes and subdivisions created for the purpose of organizing interviewers and finding sampled elements.

The sampled population was drawn using a disproportional (each town with a different sampling distance) stratified (three stripes) systematic aligned (same street) sampling to determine the location of the respondents. A nonprobability sampling design was selected due to the absence of lists of residents and maps with large scales to identify single homes. Used design allowed a better access to residents, however the underlying problem is that generalization must be carefully made to other groups or areas. As recommended by Fraenkel (1993), in general a minimum of 30 samples must be collected per group. In this study and because limited funds, 28 samples were collected in Chuburná, 30 in Chelem, 37 in Progreso, and 45 in Prochub for a total of 139 interviews.

3.4.2 Data Collection

Seven interviewers (6 males and 1 female) received training for data collection at Centro de Investigaciones y Estudios Avanzados del IPN (CINVESTAV-IPN) en Mérida, Yucatán. They received information about the main survey objectives and procedures. During the sessions for training interviewers, they worked with two respondents with characteristics similar to people living in the studied area. During the training sessions and pilot study several inadequacies were detected and corrected in the questionnaire.

Samples were taken from each of the defined strata during February and March for permanent residents and during August 1996 for temporary residents. The interviewers were instructed to interview five people in their area at regular intervals. All interviews were conducted face-to-face to a person who identified themselves as one of the heads of the household, when this person was not at home, the interview was conducted with another adult. Residents who accepted the interview were informed that they were free to reject a question that they felt were inappropriate. They were also told that their answers would not be identified in any way.

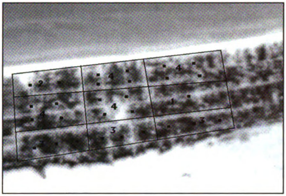


Figure 15 - Chuburná sample frame

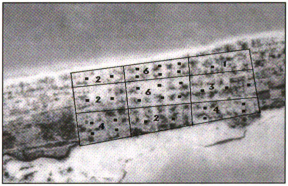


Figure 16 - Chelem sample frame

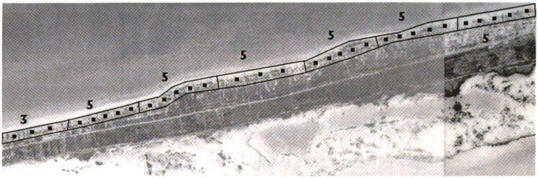


Figure 17 - Prochub sample frame "a"

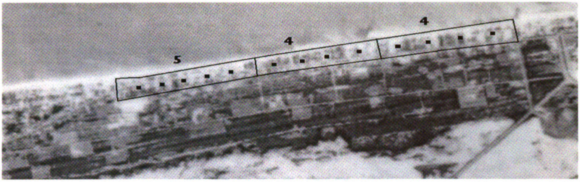


Figure 18 - Prochub sample frame "b"

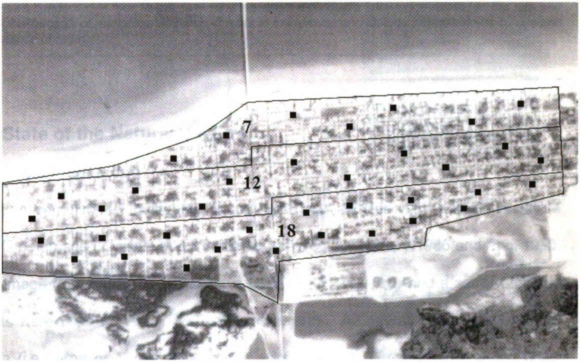


Figure 19 - Progreso sample frame

Chapter 4

RESULTS

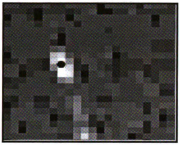
This chapter provides the results from the change detection and proximity analysis conducted in the coastal areas of the Yucatán, México to identify environmental changes and their spatial relationships with cultural features: 1) roads and 2) urban centers. It also presents the results from interviews conducted in four towns assessing residents individual's knowledge related to the use and ecological benefits of mangrove wetlands, threats to mangroves and attitude towards resource use and acceptance of regulation.

4.1 State of the Natural System.

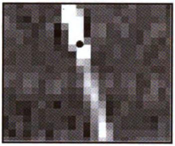
4.1.1 Data Preparation

A coregistered multi-raster project data was created with 2 MSS images, 4 bands per image (2 visible and 2 infrared) acquired in February 1986 and April 1990. The image from February 1986 was selected as a base map and a set of 6 control points were used for April 1990 image coregistry. An overall RMS error of 0.706 pixels (i.e., area of 1 pixel = 4424 m^2) was obtained. Residuals for a first order polynomial and nearest neighbor selection for selected points are: 1) 1.009 pixels for the old marine terminal in Progreso, 2) 0.8193 pixels Chicxulub saltpond, 3) 0.2084 pixels Chuburná main square plaza, 4) 0.4988 pixels road intersection, 5) 0.6588 pixels Chelem salt pond, and 6) 0.7618 pixels Chicxulub main square.

Control Point No. 1

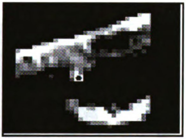


Progreso Old Marine Terminal
X = 282.5, Y = 227 February 1986
N 2 358 065 W 222 741

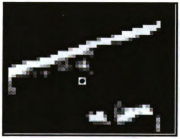


Progreso Old Marine Terminal
X = 285, Y = 227 April 1990

Control Point No.2

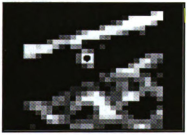


Chicxulub Salt Pond
X = 427, Y = 228 February 1986



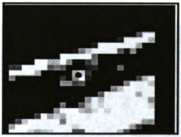
Chicxulub Salt Pond
X = 428, Y = 228 April 1990

Control Point No.3



Chuburna Main Square Plaza
X = 29, Y = 87 February 1986

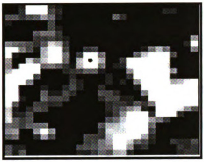
N 2 352 655 W 207 734



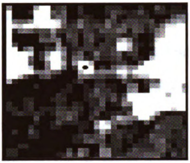
Chuburna Main Square Plaza
X = 30, Y = 88 April 1990

Figure 20 - Control point geographical positions for image coregistry.

Control Point No. 4

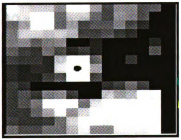


Road Intersection
X = 337 , Y = 45.5 February 1986
N 2 347 331 W 224 116

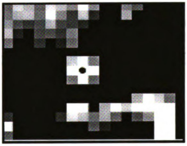


Road Intersection
X = 336.5, Y = 44.5 April 1990

Control Point No.5

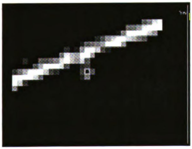


Chelem Salt Pond
X = 34, Y = 45.5 February 1986



Chelem Salt Pond
X = 33.5, Y = 46.5 April 1990

Control Point No.6



Chicxulub Main Square Plaza
X = 394.4, Y = 225.5 February 1986
N 2 356 916 W 229 522

Chicxulub Main Square Plaza
X = 395.5, Y = 224.5 April 1990

Figure 20 - (Cont'd).

Six subimages indicating the geographic positions of these control points in the UTM coordinate system and their (x,y) coordinates can be found in Figure 20.

After coregistry, the set of images acquired in February 1986 and April 1990 was georeferenced using six ground control points. The correspondence file was created with a total of six points, three points selected from those used for coregistry (*i.e.*, point 3, 4 and 6) and three additional points at which geographical positions were easily recorded. The geographical position of visited points was recorded in the field with a global positioning system (GPS) calibrated for the area. Residuals for linear geometric transformation used in this procedure are shown in Table 20 and an overall RMS = 0.839. A UTM coordinate system was overlaid on MSS images for the study area with coordinates from 206 000 E to 230 000 E and from 2 348 000 N to 2 360 000 N (Figure 21).

Table 20 - Summary of geometric transformation to UTM system for both dates based on 6 control points and linear polynomial

Num	x	y	Easting (new x)	Northing (new y)	Residual
1	258.01	304.5	222741	2362815	0.309
2	336.47	45.5	224512	2347331	1.031
3	158.79	138.0	215448	2354397	1.159
4	394.06	224.0	229522	2356916	0.470
5	29.91	87.0	207734	2352655	0.716
6	339.37	32.5	224526	2346679	0.993

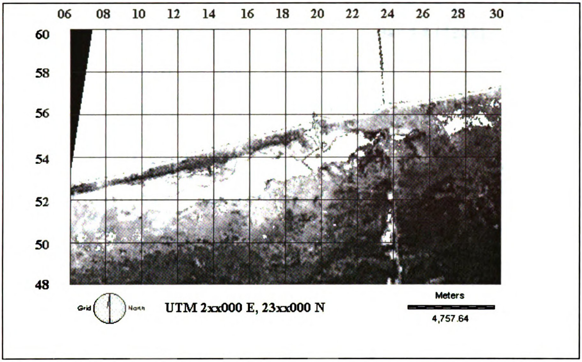
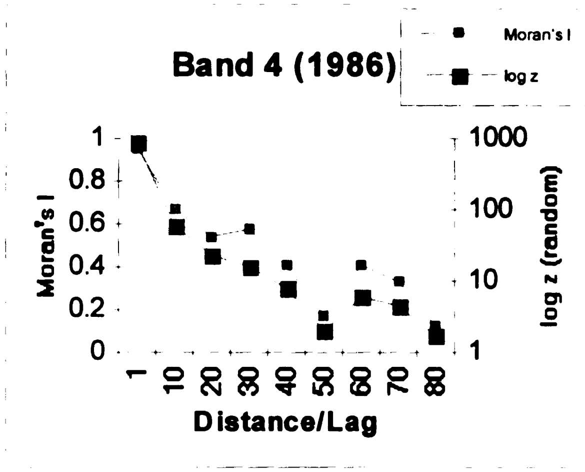


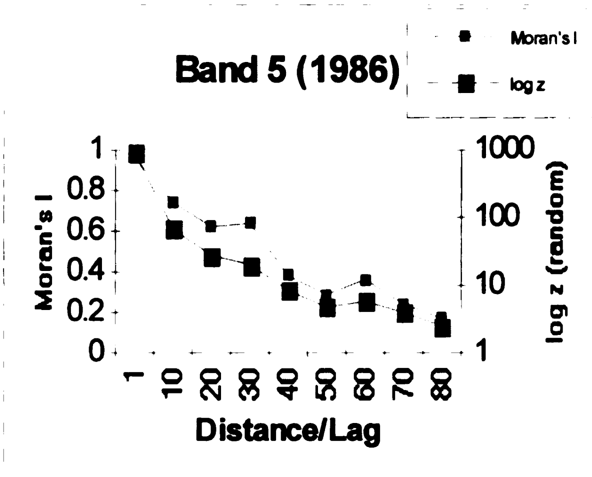
Figure 21 - UTM grid coordinate system for MSS images in the study area

Moran's I index of autocorrelation was calculated for all bands of the independent variable X (February 1986) bands 4, 5, 6 and 7 at several distances or lags: 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, and 110. Results from these calculations, for bands 4,5 and 7, indicated that suitable lags to have non autocorrelated samples occurred at distances of: 1) 80 for band 4, z random, z<2 and an index value of 0.1213, 2) 80 for band 5, z random, z<2.5, and an index value of 0.1708 and 3) 100 for band 7, z random, z<2.7 and an index value of 0.3297. Correlograms calculated from data of the independent variable are shown in Figure 22.

	Band 4	
Lag	Moran's I	z(random)
1	0.9536	868
10	0.6711	60
20	0.5417	23
30	0.5769	16
40	0.4043	8
50	0.1735	2
60	0.4084	6
70	0.3304	4.5
80	0.1213	1.71



	Band 5	
Lag	Moran's I	z(random)
1	0.9644	907
10	0.7427	68
20	0.6218	27.51
30	0.6409	20.13
40	0.3807	8.5
50	0.287	4.8
60	0.3617	5.74
70	0.2396	3.99
80	0.1708	2.49



	Band 7	
Lag	Moran's I	z (random)
1	0.976	911
10	0.7866	73
20	0.6749	30
30	0.619	18.5
40	0.5877	12.8
50	0.4108	7.06
60	0.412	6.45
70	0.5458	7.3
80	0.4339	5.06
90	0.5676	5.16
100	0.3297	2.75

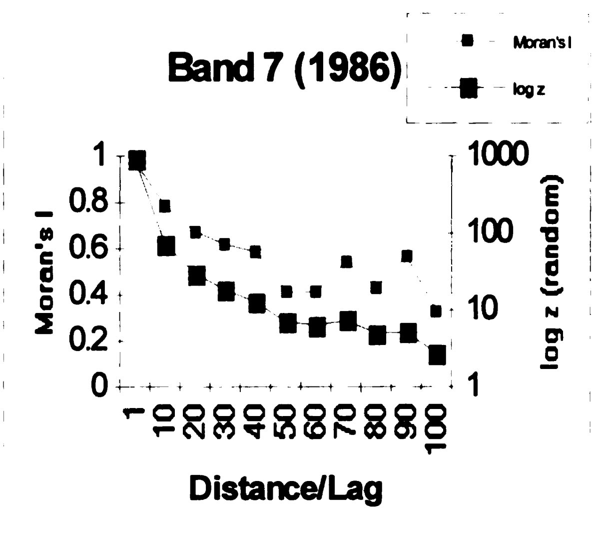


Figure 22 - Correlograms from independent variable (MSS, Feb. 1986)

With reference to previous correlograms, a distance lag of 87 pixels was used in an unaligned random sample design to select samples for a linear regression. Regressed 19 pair values per band produced the following set of equations for radiometrically corrected images (Table 21).

Table 21 - Equations for radiometric corrections of bands 4,5, 6, and 7

Regression line	r	t	n	df
y_4=-1.20+1.3x_4	0.86	6.86	19	17
y_5=-1.59+1.3x_5	0.90	8.72	19	17
y_6=1.60+1.23x_6	0.90	8.52	19	17
y_7=0.82+1.46x_7	0.94	11.65	19	17

4.1.2 Change Detection

Resulting values from the change vector analysis had a Gaussian distribution. Thresholds were selected with the use of the cumulative frequency distribution at 80%, 90%, 95%, and 99% above the lower end point. Corresponding radiometric distances of 13, 20, 31, and 56 of these previous percentages resulted with potential thresholds to decide change between the two dates. These radiometric values were selected to create 4 binary masks to indicate potential sites of change (Figure 23). The threshold value of 20 for a 90% cumulative frequency distribution was selected for potential land cover changes detected by vector analysis (10% of the largest change values were selected).

From the vegetation index by Nelson (1983) and its cumulative frequency distribution four ranges -0.35 to 0.45 , -0.45 to 0.74, -0.55 to 0.84 and -0.75 to 1.34 at 75%, 80%, 85%, and 90% respectively were selected to create 4 binary masks to indicate potential changes (Figure 24). The interval from -0.55 to 0.84 at 85% was selected for potential land cover changes detected with vegetation index. Looking at the work by Fung and LeDrew (1988), threshold values selected for this study may underestimate change since the number of s.d. was greater than 1. These two indices were combined with the OR operation to produce a binary mask for 1986-1990 total potential change (Figure 25). Clouds and oceanic waters were masked out in the right-lower corner and upper parts of the image respectively .

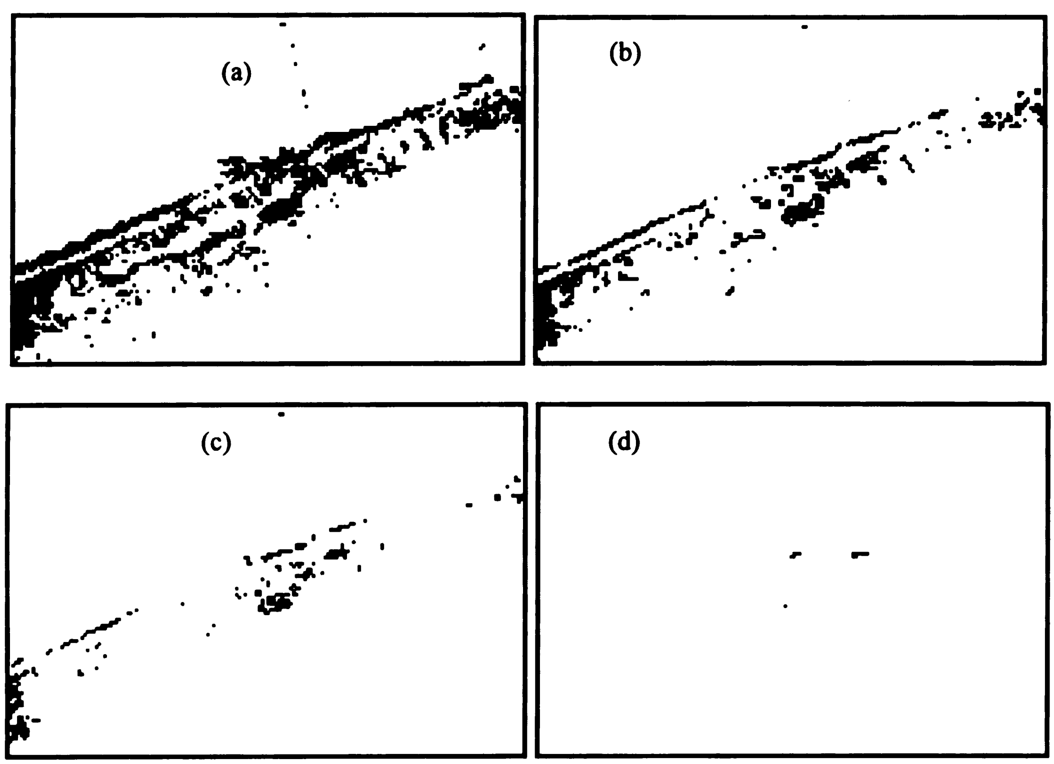


Figure 23 - Change binary masks for change vector analysis: a) distance of 13 for 81%, b) distance of 20 for 90%, c) distance of 31 for 95%, and d) distance of 56 for 99%

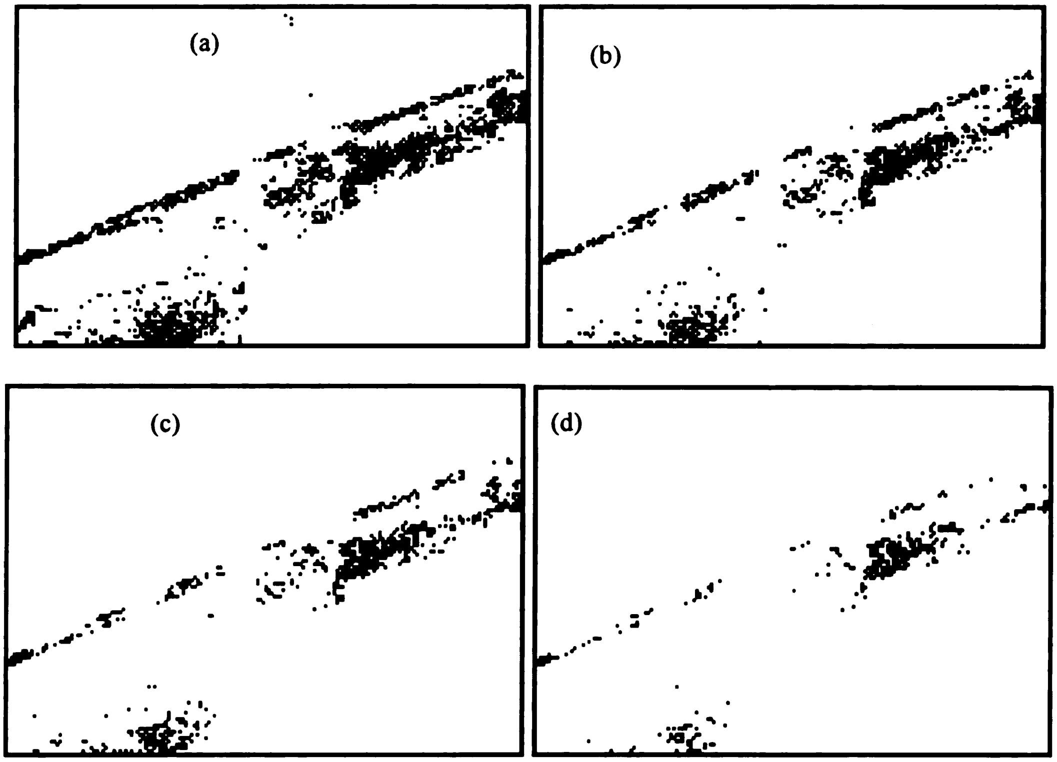


Figure 24 - Change binary masks for vegetation index: a) from -.35 to .45 for 0 at 75%, b) from -.45 to .74 for 0 at 80%, c) from -.55 to .84 for 0 at 85%, and d) from -.75 to 1.34 for 0 at 90%

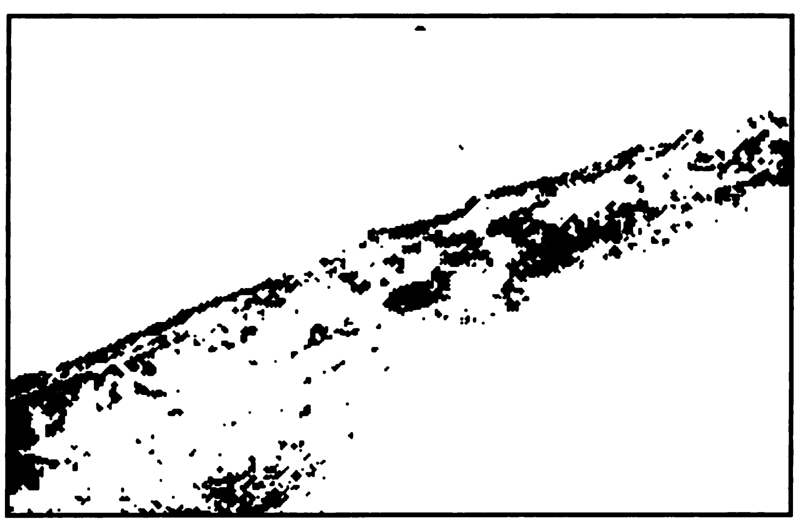


Figure 25 - Total radiometric changes: Change vector at 90% confidence interval (OR) vegetation index at 85% confidence interval

For a supervised classification, spectral signatures of training sites for developed land (dl), evergreen (eg), unconsolidated wet soil (us1), unconsolidated dry soil (us2), deciduous (de), and dune vegetation (dv) are shown in Table 22. Samples of each category were selected using photographs, false color images, and site inspections with the use of a GPS.

Table 22 - Spectral signatures of coastal classes: 1) developed land (dl), 2)evergreen (eg), 3) unconsolidated wet soil (us1), 4) unconsolidated dry soil (us2), 5) deciduous (de) and 6) dune vegetation (dv)

		Band 4			Band 5			Band 6			Band 7		
N	Name	min	max	mean	min	max	mean	min	max	mean	min	max	mean
1	dl	44	58	51.4	52	73	63.4	62	82	71.6	58	84	68.9
2	eg	21	33	25.6	18	32	25.3	37	48	42.2	42	53	46.7
3	us1	26	46	36	32	58	45.1	22	52	37.4	6	22	12.7
4	us2	59	84	70.6	67	112	87.9	80	102	91.1	65	95	80.1
5	de	20	27	22.1	14	22	17.4	54	64	58.4	64	71	67.1
6	dv	27	37	31.7	27	41	33.1	55	70	62	62	73	67.4

Land cover classes that resulted from a supervised classification algorithm (minimal distance/ normalized s.d./infinite) were reclassified to collapse and solve the confusion between classes. Classes were collapsed using the following criteria: The image was segmented in two parts: 1) dunes, and 2) wetland and upland. Dunes were reclassified as follows: a) **dl = dl or us1**, this means that beaches were included as developed land, b) **dv = dv or eg or de**, this means that all types of vegetation on the dunes were classified as dune vegetation. Wetlands and uplands were reclassified as follows: a) **us1 = us1 or dl**, incorrect classification of unconsolidated soil as developed land was corrected, **eg = eg or dv**, vegetation that was classified as dune vegetation in the wetland was included as ever green. Finally, wet unconsolidated soil (**us1**) was collapsed with dry unconsolidated soil (**us2**). Results of the classification process and training stage confusion matrices for C-CAP coastal classes inside the potential areas of change are shown in Figures 26 and 27 and error matrices and the Kappa coefficient of agreement in Tables 23 and 24.

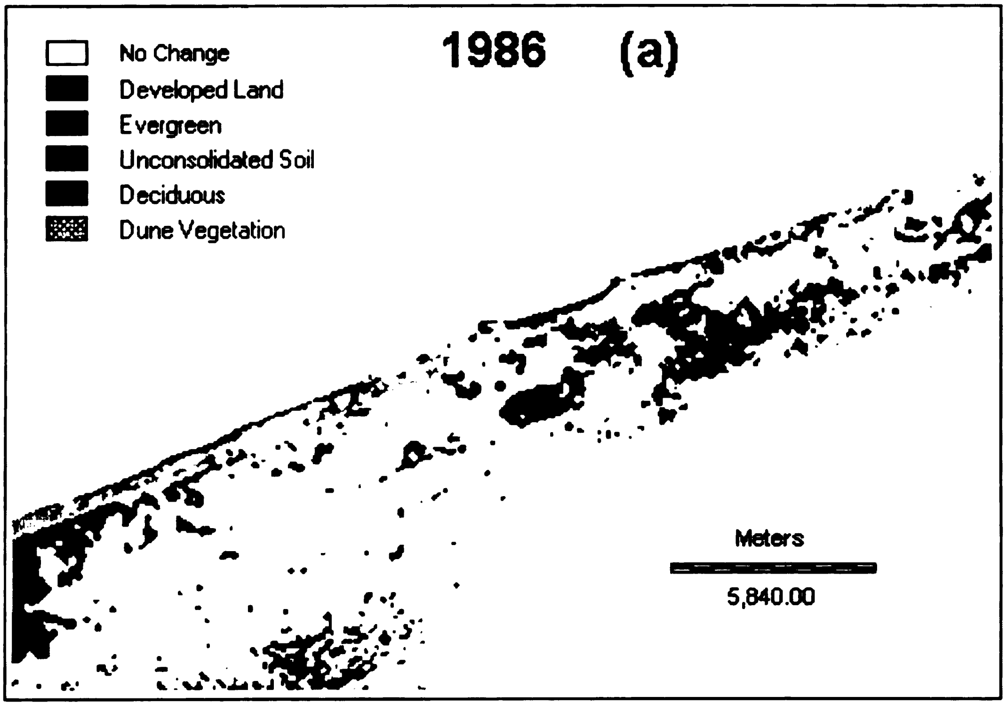


Figure 26 - Classification of changed areas for February 1986 (date 1)

Table 23 - Training stage confusion matrix and Khat output statistics for February 1986 image

Training stage confusion matrix

	ACTUAL CLASS				
MAP CLASS	1	2	3	4	5
1	349	0	0	0	30
2	0	254	5	9	0
3	0	4	1083	0	0
4	0	0	0	58	0
5	28	0	0	0	185

PCC = 96.209476
Khat = 0.940838 +/- 0.012829
Individual Class Accuracy

Class	User's (PCC and Kappa)		Producer's (PCC and Kappa)	
1	92.1,	0.903 +/- 0.044,	92.6	0.908 +/- 0.044
2	94.8,	0.940 +/- 0.043,	98.4	0.982 +/- 0.045
3	99.6,	0.992 +/- 0.044,	99.5	0.990 +/- 0.044
4	100.0,	1.000 +/- 0.047,	86.6	0.862 +/- 0.041
5	86.9,	0.853 +/- 0.044,	86.0	0.844 +/- 0.044

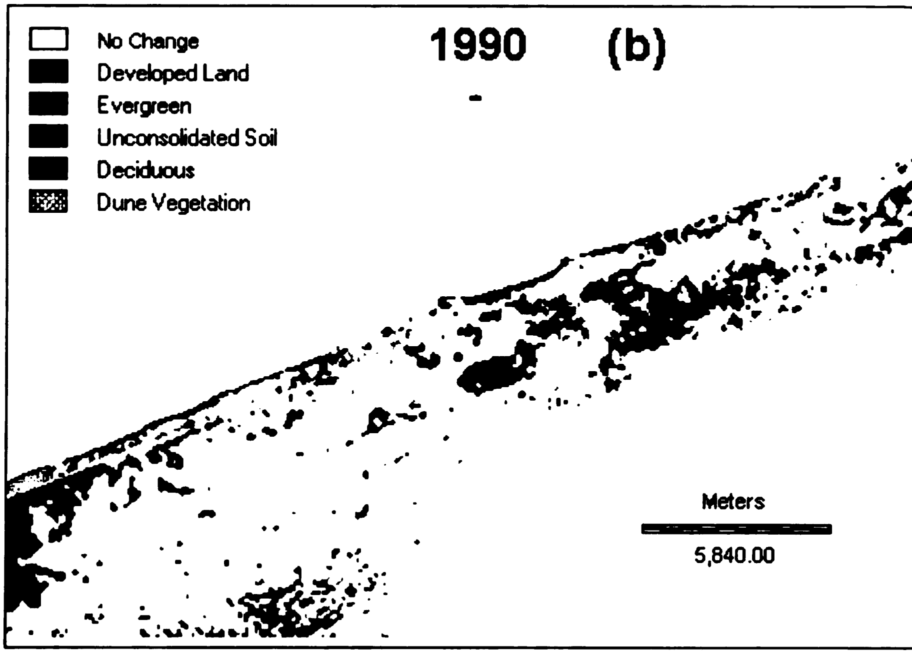


Figure 27 - Classification of changed areas for April 1990 (date 2)

Table 24 - Training stage confusion matrix and Khat output statistics for April 1990 image

Training stage confusion matrix

MAP CLASS	ACTUAL CLASS 1	2	3	4	5
1	377	0	5	0	31
2	0	248	6	32	0
3	0	8	1077	0	0
4	0	2	0	35	0
5	0	0	0	0	184

PCC = 95.810474
Khat = 0.934416 +/- 0.013463
Individual Class Accuracy

Class	User's (PCC and Kappa)		Producer's (PCC and Kappa)	
1	91.3,	0.893 +/- 0.041,	100.0	1.000 +/- 0.046
2	86.7,	0.848 +/- 0.041,	96.1	0.955 +/- 0.046
3	99.3,	0.984 +/- 0.044,	99.0	0.978 +/- 0.044
4	94.6,	0.944 +/- 0.059,	52.2	0.513 +/- 0.032
5	100.0,	1.000 +/- 0.048,	85.6	0.841 +/- 0.040

4.1.3 Coastal Land-Cover Changes Hypothesis H1

Quantitative measurements of aerial changes by land-cover class for the studied area are shown in a "from-to" matrix (Table 25). Columns represent values from the 1986 total classes "changed_to", numbers along the diagonal indicate the area that did not change, and row values indicated 1990 total classes "came_from". Marginal values in the matrix represent the total area in hectares for classes.

Table 25 - "From-To" matrix for coastal changes from 1986 to 1990

			1986	Class				
	Class	dl	eg	us	de	dv	Total	Difference
	dl	500.35	5.75	181.83	0	269.86	957.79	429.12
1990	eg	0	1012.21	48.22	192.44	1.77	1254.64	-137.15
Class	us	19.91	345.52	1747.48	12.39	3.53	2128.83	140.68
	de	0	27.43	2.21	98.21	0	127.85	-175.19
	dv	8.41	0.88	8.41	0	190.67	208.37	-257.46
	Total	528.67	1391.79	1988.15	303.04	465.83	4677.48	

Developed land (dl). Total developed land in 1986 accounted for 528.67 ha. Large sections of developed land (as expected) 94.64%, remained as part of the total developed land in 1990. Small parts of developed land went to 5.36 % of unconsolidated and dune vegetation. Conversion to developed land mainly came from 5.75 ha of evergreen, **181.83 ha unconsolidated,** and **269.86 ha dunes,** to have in March 1990, a total of 957.79 ha of developed land. An **increment of 429.12 ha (82.5 %)** resulted for this land cover type.

Evergreen (eg). Total evergreen areas in 1986 accounted for 1391.79 ha. Part of this total, 72.7% remained as part of the evergreen in 1990. The rest, 27.3 % mainly changed to the following classes: developed land by 5.75 ha, unconsolidated by 345.52 ha, and deciduous by 27.43 ha. Contributions came from unconsolidated wet by 48.22 ha, and **deciduous with 192.44** to end 1990 with a total of 1254.64 of the evergreen category. A **reduction of (9.8 %)** resulted.

Unconsolidated (us). Total unconsolidated soil in 1986 accounted for 1,988.15 ha and 87.89 % of this total remained as part of the total unconsolidated soil in 1990. The rest, 12.10 % mainly changed to developed land by 181.83 ha, evergreen by 48.22. Contributions to 1990 unconsolidated came from 345.52 evergreen to have a total of 2128 ha in 1990. An **increment of 140.68 ha (7.07 %)** resulted. .

Deciduous (de). Total deciduous in 1986 accounted for 303.04 ha. Only 32.4 % of this total remained as part of the total deciduous in 1990. The rest, 67.6 % mainly changed to evergreen in 192.44 ha, and with minor changes went to unconsolidated soil by 12.39. Contributions came from 27.43 ha of evergreen, and 2.21 ha of unconsolidated soil. 1990 finished with a total of 127.85 of deciduous vegetation. A **reduction of 175.19 ha (57.81 %)** was observed.

Dune vegetation (dv). Total dune vegetation in 1986 accounted for 465.85 ha. Only 40.9 % of the total remained as part of the total dune vegetation in 1990. A greater proportion of the total change (59.1 %), went to 269.86 ha of developed land, and a minor proportion changed to 1,77 evergreen, and 3.53 unconsilidated. Contributions to 1990 dune vegetation came from 8.4 ha developed land, and

8.41 ha unconsolidated soil. Resulting in a total of 208.37 ha of dune vegetation. A **reduction of 257.04 ha (55.17 %)** resulted.

Conditional and overall Kappa coefficient of agreement (k) computed between these two images for changed area is shown in Table 26. A coefficient value k=0 indicates obtained agreement equals chance agreement. Positive values occur from greater than chance agreement and negative values from less than chance agreement.

Table 26 - Conditional and overall Kappa coefficient of agreement (k) for land cover changes

Class	KIA when CAM90 as reference	KIA when CAM86 as reference
dl	0.4573	0.9330
eg	0.7251	0.6280
us	0.6890	0.7780
de	0.7521	0.3050
dv	0.9035	0.3818
Overall Kappa	0.6527 ± .011180	

Proportions between 1986 and 1990 are shown in Table 27, they were used for the Z test statistic $Z= (p_1-p_2)/ \sqrt{(p_2*(p_2 -1)/n)}$. Selected rejection region R: abs(Z) $\geq$ 1.96 correspond to α=.05 (see table 27). Results for significant difference between proportions indicated that individual cover classes were rejected for Ho: p1 = p2 (see Table 27). The overall hypothesis H1 was rejected as evergreen and dune vegetation had a statistically significant different proportions between 1986 and 1990.

Table 27 - Significant change for coastal land cover proportions

Class	1986 # pixels	1990 # pixels	1986 proportion	1990 proportion	abs(z)	Ho: p1=p2 abs(z) ≥ 1.96 α=.05
dl	1195	2165	0.11	0.20	30.3	rejected
eg	3146	2836	0.30	0.27	6.6	rejected
us	4494	4812	0.43	0.46	6.3	rejected
de	685	289	0.06	0.03	15.6	rejected
dv	1053	471	0.10	0.04	18.9	rejected
Total	10573	10573	1	1		

Four selected areas in the boundaries of Chuburná, Chelem, Progreso and Prochub were defined using four mask polygons 1, 2, 3, 4a and 4b indicated in Figure 28. Inside these polygons, "from-to" changes were selected using the results of the procedure described above. "From-to" matrices are shown in Tables 29, 30, 31 and 32. A summary of the differences between dates are in Table 28.

Table 28 - Differences between February 1986 and April 1990 per class

Area	Developed Land	Evergreen	Unconsolidated soil	Dune Vegetation
Chuburná	27.43	0.88	-7.96	-17.70
Chelem	56.63	-4.87	-6.19	-45.12
Progreso	150.42	-148.65	50.88	-23.89
Prochub	44.24	-0.44	-7.97	-35.83

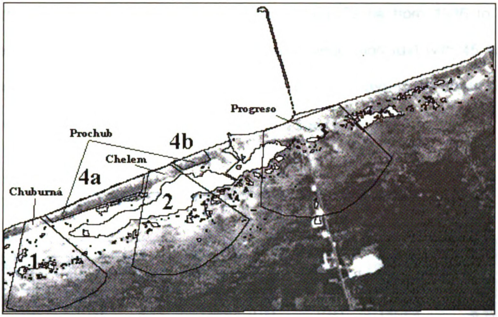


Figure 28 - Selected areas for change detection: Chuburná, 2) Chelem, 3) Progreso and 4) Prochub

Chuburná (Area 1). Total new developed land become 27 ha from 1986 to 1990. Conversion to developed land affected coastal dunes by 17 ha and unconsolidated soil by 10 ha. Mangroves, included in the evergreen (eg), in this area did not indicate major changes between these two dates (see Table 29).

Table 29 - Area 1, Chuburná "from-to" matrix 1986 - 1990

			1990				
1986	**dl**	**eg**	**us**	**de**	**dv**	**Total**	**Difference**
dl	23.89	0.00	10.62	0.00	17.70	52.20	27.43
eg	0.00	16.81	1.33	2.65	0.00	20.79	0.88
us	0.88	3.10	396.83	0.00	0.00	400.81	-7.96
de	0.00	0.00	0.00	0.00	0.00	0.00	-2.65
dv	0.00	0.00	0.00	0.00	2.65	2.65	-17.70
Total	24.77	19.91	408.78	2.65	20.35	476.46	

Chelem (Area 2). Total developed land (dl) grew 56 ha from 1986 to 1990. Conversion to developed land came from dune vegetation (dv) with 45 ha and unconsolidated soil (us) by 11 ha. Evergreen vegetation (eg) had a total loss of 4 ha to contribute increment unconsolidated soil (us) (Table 30).

Table 30 - Area 2, Chelem "from-to" matrix 1986 - 1990

			1990				
1986	**dl**	**eg**	**us**	**de**	**dv**	**Total**	**Difference**
dl	29.20	0.00	11.06	0.00	45.57	85.83	56.63
eg	0.00	14.16	3.54	0.88	0.00	18.58	-4.87
us	0.00	8.85	126.97	0.00	0.00	135.82	-6.19
de	0.00	0.44	0.00	0.44	0.00	0.88	-0.44
dv	0.00	0.00	0.44	0.00	10.18	10.62	-45.12
Total	29.20	23.45	142.01	1.33	55.74	251.73	

Progreso (Area 3). Total developed land (dl) growth 150 ha from 1986 to 1990. Conversion to developed land came from dune vegetation (dv) with 27 ha and unconsolidated soil (us) with 117 ha. Evergreen vegetation (eg) had a total loss of 148 ha to increment unconsolidated soil (us) (Table 31).

Table 31 - Area 3, Progreso "from-to" matrix 1986 - 1990

			1990				
1986	**dl**	**eg**	**us**	**de**	**dv**	**Total**	**Difference**
dl	88.48	5.31	117.68	0.00	27.43	238.90	150.42
eg	0.00	439.30	35.83	21.24	0.00	496.37	-148.65
us	0.00	198.64	285.35	10.62	0.00	494.60	50.88
de	0.00	1.77	1.33	0.44	0.00	3.54	-28.76
dv	0.00	0.00	3.54	0.00	11.50	15.04	-23.89
Total	88.48	645.02	443.73	32.30	38.93	1248.45	

Prochub (Areas 4a and 4b). Total developed land (dl) growth 44 ha from 1986 to 1990. Conversion to developed land came from dune vegetation (dv) with 45 ha and unconsolidated soil (us) with 6 ha. Evergreen vegetation (eg) did not showed a total cover change (Table 32).

Table 32 - Area 4, Prochub "from-to" matrix 1986 - 1990

			1990				
1986	**dl**	**eg**	**us**	**de**	**dv**	**Total**	**Difference**
dl	107.50	0.00	6.19	0.00	45.12	158.82	44.24
eg	0.00	0.00	0.00	0.00	0.00	0.00	-0.44
us	0.00	0.00	0.00	0.00	0.00	0.00	-7.96
de	0.00	0.00	0.00	0.00	0.00	0.00	0.00
dv	7.08	0.44	1.77	0.00	60.17	69.46	-35.83
Total	114.58	0.44	7.96	0.00	105.29	228.28	

4.1.4 Environmental Changes and Development

The following results were obtained when proximity maps, based on the distances to the road system and selected towns, were overlaid on coastal land cover changes. Distances to roads, selected at intervals of approximately 180 m (3 pixels of 60 m) and the total land cover change area are shown in Figure 29. The total number of pixels per interval are shown in Figure 30 and shows the shape of the relationship between distance to road and change. Distance to roads were overlaid on new developed land, dune vegetation losses, evergreen vegetation losses and uncosolidated soil losses.

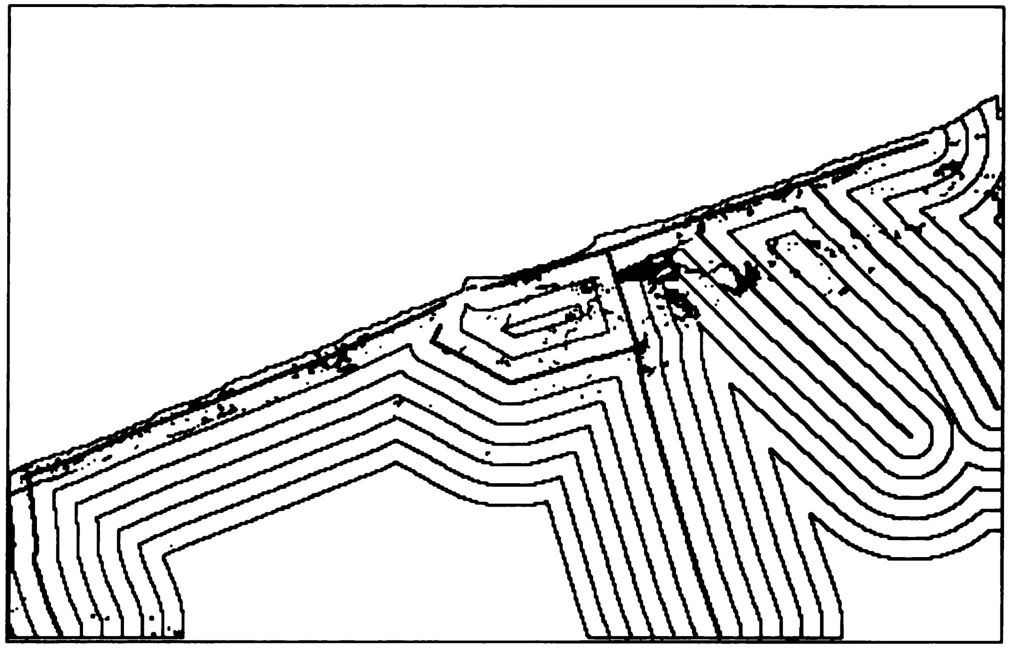


Figure 29 - Total land cover changes and road proximity map

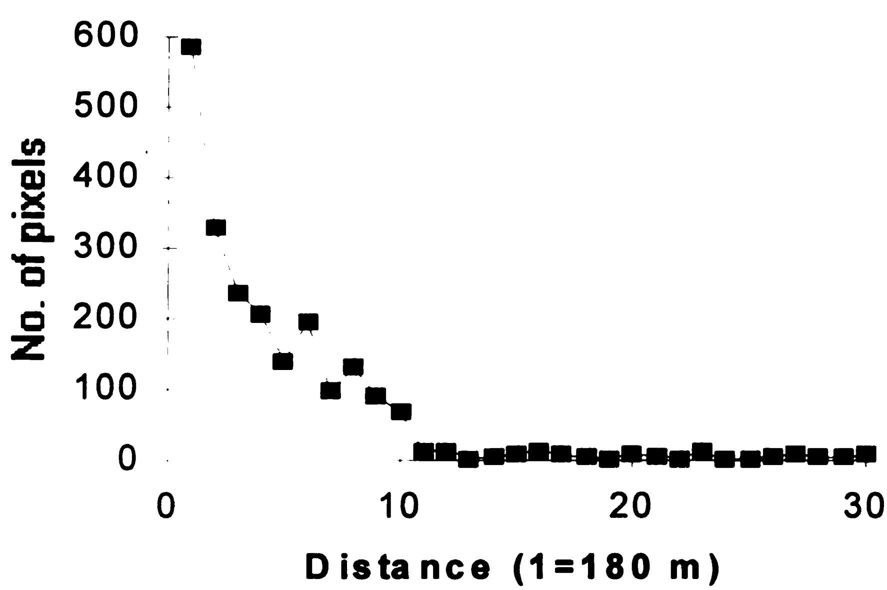


Figure 30 - Relationship between road distances and total land-cover change

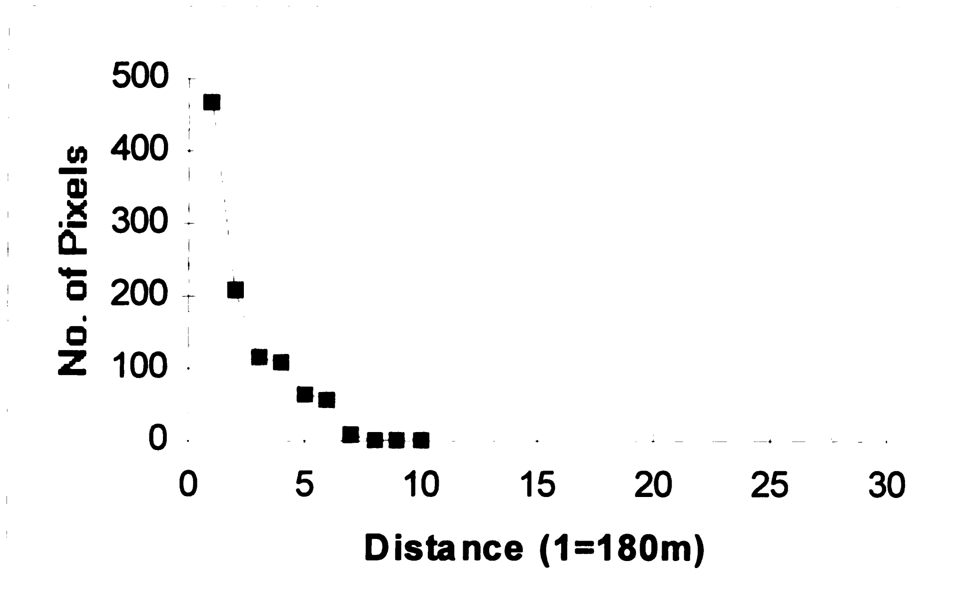


Figure 31 - Total new developed land and road proximity map

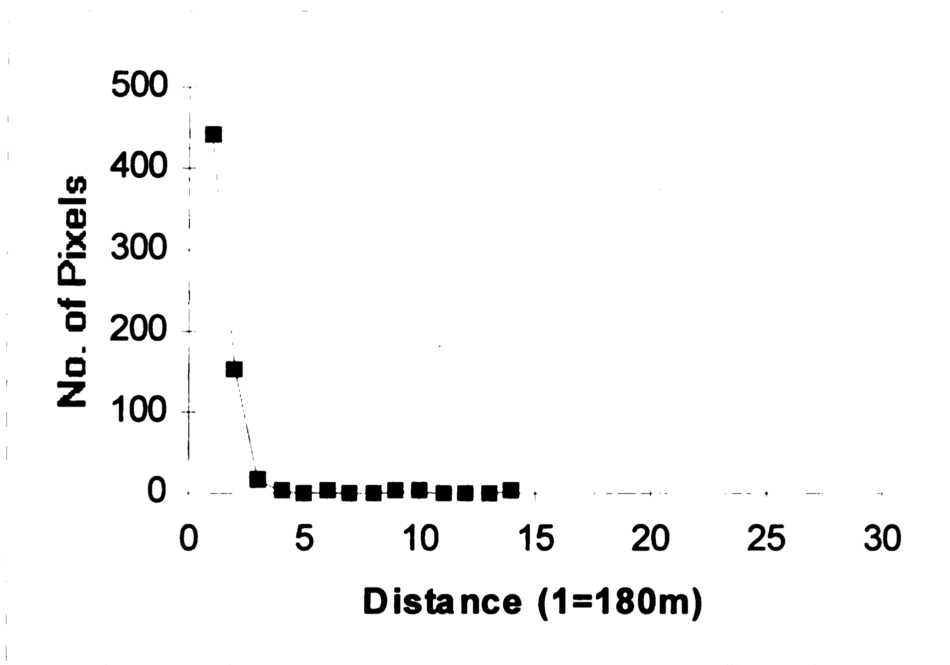


Figure 32 - Total dune vegetation losses and road proximity map

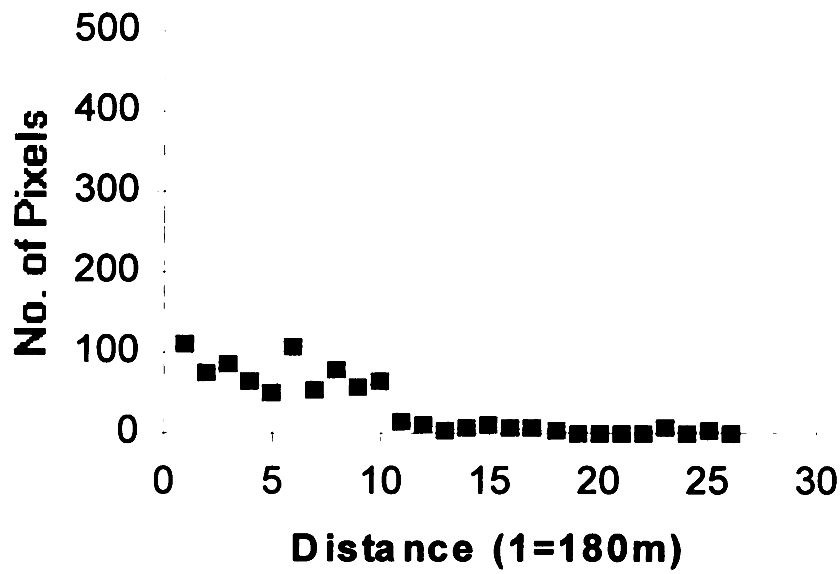


Figure 33 - Total green vegetation losses and road proximity map

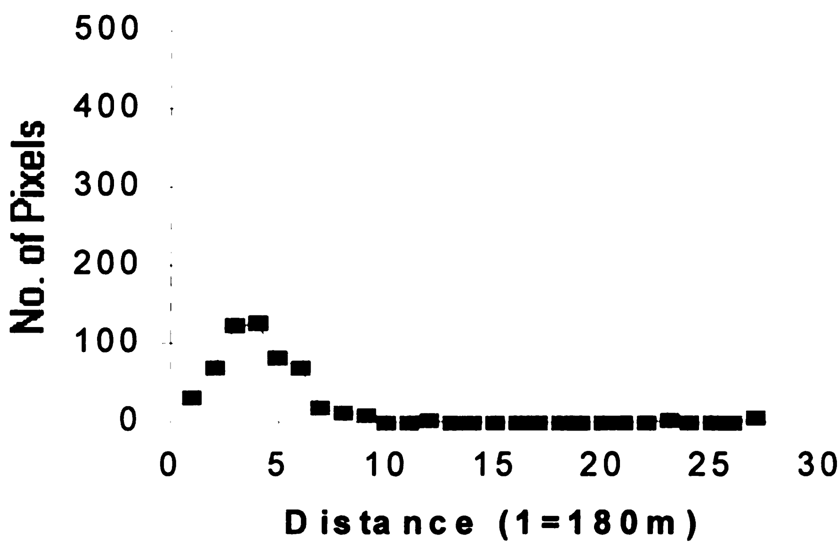


Figure 34 - Total unconsolidated soil losses and road proximity map

Similarly to the road proximity map, a town proximity map was created for Chuburná, Chelem and Progreso with Intervals of 180 m (Figure 35) according the polygons for these areas described in Figure 28. Land cover changes per class at selected lags (1 lag = 3 pixels or 180 m) for new developed land (ndl), dune vegetation losses (dvl), evergreen losses (egl) and unconsolidated soil losses(usl) are shown in Figure 36. Plots in the columns of Figure 36 indicate changes per class and the rows indicate the towns. In these plots, "x" axis indicates lag numbers and "y" axis indicates the number of pixels with change.

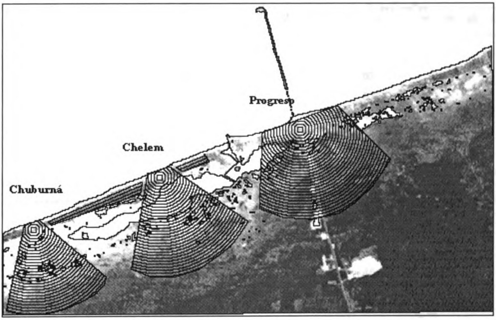


Figure 35 - Town proximity distances to selected areas in Chuburná, Chelem and Progreso

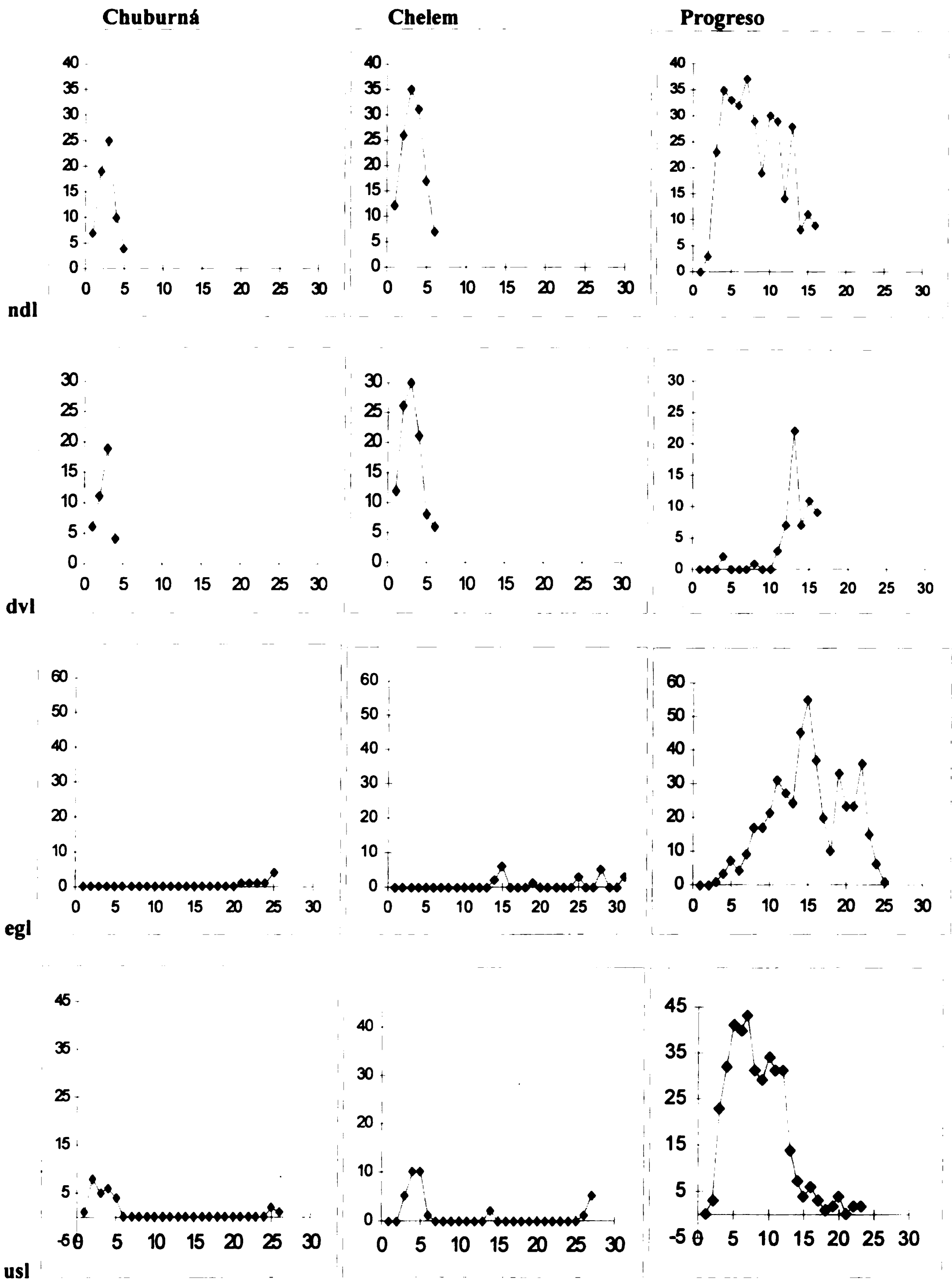


Figure 36 - Changes at different lags for new developed land (ndl), dune vegetation losses (dvl), evergreen losses (egl), and unconsolidated soil losses (usl) for Chuburná, Chelem and Progreso (labels: x=lags, 1 lag = 180 m, y=Pixels)

4.2 State of the Social System

Results from the survey conducted with permanent residents of Chuburná, Chelem, Progreso and non-permanent residents (Prochub) in the coastal areas of the Yucatán Peninsula are presented.

4.2.1 General Information

The study area in the Yucatán Peninsula included: Chuburná, Chelem, Progreso, and Prochub. These towns are located in the north west part of the State of Yucatán. Results from age (**age**), sex (**sex**), marital status (**marit**), years of residence in the area (**resti**) and educational level (**school**) of residents from Chuburná, Chelem, Progreso and Prochub, as well as from the total sample are summarized in Table 33 and Figure 37.

Table 33 - General information for variables: age, sex, marital status, years of resident, and schooling

Place	Average age n=104	Males % n=137	Females % n=137	Married % n=137	Single % n=137	Average years of residence n=133	Average educational level n=126
Chuburná	41.85	18 13.14%	10 7.30%	25 18.25%	3 2.19%	30.53	7.03
Chelem	48.30	19 13.87%	10 7.30%	23 16.79%	7 5.11%	29.26	5.03
Progreso	37.17	16 11.68%	21 15.33%	25 18.25%	10 7.30%	28.97	8.37
Prochub	37.20	21 15.33%	22 16.06%	36 26.28%	8 5.84%	17.66	14.05
Totals	40.89	74 54.01%	63 45.99%	109 79.56%	28 20.44%	26.05	8.96
F	2.49						
p	.064						

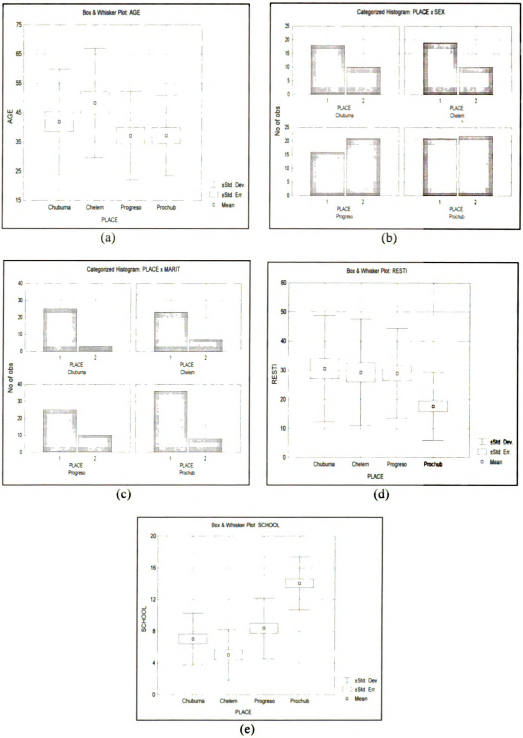


Figure 37 - General information: a) age, b) sex, c) marital status, d) years of resident, and e) schooling

4.2.2 Use and Environmental Significance Hypothesis H2a, H2b and H2c

Hypothesis H2 was developed to test the differences between residents knowledge related to: a) natural resource use of mangrove direct products, b) mangroves indirect products, c) mangroves ecological role, d) attitudes toward long term resource use, e) awareness of potential threats that will increase conversion and pollution, and f) acceptance of regulation.

4.2.2.1 Direct Use (H2a)

To test resident knowledge about direct use of the mangroves, three contingency tables were constructed for the following variables: 1) wood for energy production (**firwood**), 2) wood for construction (**conwood**), and 3) fishing tool construction (**artwood**) (Table 34).

Table 34 - Contingency tables for mangrove direct use variables firewood, conwood, and artwood.

Place	**firewood**			**conwood**			**artwood**		
	yes	no	total	yes	no	total	yes	no	total
Chuburná	22	6	28	13	15	28	7	21	28
Chelem	23	7	30	17	13	30	10	20	30
Progreso	15	22	37	4	33	37	3	34	37
Prochub	9	35	44	4	40	44	3	41	44
total	69	70	139	38	101	139	23	116	139
Expec. %	49.64			27.34			16.55		

The main purposes of the analysis was to test whether the populations were homogeneous with respect to the total cell probabilities. This allowed the null hypothesis for homogeneity Ho: p1 = p2 = p3 = p4 to be tested. The following values for χ^2 resulted: **firewood** = 34.35, p = 0.0; **conwood** = 30.59, p = 0.0 and

artwood = 12.49, p =0.006. Tabulated upper 5% value of χ^2 was 7.815 for d.f. = 3. As a result the null hypotheses were rejected at α = 0.05 for **firewood**, **conwood**, and **artwood**.

To explain the reason for rejecting the null hypothesis, observed minus expected frequencies (O-E) and interaction plots of frequencies were calculated and are shown in Table 35 and Figure 38. Table 35 shows the major departures of homogeneity. The signs of the differences that make the largest contribution to the χ^2 indicated the nature of the departures from homogeneity (*i.e.*, Prochub for variable **firewood** with 7.55 and 7.44). Figure 38, a graphical representation of the contingency tables, shows the absolute number of responses (1= yes and 2 = no) per town per variable (*i.e.*, Chuburná, in contrast to Prochub has a large number of residents (22) using wood for energy production.

Table 35 - Observed minus expected frequencies for mangrove direct use variables.

Place	firewood χ^2 = 34.35 p = 0.0 (O-E)		(O-E)^2/E		conwood χ^2 = 30.59 p = 0.0 (O-E)		(O-E)^2/E		artwood χ^2 = 12.49 p = 0.006 (O-E)		(O-E)^2/E	
	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no
Chuburná	8.10	-8.10	4.72	4.65	5.35	-5.35	3.73	1.40	2.37	-2.37	1.21	0.24
Chelem	8.11	-8.11	4.41	4.35	8.80	-8.80	9.44	3.55	5.04	-5.04	5.11	1.01
Progreso	-3.37	3.37	0.62	0.61	-6.12	6.12	3.70	1.39	-3.12	3.12	1.59	0.32
Prochub	-12.84	12.84	7.55	7.44	-8.03	8.03	5.36	2.02	-4.28	4.28	2.52	0.50

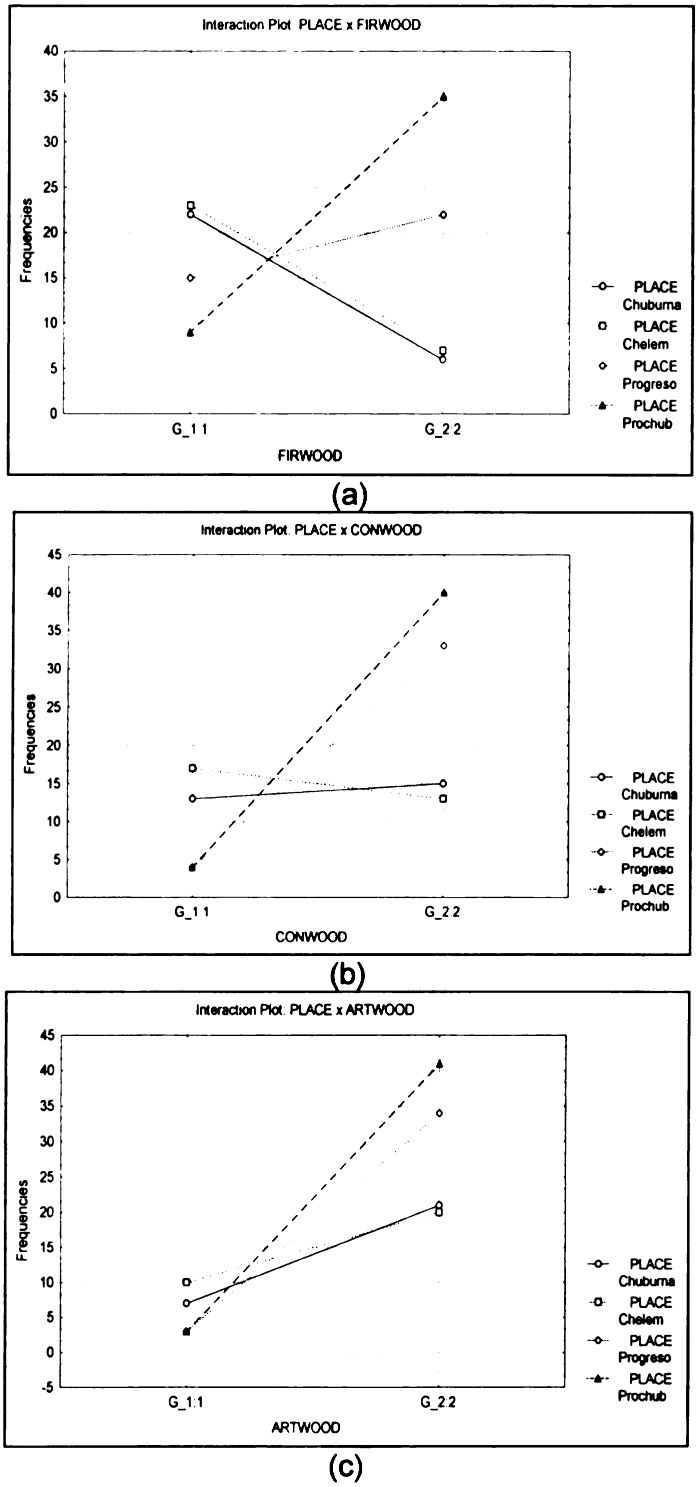


Figure 38 - Interaction plots of direct use for variables: a) firwood (firewood), b) conwood (home construction), and c) artwood (fishing tool construction).

4.2.2.2 Indirect Use (H2b)

Variables used for testing resident knowledge about mangrove indirect use included: 1) finfish used as food, fertilizer and bait (**finfish**), 2) crustaceans used as food, fertilizer and bait (**crust**), 3) mollusc used as food, fertilizer, bait, and handcraft production (**mollu**), 4) birds used as food, sport hunting, watching and handcraft production (**birds**), 5) mammals used as food, fur, and sport hunting (**mamma**), 6) reptiles used as food and skin, (**repti**), 7) insects used as food, wax, honey (**insect**), and 8) used for recreational area (**recrea**). Eight contingency tables were constructed for these variables (Table 36).

Table 36 - Contingency tables for indirect use variables finfish, crust, mollu, birds, mamma, repti, insect and recrea.

Place	finfish			crust			mollu		
	yes	no	total	yes	no	total	yes	no	total
Chuburná	20	8	28	16	12	28	22	6	28
Chelem	25	5	30	25	5	30	28	2	30
Progreso	21	16	37	21	16	37	16	21	37
Prochub	18	26	44	1	43	44	12	32	44
Total	84	55	139	63	76	139	78	61	139
Expec. %	60.43			45.32			56.12		

Place	birds			mamma			repti		
	yes	no	total	yes	no	total	yes	no	total
Chuburná	15	13	28	5	23	28	4	24	28
Chelem	13	17	30	15	15	30	3	27	30
Progreso	11	26	37	1	36	37	3	34	37
Prochub	3	41	44	13	31	44	0	44	44
Total	42	97	139	34	105	139	10	129	139
Expec. %	30.22			24.46			7.19		

Place	insect			recrea		
	yes	no	total	yes	no	total
Chuburná	3	25	28	9	19	28
Chelem	1	29	30	17	13	30
Progreso	0	36	36	10	27	37
Prochub	9	35	44	18	26	44
Total	13	125	138	54	85	139
Expec. %	9.42			38.85		

The purposes of testing H2b was to determine whether the populations are homogeneous with respect to the cell probabilities. The null hypothesis for homogeneity was tested as follows: Ho: $p_1 = p_2 = p_3 = p_4$. Results were the following values for χ^2 : **finfish** = 15.21, p = 0.00164; **crust** = 53.92, p = 0.0; **mollu** = 39.96, p = 0; **birds** = 21.11, p = 0.00001, **mamma** = 21.34, p = 0.0 , **repti** = 12.49, p = 0.006, **insect** = 21.11, p = 0.0, and **recrea** = 6.8, p = 0.08.

The null hypotheses were rejected at $\alpha = 0.05$ for all χ^2 values of variables except **recrea.** The tabulated upper 5% point of χ^2 is 7.815 for d.f. = 3. To explain the nature for rejecting the null hypothesis, observed minus expected frequencies and interaction plots of frequencies were calculated and are shown in Table 37 and Figure 38. An examination of Table 37 indicates a major departure from homogeneity. The differences in the contribution to the χ^2 shows the departures from homogeneity primarily at Prochub in the case of **finfish** with 2.77 and 4.24.

Table 37 - Observed minus expected frequencies for mangroves indirect use variables

Place	finfish $\chi^2 = 15.2$, $p = 0.001$ (O-E)		$(O-E)^2/E$		crust $\chi^2 = 53.92$, $p = 0.0$ (O-E)		$(O-E)^2/E$		mollu $\chi^2 = 39.96$, $p = 0.00$ (O-E)		$(O-E)^2/E$	
	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no
Chuburná	3.08	-3.08	0.56	0.86	3.31	-3.31	0.86	0.72	6.29	-6.29	2.52	3.22
Chelem	6.87	-6.87	2.60	3.98	11.40	-11.40	9.56	7.93	11.17	-11.17	7.41	9.47
Progreso	-1.36	1.36	0.08	0.13	4.23	-4.23	1.07	0.88	-4.76	4.76	1.09	1.40
Prochub	-8.59	8.59	2.77	4.24	-18.94	18.94	17.99	14.91	-12.69	12.69	6.52	8.34

Place	birds $\chi^2 = 21.11$, $p = 0.0$ (O-E)		$(O-E)^2/E$		mamma $\chi^2 = 21.3$, $p = 0.0$ (O-E)		$(O-E)^2/E$		repti $\chi^2 = 12.49$, $p = 0.006$ (O-E)		$(O-E)^2/E$	
	yes	no	yes	no	yes	no	yes	no	yes	no	yes	no
Chuburná	6.54	-6.54	5.05	2.19	-1.85	1.85	0.50	0.16	1.99	-1.99	1.96	0.15
Chelem	3.94	-3.94	1.71	0.74	7.66	-7.66	8.00	2.59	0.84	-0.84	0.33	0.03
Progreso	-0.18	0.18	0.00	0.00	-8.05	8.05	7.16	2.32	0.34	-0.34	0.04	0.00
Prochub	-10.29	10.29	7.97	3.45	2.24	-2.24	0.47	0.15	-3.17	3.17	3.17	0.25

Place	insect $\chi^2 = 21.11$, $p = 0.0$ (O-E)		$(O-E)^2/E$		recrea $\chi^2 = 6.8$, $p = 0.08$ (O-E)		$(O-E)^2/E$					
	yes	no	yes	no	yes	no	yes	no				
Chuburná	0.36	-0.36	0.05	0.01	-1.88	1.88	0.32	0.21				
Chelem	-1.83	1.83	1.18	0.12	5.35	-5.35	2.45	1.56				
Progreso	-3.39	3.39	3.39	0.35	-4.37	4.37	1.33	0.85				
Prochub	4.86	-4.86	5.69	0.59	0.91	-0.91	0.05	0.03				

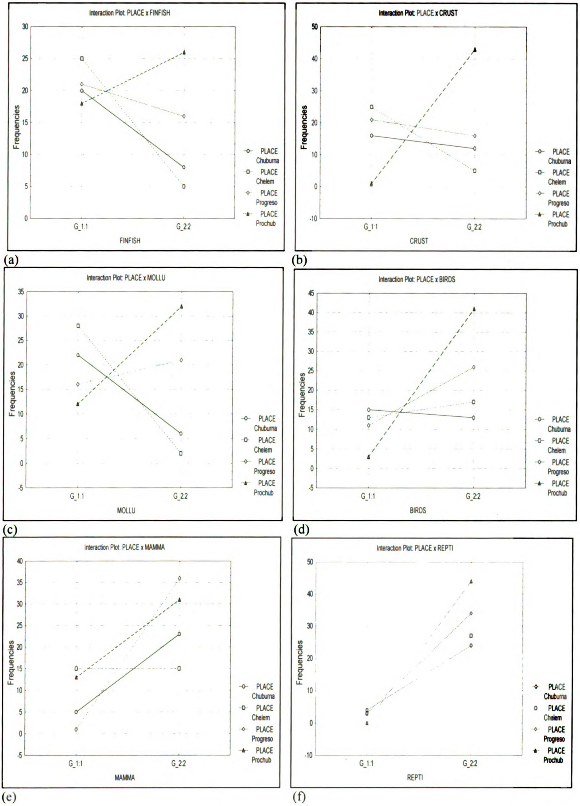
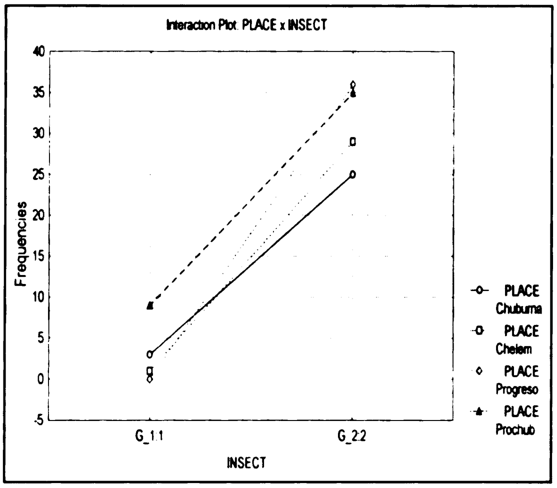
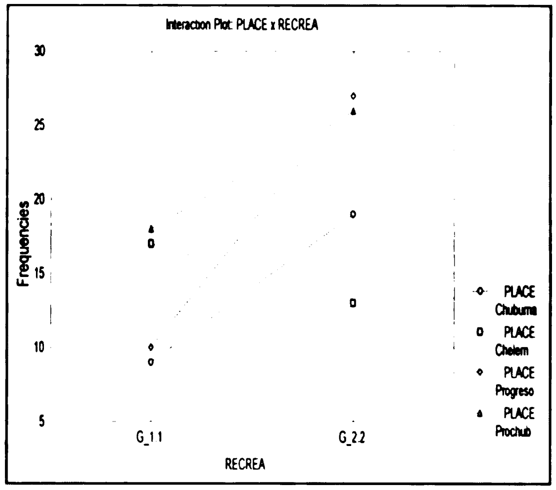


Figure 39 - Interaction plots of mangroves indirect use variables: a) finfish, b) crust, c) mollu, d) birds, e) mamma, f) repti, g) insect and h) recrea.



(g)



(h)

Figure 39. (con't)

4.2.2.3 Environmental Services (H2c)

The variables used for testing resident knowledge about environmental services were: 1) production of organic matter (**promat**), 2) soil protection (**soilpro**), 3) hurricane protection (**hurpro**), 4) nesting site (**nesit**), 5) nursery site (**nurs**), and 6) water quality (**clewa**). Contingency tables are shown in Table 38.

Table 38 - Contingency tables for indirect use variables promat, soilpro, hurpro, nesit, nurs, and clewa.

Place	promat			soilpro			hurpro		
	yes	no	total	yes	no	total	yes	no	total
Chuburná	20	8	28	19	9	28	21	6	27
Chelem	13	17	30	20	10	30	18	12	30
Progreso	29	8	37	29	7	36	26	11	37
Prochub	32	12	44	28	16	44	32	11	43
total	84	55	139	96	42	138	97	40	137
Expec. %	67.63			69.57			70.8		

Place	nesit			nurs			clewa		
	yes	no	total	yes	no	total	yes	no	total
Chuburná	26	2	28	23	5	28	17	11	28
Chelem	28	2	30	28	2	30	10	20	30
Progreso	32	2	34	31	6	37	18	19	37
Prochub	40	4	44	31	12	43	11	32	43
total	126	10	136	113	25	138	56	82	138
Expec. %	92.65			81.88			40.58		

The null hypothesis of homogeneity was tested (Ho: p1 = p2 = p3 = p4) and the results were (χ^2) : **promat** = 10.74, p=.013; **soilpro** = 2.94, p= .4; **hurpro** = 2.60, p=.45; **nesit** = 0.32, p=.95; **nurs** = 5.52, p=.13, and **clewa** = 10.37, p=0.015. The null hypotheses was rejected at α=.05 for **promat** and **clewa** (tabulated upper 5% for χ^2 is 7.815, d.f. = 3). Interaction plots of frequencies (Figure 40) and contributions to χ^2 (Table 39) were calculated.

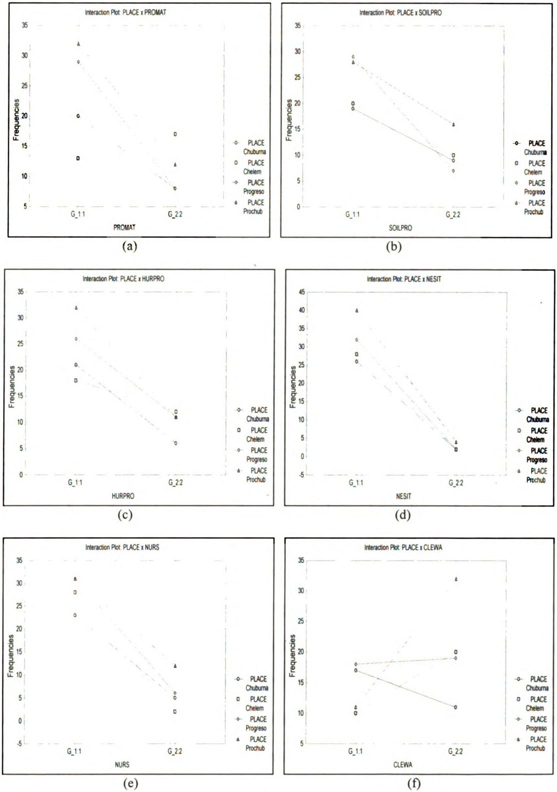


Figure 40 - Interaction plots of mangroves environmental services variables: a)promat, b)soilpro, c)hurpro, d)nesit, e)nurs, and f) clewa

Table 39 shows major departures from homogeneity, the signs of the differences that make the largest contribution to the χ^2 indicate the reason for the departures. For example, Chelem for variable **promat** contributed with 2.62 and 5.47.

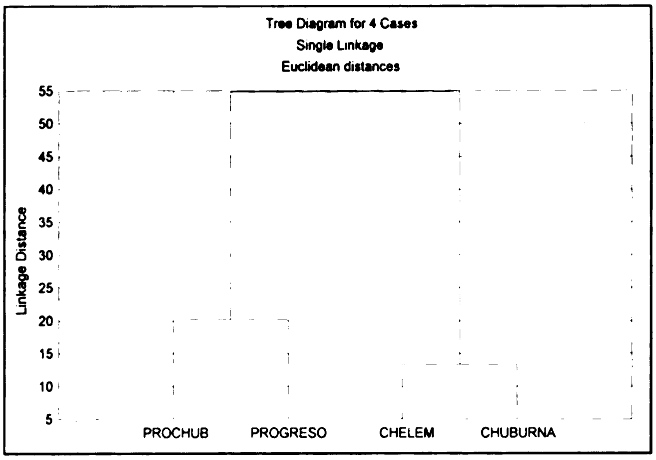
Table 39 - Observed minus expected frequencies for mangrove environmental benefits variables

Place	promat χ^2 = 10.7 p = 0.013 (O-E) yes	no	$(O-E)^2/E$ yes	no	soilpro χ^2 = 2.94, p = .4 (O-E) yes	no	$(O-E)^2/E$ yes	no	hurpro χ^2 = 2.6, p = 0.45 (O-E) yes	no	$(O-E)^2/E$ yes	no
Chuburná	1.06	-1.06	0.06	0.13	-0.48	0.48	0.01	0.03	1.88	-1.88	0.19	0.45
Chelem	-7.29	7.29	2.62	5.47	-0.87	0.87	0.04	0.08	-3.24	3.24	0.49	1.20
Progreso	3.98	-3.98	0.63	1.32	3.96	-3.96	0.63	1.43	-0.20	0.20	0.00	0.00
Prochub	2.24	-2.24	0.17	0.35	-2.61	2.61	0.22	0.51	1.55	-1.55	0.08	0.19

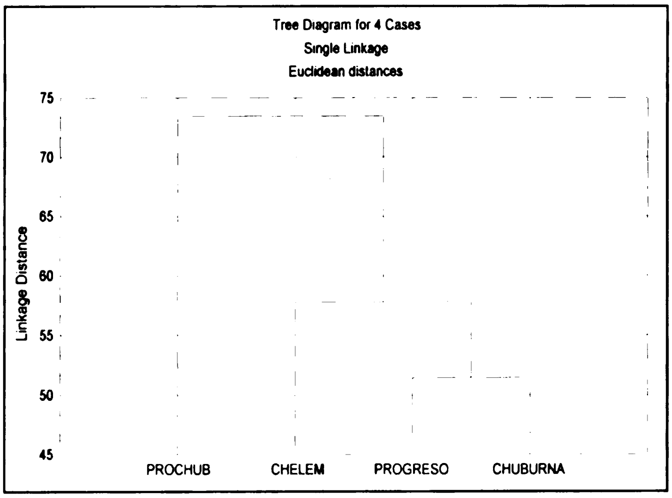
Place	nesit χ^2 = 0.32, p = 0.95 (O-E) yes	no	$(O-E)^2/E$ yes	no	nurs χ^2 = 5.52, p = 0.13 (O-E) yes	no	$(O-E)^2/E$ yes	no	clewa χ^2 = 10.37, p = 0.015 (O-E) yes	no	$(O-E)^2/E$ yes	no
Chuburná	0.06	-0.06	0.00	0.00	0.07	-0.07	0.00	0.00	5.64	-5.64	2.80	1.91
Chelem	0.21	-0.21	0.00	0.02	3.43	-3.43	0.48	2.17	-2.17	2.17	0.39	0.27
Progreso	0.50	-0.50	0.01	0.10	0.70	-0.70	0.02	0.07	2.99	-2.99	0.59	0.41
Prochub	-0.76	0.76	0.01	0.18	-4.21	4.21	0.50	2.28	-6.45	6.45	2.38	1.63

4.2.2.4 Similarities using H2a, H2b and H2c

To summarize similarities among the communities a cluster analysis was used to compare mangrove direct use, mangrove wetland indirect use and mangrove wetland environmental services. Results of the analysis, based on Euclidean distances, were graphed in a tree cluster (Figure 41). Distances were calculated based on variables that were rejected for homogeneity (*i.e.*, direct use: **firwood**, **conwood** and **artwood**; indirect use: **promat** and **clewa**; and environmental benefits: **recrea**).



(a)



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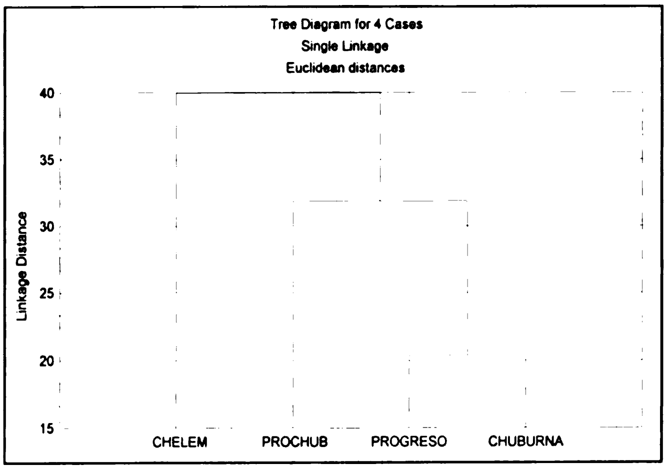


(c)

Figure 41 - Similarities among residents in studied places for: a) Direct use , b) Indirect Use and c) Environmental services provided by the mangrove wetlands

4.2.3 Regulatory Interventions Hypotheses H2d, H2e and H2f

4.2.3.1 Attitudes toward long term Resource Use (H2d)

In this section and in the two following sections, results from questions measuring the following are presented: attitudes toward long term resource use, awareness of threats that will increase conversion and pollution, and acceptance of regulation.

Results from questions to measure attitudes toward long term resource use are shown in contingency tables for the following attitudinal variables: 1) moralistic (**moral**), 2) naturalistic (**natura**), 3) ecologistic (**ecol1, ecol2, ecol3**), 4) scientistic (**scienc**), 5) negativistic (**negat**), 6) short term benefits (**short**), 7) option value (**option**), 8) equity (**equity**), 9) existence value (**exist**), 10) externalities (**exter**), 11) willingness to contribute (**willi**), and 12) willingness to participate (**parti**) (Table 40). Respondent options included: 1) yes/agree, 2) uncertain and 3) no/disagree.

The main purpose of this analysis was to test whether the populations were homogeneous with respect to the total cell probabilities computed by town. The null hypothesis for homogeneity (Ho: p1 = p2 = p3 = p4) was tested and accepted for 12 variables. The chi-square (χ^2) statistic, the degrees of freedom (d.f.), and probabilities of occurrence (p) for variables are shown in Table 41.

Table 40 - Contingency tables for long term resource use variables: moral, natura, ecol1, ecol2, ecol3, scienc, negat, short, option, equity, exist, extern, willi, and parti.

	moral				natura			
Place	**yes**	**unce-tain**	**no**	**total**	**yes**	**unce-tain**	**no**	**total**
Chuburná	27	1	0	28	28	0	0	28
Chelem	29	0	1	30	30	0	0	30
Progreso	37	0	0	37	36	0	1	37
Prochub	44	0	0	44	39	2	3	44
total	137	1	1	139	133	2	4	139
Expect. %	98.56				95.68			

	ecol1				ecol2			
Place	**yes**	**uncer-tain**	**no**	**total**	**yes**	**unce-tain**	**no**	**total**
Chuburná	24	1	3	28	17	3	8	28
Chelem	29	0	1	30	22	1	7	30
Progreso	36	0	1	37	26	3	8	37
Prochub	43	0	1	44	31	6	7	44
total	132	1	6	139	96	13	30	139
Expect. %	94.96				69.06			

	ecol3				scienc			
Place	**yes**	**uncer-tain**	**no**	**total**	**yes**	**unce-tain**	**no**	**total**
Chuburná	24	2	2	28	27	1	0	28
Chelem	28	1	1	30	29	1	0	30
Progreso	33	2	2	37	33	2	2	37
Prochub	42	2	0	44	42	1	1	44
total	127	7	5	139	131	5	3	139
Expect. %	91.37				94.24			

	negat				short			
Place	**yes**	**uncer-tain**	**no**	**total**	**yes**	**unce-tain**	**no**	**total**
Chuburná	2	1	25	28	7	1	20	28
Chelem	1	0	29	30	7	0	23	30
Progreso	4	3	30	37	15	1	21	37
Prochub	1	0	43	44	1	3	40	44
total	8	4	127	139	30	5	104	139
Expect. %	91.37						74.82	

	option				equity			
Place	**yes**	**uncer-tain**	**no**	**total**	**yes**	**unce-tain**	**no**	**total**
Chuburná	27	0	1	28	25	1	2	28
Chelem	30	0	0	30	29	0	1	30
Progreso	34	1	2	37	33	2	2	37
Prochub	42	2	0	44	43	1	0	44
total	133	3	3	139	130	4	5	139
Expect. %	95.68				93.53			

Table 40 - (con't).

	exist				extern			
Place	**yes**	**uncer-tain**	**no**	**total**	**yes**	**unce-tain**	**no**	**total**
Chuburná	22	4	2	28	11	3	14	28
Chelem	29	1	0	30	6	2	22	30
Progreso	32	3	2	37	13	4	20	37
Prochub	39	2	3	44	4	4	36	44
total	122	10	7	139	34	13	92	139
Expect.%	87.77						66.19	

	willi				parti			
Place	**yes**	**uncer-tain**	**no**	**total**	**yes**	**unce-tain**	**no**	**total**
Chuburná	26	2	0	28	6	4	18	28
Chelem	29	1	0	30	2	2	26	30
Progreso	32	3	2	37	6	4	27	37
Prochub	35	6	3	44	7	4	33	44
total	122	12	5	139	21	14	104	139
Expect. %	87.77						74.82	

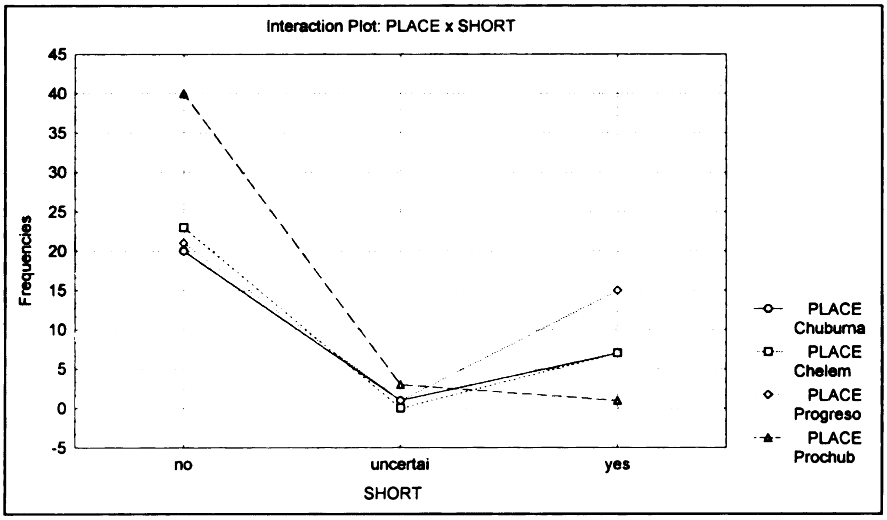
Table 41 - χ^2 values and p values for long term resource use variables: moral, natura, ecol1, ecol2, ecol3, scienc, negat, short, option, equity, exist, extern, willi, and parti.

Variable	$\chi 2$	d.f.	p	result
moral	7.63	6	.26	accept
natura	8.71	6	.19	accept
ecol1	7.65	6	.26	accept
ecol2	3.85	6	.69	accept
ecol3	3.56	6	.73	accept
scienc	3.75	6	.70	accept
negat	9.39	6	.15	accept
short	19.58	6	.003	rejected
option	6.24	6	.39	accept
equity	4.9	6	.55	accept
exist	5.64	6	.46	accept
extern	12.89	6	.04	rejected
willi	6.72	6	.34	accept
parti	4.1	6	.66	accept

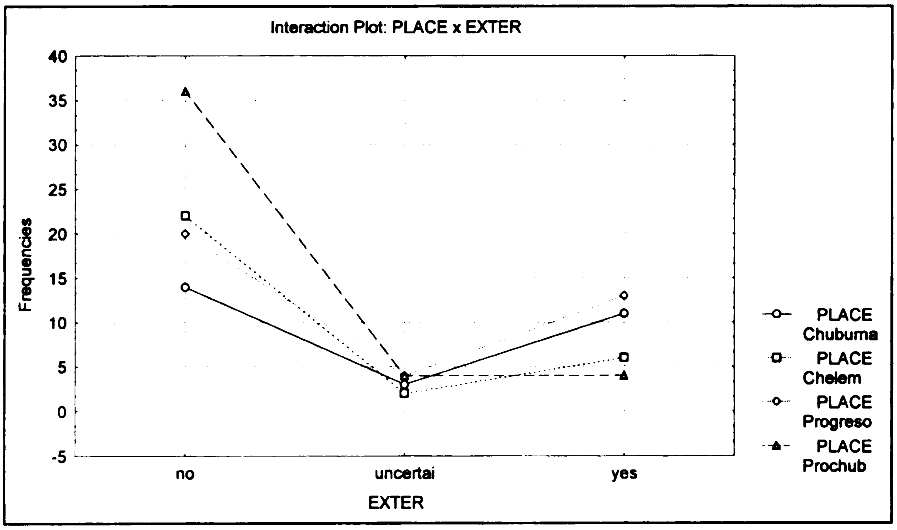
Short and **extern** were rejected for $\alpha < .05$. To further explain the reason for rejecting the null hypothesis, observed minus expected frequencies and interaction plots of frequencies are shown in Table 42 and Figure 42.

Table 42 - Observed minus expected frequencies for long term resource use. Variables: short and extern

Place	short $\chi^2 = 19.58$ p = 0.003						extern $\chi^2 = 12.89$, p = 0.04					
	(O-E)			$(O-E)^2/E$			(O-E)			$(O-E)^2/E$		
	yes	uncer-tain	no	yes	uncer-tain	no	yes	uncer-tain	no	yes	uncer-tain	no
Chuburná	-0.95	-0.01	0.96	0.04	0.00	0.15	-4.53	0.38	4.15	1.11	0.06	2.52
Chelem	0.55	-1.08	0.53	0.01	1.08	0.04	2.14	-0.81	-1.34	0.23	0.23	0.24
Progreso	-6.68	-0.33	7.01	1.61	0.08	6.16	-4.49	0.54	3.95	0.82	0.08	1.72
Prochub	7.08	1.42	-8.50	1.52	1.27	7.60	6.88	-0.12	-6.76	1.62	0.00	4.25



(a)



(b)

Figure 42 - Interaction plots of long term resource use. a) short (short term exploitation) and b) extern (externalities).

4.2.3.2 Awareness Toward Mangrove Threats (H2e)

Variables used for testing resident perceptions to environmental threats were: 1) urban growth (**urgro**), 2) port infrastructure (**porin**), 3) road system (**roads**), 4) garbage dumps (**garba**), 5) domestic and industrial wastes (**trewa**), 6) oil spills (**oilspi**), 7) amount of wood extracted (**woode**), 8) fishing volumes (**fishe**), and 9) hunting pieces (**hunte**). Nine contingency tables were constructed to evaluate the responses (see Table 43).

Table 43 - Contingency tables for perceptions to environmental threats variables urgro, porin, roads, garba, trewa, oilspi, woode, fishe and hunte.

	urgro			porin			roads		
Place	**yes**	**no**	**total**	**yes**	**no**	**total**	**yes**	**no**	**total**
Chubumá	9	19	28	11	17	28	8	20	28
Chelem	12	18	30	13	17	30	6	24	30
Progreso	21	16	37	10	27	37	16	21	37
Prochub	27	17	44	21	23	44	16	28	44
total	69	70	139	55	84	139	46	93	139
Expect. %	49.64			39.57			33.09		

	garba			trewa			oilspi		
Place	**yes**	**no**	**total**	**yes**	**no**	**total**	**yes**	**no**	**total**
Chubumá	24	4	28	20	8	28	13	15	28
Chelem	25	5	30	21	9	30	20	10	30
Progreso	35	2	37	32	5	37	34	3	37
Prochub	33	11	44	31	13	44	34	10	44
total	117	22	139	104	35	139	101	38	139
Expect. %	84.17			74.82			72.66		

	woode			fishe			hunte		
Place	**yes**	**no**	**total**	**yes**	**no**	**total**	**yes**	**no**	**total**
Chubumá	9	19	28	10	18	28	11	17	28
Chelem	12	18	30	13	17	30	13	17	30
Progreso	17	20	37	18	19	37	24	13	37
Prochub	24	20	44	27	17	44	23	21	44
total	62	77	139	68	71	139	71	68	139
Expect. %	44.6			48.9			51.08		

The purpose of the analysis was to test whether the populations were homogeneous with respect to the total cell probabilities. The null hypothesis for homogeneity (Ho: p1 = p2 = p3 = p4) was tested and accepted. The chi-square (χ^2) statistic, the degree of freedom (d.f.), and probabilities of occurrence (p) are shown in Table 44.

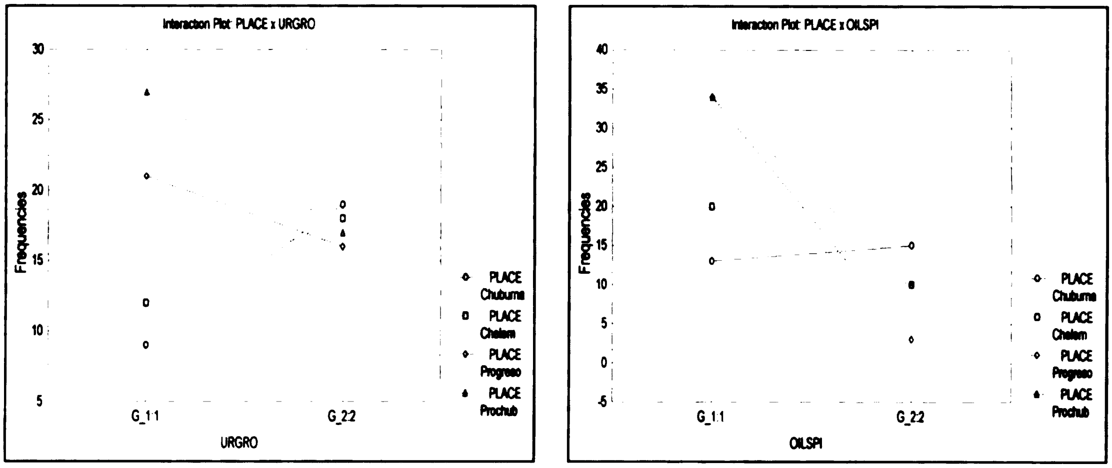
Table 44 - Results of χ^2, d.f. and p values for awareness regarding threats to mangrove. Variables urgro, porin, roads, garba, oilspi, woode, fishe, and hunte

Variable	$\chi 2$	d.f.	p	result
urgro	7.713037	3	.05235	accept
porin	3.837443	3	.27958	accept
roads	4.515430	3	.21094	accept
garba	5.861271	3	.11858	accept
trewa	3.659044	3	.30073	accept
oilspi	17.60199	3	.00053	reject
woode	3.803901	3	.28345	accept
fishe	5.056409	3	.16774	accept
hunte	5.117863	3	.16339	accept

To explain the reason for rejecting the null hypothesis, observed minus expected frequencies and interaction plots of frequencies were used (see Table 45 and Figure 43).

Table 45 - Observed minus expected frequencies for awareness regarding threats to mangroves. Variables: urgro and oilspi

Place	urgro χ^2 = 7.71, d.f. = 3 p = 0.052				oilspi χ^2 = 17.60, d.f. = 3, p = 0.00053			
	(O-E)		$(O-E)^2/E$		(O-E)		$(O-E)^2/E$	
	yes	no	yes	no	yes	no	yes	no
Chuburná	-4.90	4.90	1.73	1.70	-7.35	7.35	2.65	7.05
Chelem	-2.89	2.89	0.56	0.55	-1.80	1.80	0.15	0.39
Progreso	2.63	-2.63	0.38	0.37	7.12	-7.12	1.88	5.00
Prochub	5.16	-5.16	1.22	1.20	2.03	-2.03	0.13	0.34



(a) (b)

Figure 43. Interaction plots for threats to mangroves: a) urgro (urban growth) and b) oilspi (oil spills)

4.2.3.3 Acceptance of Regulation (H2f)

Variables used for testing the acceptance/enforcement of regulation for the mangrove wetland products and services were: 1) acceptance of regulation (**lgral**), 2) construction controls (**lcons**), 3) dumping controls (**lcont**), 4) wood cutting controls (**lwood**), 5) fishing regulation (**lfish**), 6) hunting regulation (**lhunt**), and 7) wetland transportation regulation (**ltran**). Seven contingency tables were constructed to evaluate residents responses. They are shown in Table 46.

Table 46 - Contingency tables for regulatory variables lgral, lcons, lcont, lwood, lfish, lhunt, and ltran

	lgral				lcons			
Place	**no**	**uncer-tain**	**yes**	**total**	**no**	**uncer-tain**	**yes**	**total**
Chuburná	3	1	24	28	6	1	20	27
Chelem	0	0	29	29	3	0	24	27
Progreso	1	0	36	37	4	1	28	33
Prochub	1	0	43	44	0	1	42	43
total	5	1	132	138	13	3	114	130
Expect. %			96.6				87.7	

	lcont				lwood			
Place	**no**	**uncer-tain**	**yes**	**total**	**no**	**uncer-tain**	**yes**	**total**
Chuburná	0	0	28	28	3	1	24	28
Chelem	0	0	30	30	4	0	25	29
Progreso	0	0	36	36	0	1	30	31
Prochub	1	0	43	44	1	0	42	43
total	1	0	137	138	8	2	121	131
Expect. %			99.3				92.4	

	lfish				lhunt			
Place	**no**	**uncer-tain**	**yes**	**total**	**no**	**uncer-tain**	**yes**	**total**
Chuburná	2	1	24	27	3	0	25	28
Chelem	3	1	25	29	6	1	22	29
Progreso	6	0	29	35	5	2	29	36
Prochub	1	0	42	43	1	0	42	43
total	12	2	120	134	15	3	118	136
Expect. %			89.5				86.7	

	ltran			
Place	**no**	**uncer-tain**	**yes**	**total**
Chuburná	2	2	15	19
Chelem	5	1	22	28
Progreso	3	3	24	30
Prochub	1	2	39	42
total	11	8	100	119
Expect. %			84.0	

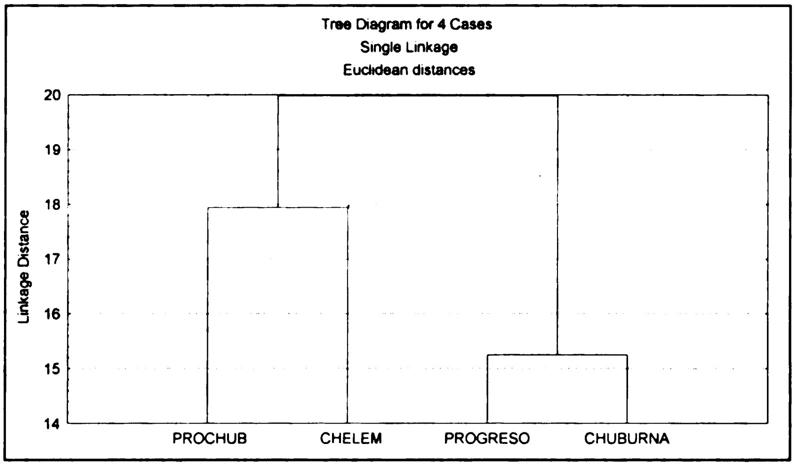
The purpose of this analysis was to test whether the populations were homogeneous by town with respect to the cell probabilities. The null hypothesis of homogeneity Ho: p1 = p2 = p3 = p4 was tested and accepted. Values of χ^2, degree of freedom (d.f.), and probabilities (p) were calculated and are shown in Table 47. All variables were accepted according the criteria that $p \geq 0.05$ indicating that no differences exist between towns.

Table 47 - Result of χ^2 values and p values for regulatory variables

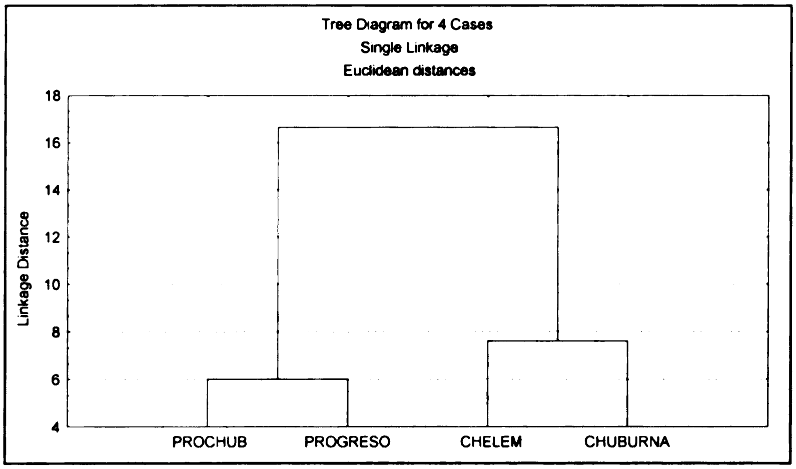
Variable	$\chi 2$	d.f.	p	result
lgral	9.549910	6	.14497	accept
lcons	10.53542	6	.10388	accept
lcont	2.151958	3	.54148	accept
lwood	9.580509	6	.14351	accept
lfish	8.186590	6	.22479	accept
lhunt	10.44450	6	.10718	accept
ltran	6.586734	6	.36079	accept

4.2.3.4 Similarities using H2d and H2e

To summarize similarities among communities, a cluster analysis was used to compare long term resource use and awareness regarding threats to mangroves. Tree clusters were graphed based on Euclidean distances (Figure 44). Distances were calculated based on variables that were rejected for homogeneity (*i.e.*, long term resource use: **short** and **extern**; and awareness regarding threats to mangroves: **urgro** and **oilspi**).



(a)



(b)

Figure 44 - Similarities between residents for: a) long term resource use, variables: short and extern and b) awareness regarding threats to mangroves, variables: urgro and oilspi

4.2.4 Relating Physical Changes to resident knowledge and attitudes

To integrate the physical and human dimensions, variables from hypotheses H1 and H2 shown in Table 48 were selected for the analysis. Variable selection was based on the test of homogeneity between towns (Chuburná, Chelem, Progreso and Prochub) according the. A summary of the social variables including percentages, confident intervals, χ^2 values, degree of freedoms and probabilities are shown in Table 49 at the end of this section.

Table 48 - Variables selected for relating natural and human variables

Physical Dimension	Human Dimension
a) Evergreen losses (**egl**)	a) Use of mangrove direct products : 1) firewood (**firewood**), 2) home repairs and construction (**conwood**), and 3) fishing tool constructions (**artwood**).
b) Dune vegetation losses (**dvl**)	b) Mangrove ecological benefits : 1) production of organic matter and feeding nursery (**promat**), 2) protection of shore erosion (**soilpro**), 3) removal of nutrients, heavy metals and other substances from the water (**clewa**), and 4) spawning area and protective cover (**nurs**).
	c) Attitudes towards long-term resource use : 1) limits on nature (**ecol2**), 2) negativist (**negat**), 3) short time preferences (**short**), and negative externalities (**extern**).
	d) Threats to mangroves : 1) urban expansion (**urgro**), 2) port infrastructure (**porin**), 3) roads (**roads**), 4) solid garbage dumps (**garba**).
	e) Acceptance of regulation : 1) untreated sewage (**trewa**), 2) oil spills (**oilspi**), 3) wood extraction (**woode**), and 4) fishing intensity (**fishe**).

a) The sample percentages of residents with knowledge of the use and/or as consumers of the direct mangrove products were related with changes on the mangrove wetland. The following three social variables were selected based on the higher χ^2 values : 1) firewood (**firewood**), 2) home repairs and constructions (**conwood**), and 3) fishing tools construction (**artwood**). They were related with evergreen vegetation losses (**egl**) and dune vegetation losses (**dvl**) per habitant (Figure 45).

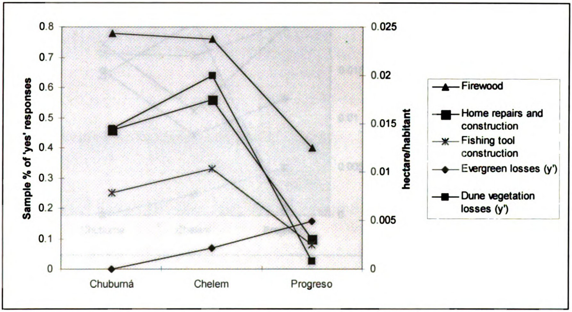


Figure 45 - Vegetation losses and direct mangrove consumption

b) The percentage of residents from Chuburná, Chelem and Progreso based on their knowledge of ecological benefits of the mangroves were related with changes on vegetation. The following three social variables were selected based on their highest value for χ^2 statistic: 1)production of organic matter and feeding nursery (**promat**), 2)protection of shore erosion (**soilpro**), 3)removal of nutrients heavy metals and other substances from the water (**clewa**), and 4) spawning area and protective cover (**nurs**). They were related with evergreen vegetation losses (**egl**) and dune vegetation losses (**dvl**) per habitant (Figure 46).

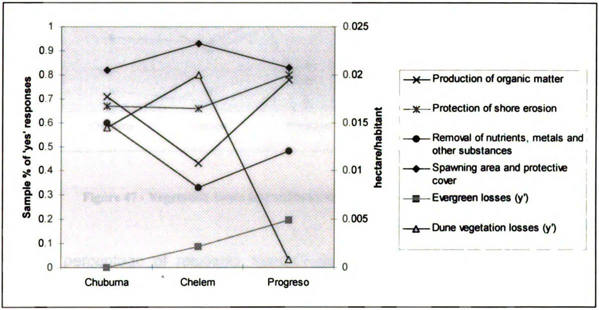


Figure 46 - Vegetation losses and mangroves ecological benefits

c) Result from the change detection and residents attitudes towards long-term resource use allow to relate the percentage of residents from Chuburná, Chelem and Progreso about their attitudes towards the long-term resource use and with changes on evergreen vegetation (**egl**) and dune vegetation (**dvl**) losses (Figure 47). The following three variables were selected based on their highest values for χ^2 statistic : 1) limits on nature (**ecol2**), negativist (**negat**), 3) short time preferences (**short**), and 4) externalities (**exter**).

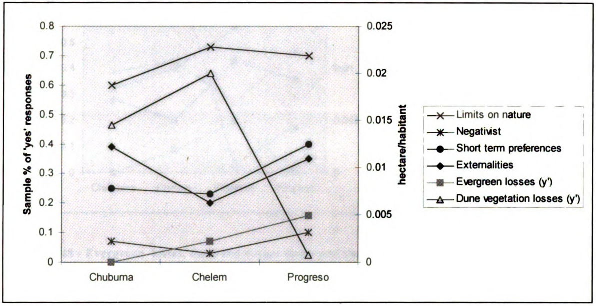


Figure 47 - Vegetation losses and attitudes toward long-term resource use

d) The percentage of residents from Chuburná, Chelem and Progreso that accepted that : 1) urban expansion (**urgro**), 2) port infrastructure (**porin**), 3) roads (**roads**), 4) solid garbage (**garba**), are threats to the mangrove wetland and linked to vegetation losses are shown in Figure 48. Also 1) untreated sewage (**trewat**), 2) oil spills (**oilspi**), 3) wood extraction (**woode**) and 4) fishing intensity (**fishe**) were included and related to vegetation losses and are shown in Figure 49. The graphs illustrate the number of hectare/habitant of greeen vegetation losses (**egl**) and also dune vegetation losses (**dvl**) per town during the studied period.

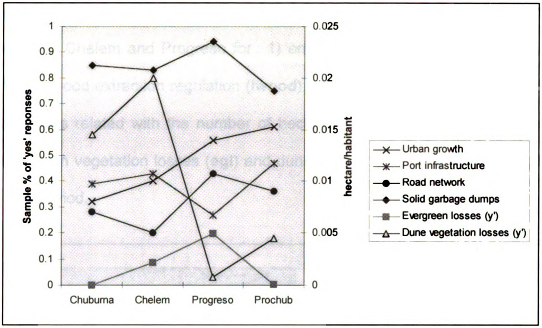


Figure 48 - Evergreen losses, dune vegetation losses and awareness toward threats to mangrove wetland : 1) urban expansion (urgro), 2) port infrastructure (porin), 3) roads (roads), 4) solid garbage dumps (garba).

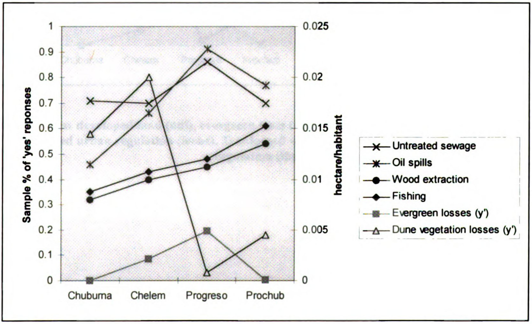


Figure 49 - Evergreen losses, dune vegetatrion losses and awareness toward threats to mangrove wetland : 1) untreated sewage (trewat), 2) oil spills (oilspi), 3) wood extraction (woode) and 4) fishing intensity (fishe).

e) Acceptance of regulation indicated by the percentage of residents from Chuburná, Chelem and Progreso for : 1) enforced urban regulation (**Icons**), 2) enforced wood extraction regulation (**Iwood**), and 3) enforced hunting regulation (**Ihunt**) was related with the number of hectar/habitant of new developed land (**ndl**), green vegetation losses (**egl**) and dune vegetation losses (**dvl**) during the studied period.

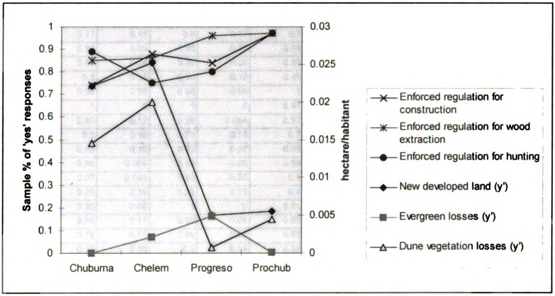


Figure 50 - New developed land (ndl), evergreen loses (egl), dune vegetation losses and acceptance of 1) enforced urban regulation (Icons), 2) enforced wood extraction, and 3) enforced hunting regulation (Ihunt).

Table 49- Summary of the social variables. Proportion of the 'yes/agree' answares, confident interval (+/-), χ^2 for homogeneity by town, degree of freedom and probability level.

Vaiable	Chuburná	Conf. int.	Chelem	Conf. int.	Progreso	Conf. int.	Procchub	Conf. int.	χ^2	d.f.	p
Firewood	0.78	0.15	0.76	0.15	0.4	0.15	0.2	0.11	34.35	3	0
conwood	0.46	0.18	0.56	0.17	0.1	0.1	0.09	0.08	30.59	3	0
artwood	0.25	0.16	0.33	0.16	0.08	0.08	0.06	0.07	12.49	3	0.006
finfish	0.71	0.16	0.83	0.13	0.56	0.15	0.4	0.14	15.21	3	0.001
crust	0.57	0.18	0.83	0.13	0.56	0.15	0.02	0.04	53.92	3	0
mollu	0.78	0.15	0.93	0.08	0.43	0.15	0.27	0.13	39.96	3	0
birds	0.53	0.18	0.43	0.17	0.29	0.14	0.06	0.07	21.11	3	0
mamma	0.17	0.14	0.5	0.17	0.02	0.05	0.29	0.13	21	3	0
repti	0.14	0.12	0.1	0.1	0.08	0.08	0	0	12	3	0.006
insect	0.1	0.11	0.03	0.06	0	0	0.2	0.11	21	3	0
recrea	0.32	0.17	0.56	0.17	0.27	0.14	0.4	0.14	6.8	3	0.08
promat	0.71	0.16	0.43	0.17	0.78	0.13	0.72	0.13	10.74	3	0.013
soilpro	0.67	0.17	0.66	0.16	0.8	0.12	0.63	0.14	2.94	3	0.4
hurpro	0.77	0.15	0.6	0.17	0.7	0.14	0.74	0.12	2.6	3	0.45
nesit	0.92	0.09	0.93	0.08	0.94	0.07	0.9	0.08	0.32	3	0.95
nurs	0.82	0.14	0.93	0.08	0.83	0.11	0.72	0.13	5.52	3	0.13
clewa	0.6	0.18	0.33	0.16	0.48	0.16	0.25	0.12	10.37	3	0.015
moral	0.96	0.06	0.96	0.06	1	0	1	0	7.63	6	0.26
natura	1	0	1	0	0.97	0.05	0.88	0.09	8.71	6	0.19
ecol1	0.85	0.12	0.96	0.064	0.97	0.05	0.97	0.044	7.65	6	0.26
ecol2	0.6	0.18	0.73	0.15	0.7	0.14	0.7	0.13	3.85	6	0.69
ecol3	0.85	0.12	0.93	0.08	0.89	0.1	0.95	0.06	3.56	6	0.73
scienc	0.96	0.068	0.96	0.06	0.89	0.1	0.95	0.06	3.75	6	0.7
negat	0.07	0.095	0.03	0.06	0.1	0.1	0.02	0.04	9.39	6	0.15
short	0.25	0.16	0.23	0.15	0.4	0.15	0.02	0.04	19.58	6	0.003
option	0.96	0.06	1	0	0.91	0.08	0.95	0.06	6.24	6	0.39
equity	0.89	0.11	0.96	0.06	0.89	0.1	0.97	0.04	4.9	6	0.55
exist	0.78	0.15	0.96	0.06	0.86	0.11	0.88	0.09	5.64	6	0.46
extern	0.39	0.18	0.2	0.14	0.35	0.15	0.09	0.08	12.89	6	0.04
willi	0.92	0.09	0.96	0.06	0.86	0.11	0.79	0.11	6.72	6	0.34
parti	0.21	0.15	0.06	0.08	0.16	0.11	0.15	0.1	4.1	6	0.66
urgro	0.32	0.17	0.4	0.17	0.57	0.15	0.61	0.14	7.71	3	0.05
porin	0.39	0.18	0.43	0.17	0.27	0.14	0.47	0.14	3.83	3	0.27
roads	0.28	0.16	0.2	0.14	0.43	0.15	0.36	0.14	4.51	3	0.21
garba	0.85	0.12	0.83	0.13	0.94	0.07	0.75	0.12	5.86	3	0.11
trewa	0.71	0.16	0.7	0.16	0.86	0.11	0.7	0.13	3.65	3	0.3
oilspi	0.46	0.18	0.66	0.16	0.91	0.08	0.77	0.12	17.6	3	0
woode	0.32	0.17	0.4	0.17	0.45	0.16	0.54	0.14	3.8	3	0.28
fishe	0.35	0.17	0.43	0.17	0.48	0.16	0.61	0.14	5.05	3	0.16
hunte	0.39	0.18	0.43	0.17	0.64	0.15	0.52	0.14	5.11	3	0.16
lgral	0.85	0.12	1	0	0.97	0.05	0.97	0.04	9.54	6	0.14
lcons	0.74	0.16	0.88	0.11	0.84	0.11	0.97	0.04	10.53	6	0.1
lcont	1	0	1	0	1	0	0.97	0.04	2.15	3	0.54
lwood	0.85	0.12	0.86	0.12	0.96	0.05	0.97	0.04	9.58	6	0.14
lfish	0.88	0.11	0.86	0.12	0.82	0.12	0.97	0.04	8.18	6	0.22
lhunt	0.89	0.11	0.75	0.15	0.8	0.12	0.97	0.04	10.44	6	0.1
ltran	0.78	0.15	0.78	0.14	0.8	0.12	0.92	0.07	6.58	6	0.36

Table 50 - Summary of the social variables. Proportion of the 'yes/agree' answers and z values for $p = .5$ vs $p \neq .5$, $\alpha = 0.05$ (accept the null hypothesis if abs(z) $Z < 1.96$).

Vaiable	Chuburná	Chelem	Progreso	Procchub	Chuburná z for p ≠ .5	Chelem z for p ≠ .5	Progreso z for p ≠ .5	Prochub z for p ≠ .5
Firewood	0.78	0.76	0.40	0.20	2.96	2.85	-1.22	-3.98
conwood	0.46	0.56	0.10	0.09	-0.42	0.66	-4.87	-5.44
artwood	0.25	0.33	0.08	0.06	-2.65	-1.86	-5.11	-5.84
finfish	0.71	0.83	0.56	0.40	2.22	3.61	0.73	-1.33
crust	0.57	0.83	0.56	0.02	0.74	3.61	0.73	-6.37
mollu	0.78	0.93	0.43	0.27	2.96	4.71	-0.85	-3.05
birds	0.53	0.43	0.29	0.06	0.32	-0.77	-2.55	-5.84
mamma	0.17	0.50	0.02	0.29	-3.49	0.00	-5.84	-2.79
repti	0.14	0.10	0.08	0.00	-3.81	-4.38	-5.11	-6.63
insect	0.10	0.03	0.00	0.20	-4.23	-5.15	-6.08	-3.98
recrea	0.32	0.56	0.27	0.40	-1.90	0.66	-2.80	-1.33
promat	0.71	0.43	0.78	0.72	2.22	-0.77	3.41	2.92
soilpro	0.67	0.66	0.80	0.63	1.80	1.75	3.65	1.72
hurpro	0.77	0.60	0.70	0.74	2.86	1.10	2.43	3.18
nesit	0.92	0.93	0.94	0.90	4.44	4.71	5.35	5.31
nurs	0.82	0.93	0.83	0.72	3.39	4.71	4.01	2.92
clewa	0.60	0.33	0.48	0.25	1.06	-1.86	-0.24	-3.32
moral	0.96	0.96	1.00	1.00	4.87	5.04	6.08	6.63
natura	1.00	1.00	0.97	0.88	5.29	5.48	5.72	5.04
ecol1	0.85	0.96	0.97	0.97	3.70	5.04	5.72	6.24
ecol2	0.60	0.73	0.70	0.70	1.06	2.52	2.43	2.65
ecol3	0.85	0.93	0.89	0.95	3.70	4.71	4.74	5.97
scienc	0.96	0.96	0.89	0.95	4.87	5.04	4.74	5.97
negat	0.07	0.03	0.10	0.02	-4.55	-5.15	-4.87	-6.37
short	0.25	0.23	0.40	0.02	-2.65	-2.96	-1.22	-6.37
option	0.96	1.00	0.91	0.95	4.87	5.48	4.99	5.97
equity	0.89	0.96	0.89	0.97	4.13	5.04	4.74	6.24
exist	0.78	0.96	0.86	0.88	2.96	5.04	4.38	5.04
extern	0.39	0.20	0.35	0.09	-1.16	-3.29	-1.82	-5.44
willi	0.92	0.96	0.86	0.79	4.44	5.04	4.38	3.85
parti	0.21	0.06	0.16	0.15	-3.07	-4.82	-4.14	-4.64
urgro	0.32	0.40	0.57	0.61	-1.90	-1.10	0.85	1.46
porin	0.39	0.43	0.27	0.47	-1.16	-0.77	-2.80	-0.40
roads	0.28	0.20	0.43	0.36	-2.33	-3.29	-0.85	-1.86
garba	0.85	0.83	0.94	0.75	3.70	3.61	5.35	3.32
trewa	0.71	0.70	0.86	0.70	2.22	2.19	4.38	2.65
oilspi	0.46	0.66	0.91	0.77	-0.42	1.75	4.99	3.58
woode	0.32	0.40	0.45	0.54	-1.90	-1.10	-0.61	0.53
fishe	0.35	0.43	0.48	0.61	-1.59	-0.77	-0.24	1.46
hunte	0.39	0.43	0.64	0.52	-1.16	-0.77	1.70	0.27
lgral	0.85	1.00	0.97	0.97	3.70	5.48	5.72	6.24
lcons	0.74	0.88	0.84	0.97	2.54	4.16	4.14	6.24
lcont	1.00	1.00	1.00	0.97	5.29	5.48	6.08	6.24
lwood	0.85	0.86	0.96	0.97	3.70	3.94	5.60	6.24
lfish	0.88	0.86	0.82	0.97	4.02	3.94	3.89	6.24
lhunt	0.89	0.75	0.80	0.97	4.13	2.74	3.65	6.24
ltran	0.78	0.78	0.80	0.92	2.96	3.07	3.65	5.57

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Chapter 5

CONCLUSIONS & RECOMMENDATIONS

Findings from the change detection analysis and survey research provided the foundations for the following: 1) green vegetation losses, dune vegetation losses and urban and unconsolidated soil growth are changing the mangrove wetland, 2) differences were found between Chuburná, Chelem, Progreso and Prochub residents in their knowledge base for mangrove direct and indirect products use, and also in their knowledge of mangrove environmental services, attitudes toward resource use and awareness toward threats to mangroves. The implications of these findings to coastal management are discussed which leads us to several recommendations.

5.1 Assessment of the Natural Systems

5.1.1 Total Land Cover Changes and Road Proximity Map

Results of the change detection analysis indicated that land cover modifications have occurred for dune vegetation, evergreen vegetation and unconsolidated soil in the coastal areas of the State of Yucatán. Hypothesis **H1,** stating that *there has not been significant changes in the coastal areas of Progreso, Yucatán, México from 1986 to 1990*, was **rejected**. Dune vegetation, evergreen vegetation and unconsolidated soil has been converted from 1986 to 1990 to: 1) urban areas and 2) garbage dump facilities. Additional losses of green vegetation that changed to unconsolidated soil has been attributed to the effects of the road system.

A reduction of approximately 250 ha of dune vegetation was observed during the period 1986 - 1990 in the whole area. Dune vegetation was converted to urban area and providied nearly 61% of the total urban land growth. Total dune vegetated area was calculated to be 733 ha in 1990.

Unconsolidated soil also supplied land for urban development in the period, their contribution accounted for a total of 162 ha. This amount represents approximately 38% of the total urban land growth. Unconsolidated soil, even though converted to urban, grew during the studied period. This increment of unconsolidated soil was mainly a consequence of the loss of green vegetation (345.52 ha). Changes of unconsolidated soil were mainly located in the area of Progreso where clearing and filling for conversion to urban were taking place.

Green vegetation losses were linked to areas for solid garbage disposal. A large area was detected that changed form green vegetation to unconsolidated soil close to an unpaved road located between Progreso and Lactun. The area was cleared and impoverished by the dumping of solid garbage.

Dead mangrove trunks were found in the "Estero de Yucaltepen" on the road 261 between Progreso and Mérida (State capital) where loss of green vegetation was identified. The area of dead trees is contiguous to previously destroyed areas and located in semi-enclosed areas artificially created by the road network (see Figure 31 for main roads). Mangroves in this area are dying at the edge of the forest.

To illustrate possible trends in the development of the changed areas including the mangrove wetland, relationships were established between variables representing total changing areas and their distance to roads.

Road proximity maps and total changes indicated that:

1. Land cover changes decrease as distance to roads increases. It was observed that 52% of the total changes detected from 1986 to 1990 occurred at a distance of 600 m from the roads and 92% of the total changes occurred in the first 1800 m (Figure 30).
2. Similar patterns were also observed when new developed land, green vegetation losses and dune vegetation losses were overlaid on the road proximity map (Figure 31, Figure 32 and Figure 33)
3. A different pattern was observed for unconsolidate soil losses when it was overlaid on the road proximity map. Changes increase as distance from towns increase until they reach a maximum and start decreasing again (Figure 34).

5.1.2 Towns Land Cover Changes and Town Proximity Maps

Further analysis of the physical changes limited to the polygons in Figure 28 indicated that Progreso, the larger town, grew by approximately 150 ha during the period from 1986 to 1990. In contrast, Chuburná (the smaller town) grew by approximately 27 ha and Chelem by 56 ha during the period. These figures when divided by the population in Progreso 30,037, Chelem 2249 and Chuburná 1244 (INEGI 1990) shown that Chelem is the area that grew more per habitant.

Chuburná, Chelem and Prochub have affected the dune vegetation while Progreso has affected the unconsolidated soil including the dead mangrove areas. The reason Progreso is incorporating unconsolidated soil to urban is because almost all the dunes have already been converted to urban. Green vegetation losses in the area of Progreso accounted for approximately 148 ha in contrast to Chelem with 5 ha and Chuburna where regrowth was observed. Green vegetation in the area of Progreso changed primarily to unconsolidated soil due to solid garbage dumps and probably because of the effect of the road system.

Town proximity map and land cover changes per town indicated that:

1. Land cover changes had a similar pattern for all categories, it was observed that changes increase as distance from towns increases until they reach a maximum and start decreasing again (Figure 36).
2. Changes in Chuburná, Chelem and Prochub occurred primarily between developed land (↑) and dune vegetation (↓) with a maximum peak of change close to a distance of 500m from downtown (Figure 36).
3. Changes in Progreso occurred primarily between developed land (↑) and unconsolidated soil (↓) with a maximun peak of change close to a distance of 1200m from downtown and less with the dune vegetation (↓) with larger changes close to a distance of 2300m from downtown (Figure 36).

5.2 Assessment of the Social Systems

5.2.1 Knowledge about Mangrove Direct Use

Hypothesis for the analysis of mangrove direct use **H2a,** stating that *no differences exist across residents from Chuburná, Chelem, Progreso, and non-permanent residents in their knowledge about mangroves direct use*, was **rejected**. The test of homogeneity among Chuburná, Chelem, Progreso and Prochub was rejected, as 3 out of 3 variables did not meet the criteria to accept (*i.e.*, χ^2 goodness of fit). Results showed that different proportions of the residents use or/and know that other residents in the area use mangrove direct products for: 1) energy production, 2) home repairs and construction, and 3) fishing tools construction.

An examination of Table 51 for the departure of homogeneity and a tree diagram for cluster analysis Figure 41(a) revealed that residents from **Chuburná** and **Chelem** were the most **similar**. Observed values in the number of responses for all mangrove direct use variables were above the expected values. Similarities were also found with residents from **Prochub** and **Progreso** where all observed values were below the expected values.

Table 51 - Departures from homogeneity for mangrove direct use: firewood, home construction, and fishing tool construction

Variable	Expected Value	Chelem (residuals)	Chuburná (residuals)	Progreso (residuals)	Prochub (residuals)
Firewood	49.64%	Above (8.1)	Above (8.1)	Below (3.3)	Below (12.8)
Construction	27.34%	Above (5.3)	Above (8.7)	Below (6.1)	Below (8.0)
Fishing tools Construction	16.55%	Above (2.36)	Above (5.03)	Below (3.12)	Below (4.28)

From these data the following was concluded:

1. **Larger** proportions of residents from **Chuburná** and **Chelem** use or/and know that others use mangrove wetland wood for **energy production** than do residents from **Progreso** and **Prochub**.
2. **Larger** proportions of residents from **Chuburná** and **Chelem** use or/and know that others use mangrove wetland wood for **home construction** than do residents from **Progreso** and **Prochub**.
3. **Larger** proportions of residents from **Chuburná** and **Chelem** use or/and know that others use mangrove wetland wood for **fishing tool construction** than do residents from **Progreso** and **Prochub**.
4. **Larger** proportion of residents from **Chuburná** and **Chelem** know that **direct products** are taken from the mangroves, than do residents from **Progreso** and **Prochub**.

Expected proportions in the number of answers computed from the total population for mangrove direct products (energy production 49.64%, home construction 27.34%, and fishing tool construction 16.55%) indicate: 1) 1 out of 2 residents from the whole sample use and/or know that wood from the mangrove wetland is used in the area for energy production, 2) 1 out of 4 use and /or know that mangroves are used for home repairs and construction and 3) 1 out of 6 use and/or know that mangroves are used for fishing tool construction.

5.2.2 Knowledge about Mangrove Indirect Use

Hypothesis for the analysis of the mangrove indirect product use under **H2b**, stating that *no differences exist across residents from Chuburná, Chelem, Progreso, and non-permanent residents in their knowledge about mangroves indirect use*, was **rejected**. Hypothesis H2b, which test for homogeneity between Chuburná, Chelem, Progreso and Prochub was rejected, as 7 out of 8 variables did not meet the criteria to accept. Analysis showed that different proportions of the residents use or/and know that other residents in the area use the following mangrove indirect products: 1) finfish, 2) crustacean, 3) mollusk, 4) bird, 5) mammal, 6) reptiles, 7) insects, and 8) recreational purposes.

Deviation from homogeneity (Table 52) and cluster analysis (Figure 51) for fishing activities related to finfish, mollusks and crustaceans indicated that residents from **Chuburná** and **Chelem** are the most **similar** in their knowledge about fish and shellfish **mangroves indirect use** products.

Table 52 - Departures from homogeneity for mangroves indirect products: finfish, crustacean and mollusk.

Variable	Expected Value	Chuburná (residuals)	Chelem (residuals)	Progreso (residuals)	Prochub (residuals)
Finfish	60.53%	Above (3.0)	Above (6.8)	Below (1.3)	Below (8.5)
Crustacean	56.12%	Above (3.3)	Above (11.4)	Above (4.2)	Below (18.9)
Mollusk	45.32%	Above (6.28)	Above (11.1)	Below (4.7)	Below (12.7)

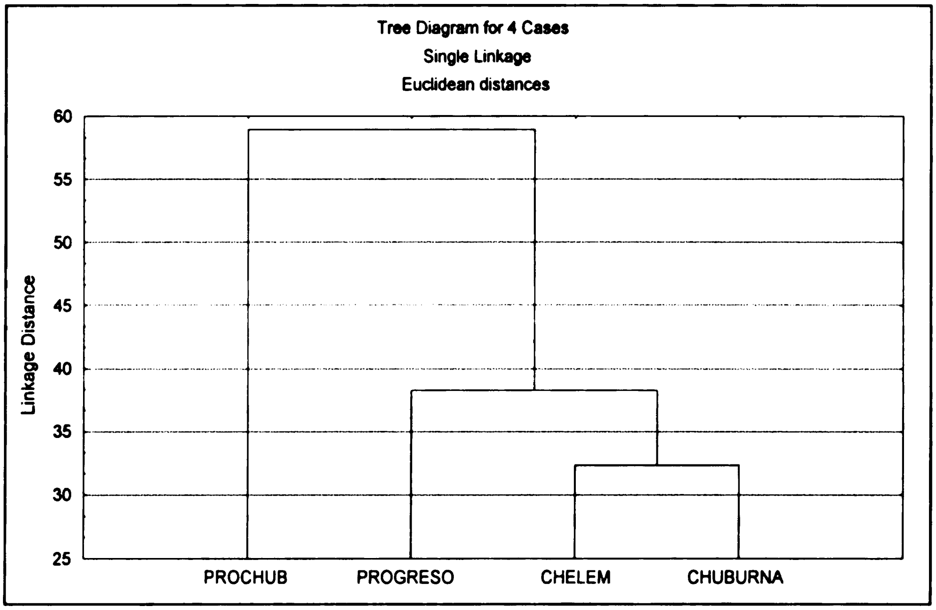

Figure 51 - Tree cluster analysis for mangroves indirect products: finfish, mollusk and crustacean.

From this data the following was concluded:

1. **Larger** proportions of residents from **Chuburná** and **Chelem** harvest or/and know that others harvest **finfish** than do residents from **Progreso** and **Prochub** .
2. **Larger** proportions of residents from **Chuburná**, **Chelem**, and **Progreso** harvest or/and know that others harvest **crustaceans** than do residents **Prochub**.
3. **Larger** proportions of residents from **Chuburná** and **Chelem** harvest or/and know that others harvest **mollusks** than do residents from **Progreso** and **Prochub.**

4. **Lower** proportion of residents from **Prochub** harvest or/and know that others harvest **finfish**, **mollusks** and **crustaceans** than do residents from **Chuburná**, **Chelem** and **Progreso**.

5. **Chuburná** and **Chelem** were the most similar towns followed by **Progreso** and **Prochub** when variables for finfish, crustacean and mollusk were taken simultaneously in a cluster analysis (Figure 51).

Deviation from homogeneity (Table 53) and cluster analysis (Figure 52) showed that hunting activities related to birds, mammals and reptiles indicated that residents from **Progreso** and **Chuburná** were the most **similar** when use and/or knowledge about **hunting in the mangrove** wetland was considered.

Table 53 - Departures from homogeneity for mangrove indirect products: birds, mammals and reptiles.

Variable	Expected Value	Chuburná (residuals)	Chelem (residuals)	Progreso (residuals)	Prochub (residuals)
Birds	30.22%	Above (6.5)	Above (3.9)	Below (0.2)	Below (10.3)
Mammal	24.46%	Below (1.8)	Above (7.6)	Below (8.0)	Above (2.2)
Reptiles	7.19%	Above (1.9)	Above (.84)	Above (.34)	Below (3.17)

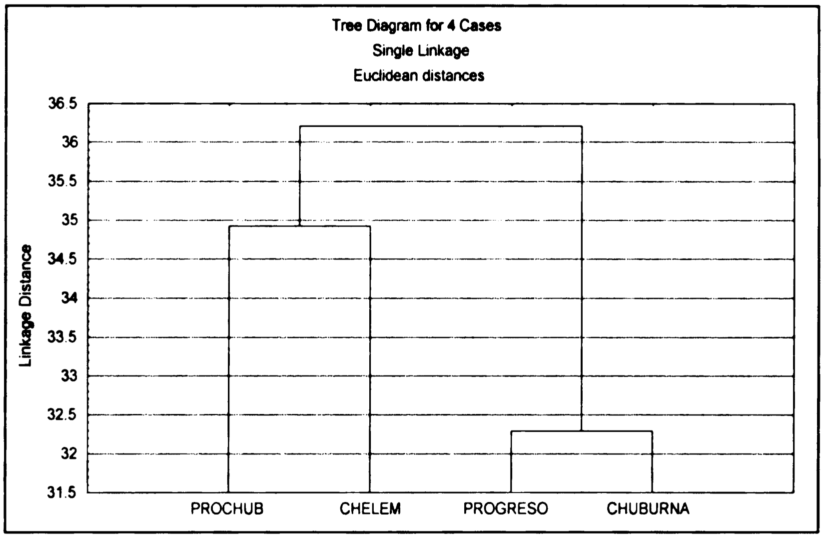

Figure 52 - Tree cluster analysis for mangroves indirect products: birds, mammals and reptiles.

The following conclusions were drawn:

1. **Larger** proportions of residents from **Chuburná** and **Chelem hunt birds** or/and know that others hunt birds than do residents from **Progreso** and **Prochub**.
2. **Larger** proportions of residents from **Chelem** and **Prochub hunt mammals** or/and know that others hunt mammals than do residents from **Progreso** and **Chuburná**.
3. **Larger** proportions of residents from **Chuburná**, **Chelem** and **Progreso hunt reptiles** or/and know that others hunt reptiles than do residents from **Prochub**.
4. Residents from **Progreso** and **Chuburná grouped** as well as residents from **Prochub** and **Chelem** when **birds, mammals and reptiles** variables are considered.

5. **Larger** proportions of residents from **Chelem** and **Prochub** use the area for **recreational purposes** and/or know that others use the area for recreational purposes than do residents from **Chuburná** and **Progreso**.

5.2.3 Knowledge about Environmental Services

Resident knowledge about the mangrove environmental services were studied under **H2c** for homogeneity. H2c stating that, *no differences exist across residents from Chuburná, Chelem, Progreso, and non-permanent residents in their knowledge about mangroves environmental services*, was **accepted.** This analysis found that there was not a significant variability amongst the residents responses in 4 out of 6 mangrove environmental service variables (*i.e.*, soil protection, hurricane protection, nesting site and nursery places). Significant differences, however, were found for production of organic matter and water quality.

Expected values and deviations from homogeneity for each town are shown in Table 54. Cluster analysis in Figure 53 showed that residents from **Progreso** and **Chuburná** are the most **similar**, followed by residents from Prochub and Chelem when the production of organic matter and the remotion of nutrients by the mangroves were introduced in the analysis (**environmental benefits**).

Table 54 - Departures from homogeneity for mangrove environmental benefits.

Variable	Expected Value	Chuburná (residuals)	Chelem (residuals)	Progreso (residuals)	Prochub (residuals)
Production of organic matter	67.63 %	above (1.06)	below(7.28)	above(3.9)	above(2.24)
Soil protection	69.57 %	below(.47)	below(.86)	above(3.95)	below(2.6)
Hurricane protection	70.8	above(1.88)	below(3.24)	below(.19)	above(1.55)
Nesting site	92.65 %	above(.05)	above(.2)	above(.5)	below(.76)
Nursery area	81.88 %	above(.07)	above(3.4)	above(.7)	below(4.2)
Water quality	40.58 %	above(5.6)	below(2.17)	above(2.9)	below(6.4)

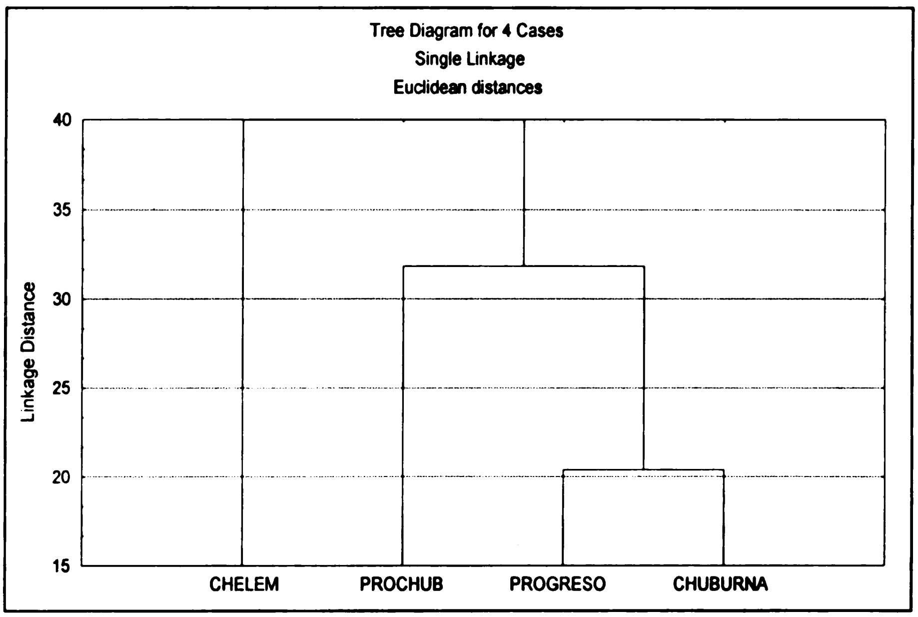

Figure 53 - Tree cluster analysis for mangrove environmental benefits.

Even though statistical differences were not found in 4 out of 6 variables, non-permanent residents (Prochub) had the largest negative distance from the expected value for variables, soil protection, nesting site, nursery area and water quality. Additional information provided by residents during the interviews, it appears that permanent residents are more knowledgeable about the environmental benefits provided by the mangrove wetland. Examples were given by permanent residents about hurricane and storm protection, and mangrove wetland use as a feeding and nursery areas for fish, crustacean and mollusks and for bird nesting sites.

5.2.4 Attitudes toward Resource Use

Attitudes toward resource use were studied under H2d. Hypothesis **H2d** stating that, *no differences exist across residents from Chubumá, Chelem, Progreso and non-permanent residents in their attitudes towards long term resource*, was **accepted.** Results from the 14 variables analyzed for attitudes (H2d), provided little evidence about the differences between residents, as 12 out of 14 variables were not rejected for homogeneity. The following expected values for attitude variables were found: 1) **moral obligation** 98.56% (which means that a high percentage of residents were in agreement), 2) **cause satisfaction** 95.68%, 3) **environmental changes** may affect fish 94.96%, 4) **excessive harvesting** affect natural production 69%, 5) **vegetation** the basis of fish production 91.37%, 6) **conservation** for research purposes 94.24, 7) wetland as producer of **dangerous creatures** 91.5%, 8) **no short term benefits** 74.82%. 9) **option for the future** 95.68%, 10) wetlands for **future generations** 93.53, 11) **existence value** 87.77, 12) **externalities** 66.19, 13) **willingness to contribute** (*i.e.*, money, work) for mangroves conservation 87.77, and 14) **willingness to participate** 74.82.

The following conclusions were drawn (percentages and their confident intervals are shown in Table 49):

1. Close to thirty percent (**30%**) of the residents do **not agree** that **intense harvesting** would **affect** the **natural production** and may reduce flora and fauna populations to undesirable levels for harvesting.
2. Close to thirty percent **(30%)** of the residents do **not believe** that their **actions impact other residents.**
3. Close to twenty five percent **(25%)** of the residents **believe** that is **better** to **receive at the present** as many **benefits** as possible from the wetland whatever the consequences in the future.
4. An overall value of **86.7%** of responses had a positive attitude. This value was **interpreted** as **residents who have a positive attitude** for **long term resource use.**

5.2.5 Awareness regarding threats to mangroves

Awareness regarding threats to mangroves was studied under **H2e** for homogeneity. Hypothesis H2e, stating that *no differences exist across residents from Chubumá, Chelem, Progreso and non-permanent residents in their attitudes regarding threats to mangroves*, was **accepted**. This analysis found that 8 out of 9 nine variables (urban growth, port infrastructure, road network, solid garbage disposal, untreated waste water, wood extraction, fishing, and hunting) met the criteria for acceptance. Oil spills was significantly different between groups.

Expected values and deviations from homogeneity for each area are shown in Table 55 for urban growth (p = 0.5235) and oil spills. Cluster analysis in Figure 54 showed that resident from Progreso and Prochub are similar and more aware than are residents from Chuburná and Chelem regarding the impacts that urban growth and oil spills may have on the mangrove wetland.

Table 55 - Departures from homogeneity for awareness regarding threats to mangroves.

Variable	Expected Value	Chuburná (residuals)	Chelem (residuals)	Progreso (residuals)	Prochub (residuals)
urban growth	49.64 %	below (4.9)	below (2.89)	Above (2.63)	Above (5.16)
oil spills	72.66 %	below (7.35)	below (1.8)	Above (7.12)	Above (2.03)

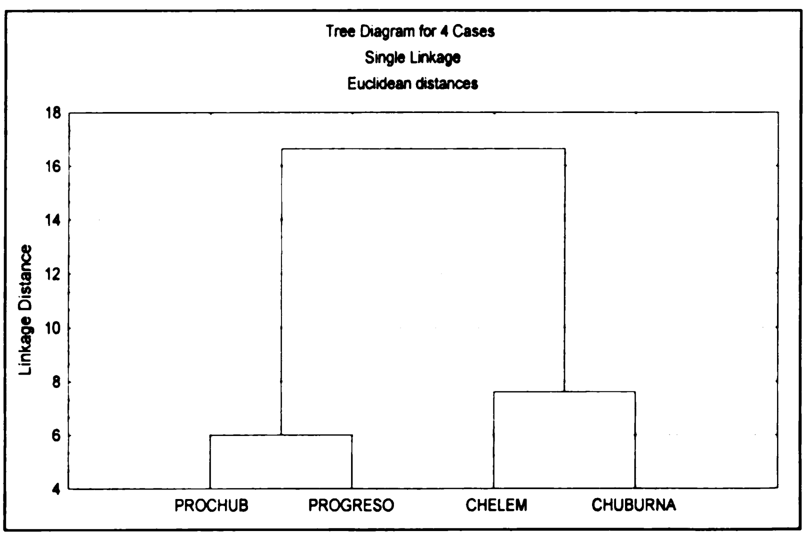

Figure 54 - Tree cluster analysis for awareness regarding threats to mangroves.

The following conclusions were drawn:

1. **Larger** proportion of residents from **Progreso** and **Prochub** are **aware** of **urban growth** and **oil spills** than are residents from **Chuburná** and **Chelem**.
2. Residents felt that there is a **current threat** to mangroves and associated fauna. Resident responses indicated that: a) threats above the 50% response rate are: **solid garbage** (84.17%), **untreated water** (74.82%), and **oil spills** (72.66%); b) threats with 50% response rate: **urban growth** (49.64%), **wood extraction** (44.6%), **fishing** (48.9%), and **hunting** (51.08%); and c) threats below the 50% response rate: **port infrastructure** (39.57%) and **road system** (33.09%). Table 50 at the end of Chapter 4 summarize the variables with z values for testing $p = 0.5$ vs. $p \neq 0.5$.

5.2.6 Acceptance of Regulation

Testing of hypothesis **H2f**, stating that *no difference exist across residents from Chuburná, Chelem, Progreso, and non-permanent residents to accept mangrove wetland regulation*, resulted in the **acceptance** of the null hypothesis H_0 . Results indicated that all proposed needs of regulation had a high rate of acceptance and no significant differences were found across the groups. The expected values (percentages of responses) for all variables were as follows: 1) 95.65% agreed with the need to enforce regulation, 2) 87.69% agreed with strength regulation for construction, 3) 99.28% agreed with the prohibition of dumping in wetland, 4) 92.37% agreed with the prohibition of cutting living trees,

5) 89.55% agreed with the need for licenses and seasons for hunting, 6) 86.76% agreed with the need for licenses, art regulation and seasons for fishing, and 7) 84.03% agreed with motor boat traffic regulation.

A test for significant difference indicated that all responses were above 50% rate of response. The researcher concludes that residents from the study areas are in general willing to accept regulation in order to control several activities to protect vegetation, wildlife, fish, and water in the area. Significant differences were not found between groups.

5.3 Implications and Recommendations

Observed physical changes in the study area provide indications of how urban development and infrastructure projects have changed fragile ecosystems such as dune vegetation and mangrove ecosystems. Study results can contribute to the design of environmental policies in the area that account for the heterogeneity in residence knowledge base concerning: (i) the potential use a non-use values of mangrove wetlands, (ii) the intertemporal preferences in resource use, and (iii) the awareness of environmental impacts of urban expansion, solid waste disposal in wetlands, and coastal road network. Effective implementation of Mexican environmental policy in the study area most consider the above mentioned findings in order to design and implement effective coastal policies and regulations. The identified resident knowledge base could provide a relevant input for the design of environmental education programs dealing with coastal resource development and conservation. Both, regulatory and environmental education may help in the mitigation of reversible negative effects created by coastal growth, and provide a solid base for sustainable development in areas close to coastal wetland ecosystems of the Yucatan.

a) Mangrove direct use. The mangrove wetland is a source of important resources for coastal communities in Chuburná, Chelem and Progreso. It provides wood for energy production, home repairs and construction, and fishing tool construction. Results from this study indicated that a proportion of 78% ± 1.5 of the residents from Chuburná and 76% ± 1.5 from Chelem with populations around 1250 and 2250 habitants use or/and know about the uses of the mangrove wetland firewood (see Table 48 for % figures related to home repairs and fishing tool construction). In Chuburná and Chelem the evergreen losses detected were close to 0.0 and 4.0 ha respectively. Progreso has a population close to 30,000, and 40% ± 1.5 of the residents have knowledge about the direct use of the mangroves for firewood. This area has sustained evergreen losses close to 150 ha from 1986 to 1990.

The above findings have strong implications for Progreso residents who daily depend upon the mangrove wood (especially for those residents living on the borders of the mangroves where the town figure of 40% changed to 67% when data is analyzed by stripes). A large and increasing population and the decreasing resource size will increase the pressure on the wood mangrove wetland and on the people living in Progreso in the stripe facing the mangrove wetland.

b) Mangrove indirect use. Mangrove wetland also supports fish and other wildlife populations with value for coastal communities. As indicated by the survey, 71% ± 1.6 residents from Chuburná , 83% ± 1.3 from Chelem and 56% ± 1.5 from Progreso capture or/and know others who capture finfish. Percentage figures for mollusks and crustaceans percentage are in Table 48. Awareness that many of the captured species rely on the abundance and health of the mangrove wetland vegetation, means that mangrove losses in the area of Progreso will lead to fewer fish, mollusk, crustaceans and birds for fishing and hunting. This in turn will increase the pressure on people already living at the poverty level who depend on daily capture for food.

d) Mangrove ecological benefits. In the survey, the proportion of residents who indicated that they knew the ecological functions of the mangroves were as follows: for production of organic matter: Chuburná (71% ± 1.6), Chelem (43% ± 1.7, Progreso (78% ± 1.3), and Prochub (72% ± 1.3. Similar results were also found for mangroves soil erosion protection, hurricane protection and removal of nutrients in the water (these results can be found in Table 48). These findings have implications for mangrove conservation as well as for the dependent biota because this lack of resident knowledge may lead to practices which contribute to mangrove alteration. An Improvement in resident knowledge concerning the ecological functions and a recognition of the benefits gained in sustaining healthy the mangrove wetlands in the area will help the communities in Chuburná, Chelem and Progreso to appreciate and give more value to mangroves.

e) Attitudes toward resource use. Vegetation and other dependent resources from the mangrove wetlands are also negatively affected by residents attitudes. Even though there was a the high rate of positive responses (statistically significant $p \neq 0.5$), awareness must be raised in these communities concerning for the long term use of mangrove wetlands and their natural resources in the following areas:

1) That a balance must exist between natural production and harvesting. At present 60% ± 1.8 of residents in Chuburná, 73% ± 1.5 in Chelem, 70% ± 1.4 in Progreso, and 70% ± 1.3 in Prochub agree that intense harvesting would affect the natural production. Attention must be paid in Chuburná where $p \neq 0.5$ was not rejected. This has implications for regulations that attempt to limit captures or extraction, because closing seasons or limiting fishing may not be well received.

2) That we need to think more regarding the future of the mangroves since 25% ± 1.2 of the residents from Chuburná, 23% ± 1.5 from Chelem, 40% ± 1.5 from Progreso and 2% from Prochub want to receive as many benefits as possible in the present from the mangroves regardless of future consequences. Chuburná, Chelem, and Prochub were statistically rejected to be $p = 0.5$ (with values in the lower tail), however Progreso was not rejected indicating more preference in receiving the benefits today even though residents were aware (70% ± 1.4) that the natural production will be affected.

3) That we must understand that some of our actions have a negative effect on others. This is in contrast with the belief of 40% ± 1.8 of the residents from Chuburná, 20% ± 1.4 from Chelem, 35% ± 1.5 from Progreso and 9% ± 8.0 from Prochub who think that their actions do not have negative consequences for

others. In this case % figures from Chuburná and Progreso were not rejected for $p \neq 0.5$. This have implications in connection with the regulation of residents action towards the mangrove wetland.

e) Awareness regarding threats to mangroves. Lack of awareness regarding threats to mangroves also have implications for mangrove wetland conservation and resource use.

1) Urban areas as a threat to mangroves were perceived by 32% ± 1.7 from Chuburná and 40% ± 1.7 from Chelem in contrast to 57% ± 1.5 of residents from Progreso, 61% ± 1.4 from Prochub. These figures do not support a clear positive or negative position concerning urban developments as threats to mangroves (-1.88, -1.09, 0.82, 1.5, $p \neq 0.5$ accepted) Table 49. However, this data could help to understand residents reaction towards a policy for the control of urban expansion. Urban constructions in Chuburná, Chelem and Progreso have eliminated close to 130 ha of dune vegetation. Furthermore in Progreso decisions relating to the new developments have also led to the filling of the mangrove wetland.

2) The road system is perceived as an even lower threat to mangroves since 28% ± 1.6 from Chuburná, 20% ± 1.4 of the residents from Chelem, 43% ± 1.5 Progreso, and 36% ± 1.4 from Prochub perceived that the road system has an impact on the mangrove wetland (-2.26, -3.28, -0.82, -1.8) Table 49. This, probably, is a reason that new road developments have encountered little resistance. Residents did not even request that roads were constructed in a way that minimize their ecological damage to the mangrove wetland.

3) Solid garbage and untreated water dumped and discharged in the wetland were seen as high threats to mangroves in all of the towns (3.7, 3.6, 5.4, 3.3). This suggests that there would be support from residents against untreated discharges and disposal of solid garbage in the mangrove wetland. This also suggests that resident may wish to move current garbage facilities to other safety areas.

4) Regarding fishing, hunting and wood extraction residents do not appear to favor a position that these actions are now a threat to mangroves and dependent resources since all towns were not significant different to $p \neq 0.5$. These in addition to previous discussed factors may not facilitate the implementation of regulation and control of these activities.

Results from this study indicate that mangrove wetland wood and related finfish and shellfish in the Chelem Lagoon are important resources for residents living in Progreso, Chuburná and Chelem all year around and appear to be especially important during the hurricane season. In the light of the following: 1) that mangrove wetland vegetation support coastal resources, 2) that mangroves are threatened by a complex mix of cumulative effects of conversion, solid garbage dumps and the road network, 3) that residents seems to have in general a positive attitude towards long term resource use, 4) that residents are aware of some of the threats to mangroves, and 5) that residents are willing to accept and participate in enforcing regulation, the following recommendations were made:

1) decisions affecting the mangrove wetland must take note of the results of this study in considering projects that may negatively impact the mangrove wetland.

This also is true for the well being of the people in the area (i.e., Chelem and Chuburná).

2) The ongoing fisheries in the lagoon must be studied to keep them in balance with their natural production and with the environment. The low capture from marine fisheries, increasing coastal population, and the alternative use of the lagoon for fishing during storms and the hurricane season, will increase the pressure on finfish and shellfish resources (*i.e.*, the fisheries of the *Melongena corona*, *Callinectes sapidus* and *Libinia dubia*, as well as, the multispecific finfishery in the coastal lagoon.

3) The amount of wood extracted and their economic value must be known (i.e., for energy production and construction).

4) A complete and precise calendar of coastal activities to identify critical dates and activities must be identified (*i.e.*, who, when, what, and where is to be harvested).

5) Food and health conditions of the human population must be known in the stripe facing the mangrove wetland (*i.e.*, contribution of wetland products to protein intake and the state of health of these population)

6) Urban growth in Progreso must be controlled as the primary threat to the mangrove wetland, as well as construction of vacation homes that are eliminating the dune vegetation.

7) A regular water-quality monitoring program must be considered and initiated in several critical points (*i.e.*, Progreso, where dump facilities are located and also in the lagoon Chelem, where oil spills produced by boat repair and maintenance may have an impact on mangroves and related fauna).

8) Critical information about the ecological role of the mangrove wetland must be provided to residents to promote the long term use of the coastal natural resources.

9) Environmental problems that were frequently perceived by residents must be considered as topics for future research and implementation (*i.e.*, the solid garbage disposal, the treatment of sewage, and oil disposal)

10) An integrated coastal zone management program must be implemented as an alternative to minimize the negative effects on the environment created by the needs, lack of knowledge and attitudes of all participants in the development of the coast. The integrated program will benefit all and specially those groups who's daily survival is based on the mangrove wetland.

APPENDICES

APPENDIX A

Coastal Zone Management Research Project

Mangrove Wetlands:

Uses, Environmental Knowledge, and Attitudes of their People

Centro de Investigación y de Estudios Avanzados del IPN
Department of Marine Resources
Unidad Mérida
1996

Introduction and Consent

Good morning, my name is José . I am from CINVESTAV, a research and educational institution in Mérida, Yucatán, México. We are talking to people living in the coastal areas of Progreso Yucatán, México. The main subjects in this interview are related to: 1) current uses of the mangrove wetland, 2) information about the mangroves ecological functions, and 3) attitudes towards long term use of natural resources in the area. Information learned from this study will help to us understand coastal zone development.

The characteristics of this survey are as follows:

- The questionnaire has several short sections
- The survey will take about 1/2 an hour.
- All your answers will remain confidential.
- You do not have to answer any question you feel is inappropriate.
- There is no right or wrong answare
- You may also withdraw from the interview
- All your answers are very valuable to the project
- Your cordial participation is important and greatly appreciated.

To continue with the interview, I WANT TO MAKE SURE YOU UNDERSTAND THE PROCEDURE AND THAT YOU AGREE TO PROCEED WITH THE INTERVIEW.

Please check the appropiate box: YES ☐ NO ☐

If you have any questions or would like to receive a copy of our findings, please contact:

Jorge I Euan-Avila of the Department of Marine Resources, AP 73 Cordemex, 97310, Mérida, Yucatán, México at (99) 81-29-03 or (99) 81-29-05 Ext 273, CINVESTAV Unidad Mérida.

Thank you very much.

Section 1. Mangroves Wetland Use

A picture (photo No. 1) of the area where the respondent live is used to indicate the site of interest of this study .

Q.1 Would you like to tell us the name you use to designate the area that is shown inside the RED circle in PHOTO #1?

R ______________________________

In picture (Photo #2) we have trees that live partially submerged in water.

Q.2 Would you like to tell us the name you use to designate those trees shown inside the RED circle in PHOTO #2?

R: ______________________________

Q.3 Do you make use of any part of these trees such as the wood, roots, flowers, leaves or any other part of the tree?

Yes No

In talking with various members of the community, we learned of some possible uses of these trees.

Q.4 Please indicate from the following list your current uses and add other uses people make of these trees. Add any others not present on the list.

He (✓)
Others (✓)

1. Firewood

Cooking or heating ....
Smoking fish ....
Burning bricks ....
Comercial purposes ....
Other ....

2. Wood for construction

Beams and Poles for houses ....
Boat-building Materials ....
Fence posts..
Furniture ....
Toys ....
Comercial purposes ....
Other ....

3. Fishing Arts

Poles for fish traps ....
Fishing floats ....
Tannins for net preservation ....
Fish attracting shelters ....
Comercial purposes ....
Other ....

4. Agriculture

Fodder ....
Green Manure ....
Comercial purposes ....
Other ....

5. Food and Drugs

Tea ....
Condiments ....
Medicines ....
Comercial purposes ....
Other ....

Q.5 Do you know of any other trees harvested in this area Photo #1 that people make use of them?

Yes ☐ No ☐

Q.6 Can you mention them?

R:____

Q.7 What other benefits you receive from this area (Photo #1) in practicing hunting, fishing, swimming, bird watching or any other activity? Use the following list.

He (✓)
Others (✓)

	He	Others
1. Finfish		
Food	☐	☐
Bait	☐	☐
Fertilizer	☐	☐
Comercial purposes	☐	☐
Other	☐	☐
3. Crustacean		
Food	☐	☐
Bait	☐	☐
Fertilizer	☐	☐
Shells	☐	☐
Comercial purposes	☐	☐
Other	☐	☐
5. Mollusc		
Food	☐	☐
Bait	☐	☐
Fertilizer	☐	☐
Shells	☐	☐
Comercial purposes	☐	☐
Other	☐	☐
7. Birds		
Food	☐	☐
Feather	☐	☐
Watching	☐	☐
Hunting	☐	☐
Comercial purposes	☐	☐
Other	☐	☐

	He	Others
2. Mammals		
Food	☐	☐
Fur	☐	☐
Watching	☐	☐
Sport Hunting	☐	☐
Comercial purposes	☐	☐
Other	☐	☐
4. Reptiles		
Food	☐	☐
Skins	☐	☐
Comercial purposes	☐	☐
Other	☐	☐
6. Insects		
Honey	☐	☐
Wax	☐	☐
Comercial purposes	☐	☐
Other	☐	☐
8. Services		
Swiming	☐	☐
Walking	☐	☐
See the Sunrise	☐	☐
Playing	☐	☐
Other	☐	☐

Section 2. Mangroves Wetland Conversion

Q.8 Do think that in the area shown in Photo #1 there are important changes in the land use or cover?

Yes No

Q.9 How do you think this changes are ocurring?

Fast (in less than 5 years) moderate (5 to 15) Low (more than 15)

Q.10 Can you tell us the current use(s) of the area(s), starting year, and place. Use the following list.

	Check Here (✓)	Year	Place
Residential use	☐	....	....
Road Constructions	☐	....	....
Pipe Introductions	☐	....	....
Parking Lots	☐	....	....
Aquacultural ponds	☐	....	....
Agriculture	☐	....	....
Marine Infraestructure	☐	....	....
Solid waste Disposal	☐	....	....
Salt pond developments	☐	....	....
Storage Areas	☐	....	....
Oil Industry	☐	....	....
Fish Industry	☐	....	....
Sewage	☐	....	....
Recreational and Tourism facilities	☐	....	....

Section 3. Attitudes Toward Sustainable Resource Use

Q.11 We want you to rate the following sentences using the following options: Agree (3), Neutral (2), Disagree (1), and No answare (0).

Agree	Neutral	Desagree	
☺	😐	☹	No answer
3	2	1	

1.	We have a moral obligation to protect fish and wildlife	3	2	1	0
2.	It cause me satisfaction to see the wetland and its wildlife	3	2	1	0
3.	Nature is interesting	3	2	1	0
4.	Wetlands are ugly places	3	2	1	0
5.	Wetland animals do not become sick	3	2	1	0
6.	Sewage discharged into the wetland affects the fish	3	2	1	0
7.	Regardless of how much we exploit resources nature will always continue to provide enough for our needs	3	2	1	0
8.	More vegetation mens more fish	3	2	1	0
9.	Fish in the sea depend on the wetlands	3	2	1	0
10.	We need to conserve the wetlands for study	3	2	1	0
11.	It is the same to catch young or old animals	3	2	1	0
12.	Wetlands are not important for fish and birds	3	2	1	0
13.	We know everything about the wetlands	3	2	1	0
14.	We have large wetlands and should not be worried now for their future	3	2	1	0
15.	Different plants and animals add value to wetlands	3	2	1	0
16.	Wetlands only produce dangerous animals to people	3	2	1	0
17.	Crocodiles and aligators should exclusive be kept in zoos	3	2	1	0
18.	Wetlands are only valuable because their products	3	2	1	0
19.	Wetlands may not exist in the future. Therefore, I must exploit them as much as possible now.	3	2	1	0
20.	Wetlands conservation is needed because may be in the future we will find valuable things in the wetland	3	2	1	0
21.	I do not have an obligation to conserve the wetlands for others	3	2	1	0
22.	The only reason that wetlands will exist in the feature is important to me to participate in conservation.	3	2	1	0
23.	Anything people do on their property will not create problems for others	3	2	1	0
24.	Wetlands areas are not sufficiently important for us to make too many provision efforts to save them.	3	2	1	0
25.	I would sacrifice something to uphold the purpose of wetland conservation	3	2	1	0
26.	Because elections are important, I always vote	3	2	1	0
27.	Wetland meetings are a waste of time	3	2	1	0

Section 4. Land Use

Q.12 Thinking in the area shown in PHOTO #1, would you like to tell us your opinion about the next questions?

		Agree ☺ 3	Neutral 😐 2	Desagree ☹ 1	No answer
1.	Are you willing to accept the use of the law to control some activities to protect land, vegetation, wildlife, and water in this area?	3	2	1	0
2.	This law may demand more control on home, roads, and boat landing constructions. Is this acceptable?	3	2	1	0
3.	This law may prohibit the use of wetlands for dumping. Is this acceptable?	3	2	1	0
4.	This law may prohibit the cutting of living trees. Is this acceptable ?	3	2	1	0
5.	This law may prohibit hunting during some seasons. Is this acceptable?	3	2	1	0
6.	This law may close fishing grounds and regulate fishing arts. Is this acceptable?	3	2	1	0
7.	This law may control the number of boats and trips. Is this acceptable ?	3	2	1	0
8.	Do you support hunting permits?	3	2	1	0
9.	Do you support fishing permits?	3	2	1	0
10.	Do you support wetland conversion?	3	2	1	0
11.	Are you willing to participate in discussing this regulations?	3	2	1	0

Section 5. Perceptions towards menaces

Q.13 From the following list please tell us which ones you consider current threats to mangrove wetlands and your perception of the environmental impact magnitude (1 minor, 2 moderate, 3 mayor)

(3 mayor, 2 moderate, 1 minor, 0 I can not rate)

Growing Land Uses	y/n				
Urban expansion		3	2	1	0
Port Infrastructure		3	2	1	0
Salt pond expansion		3	2	1	0
Aquaculture Development		3	2	1	0
Roads expansion		3	2	1	0
Cattle		3	2	1	0
Agriculture		3	2	1	0
Wastes					
Home/Industrial/markets/ or commercial wastes		3	2	1	0
Septic Tank Leaks		3	2	1	0
Garbage from Vessels		3	2	1	0
Oil pipes Leaks		3	2	1	0
Animals waste		3	2	1	0
Use Rate					
Wood extraction		3	2	1	0
Commercial Fishing		3	2	1	0
Subsistance Fishing		3	2	1	0
Hunting		3	2	1	0
Population Growth					
Population Size		3	2	1	0
Location		3	2	1	0
Proposed Developments					
Srimp aquaculture		3	2	1	0
Open sea fishing		3	2	1	0
Port infraestructure		3	2	1	0
Artificial reefs		3	2	1	0
Tourism		3	2	1	0

Sección 6. Servicios al Ambiente.

Q. 14 Below we have a list of environmental services provided by mangrove wetland. For each one, please check those that you know and your opinion about how important are they for the environment.

	Know? (Y/N)	+ important - H	M	L	N
1. Mangroves are a source of food for many small animals that live in the swamp. These small animals are also food for other useful animals.		3	2	1	0
2. Mangrove protect the soil. Without this plants tides would erode the soil.		3	2	1	0
3. Mangrove trunks and branches protect other plants and animals from hurricanes and storms.		3	2	1	0
4. Mangrove branches are the place where birds construct their nests to reproduce, protect, and grow.		3	2	1	0
5. Calm waters close to mangrove roots are the place where fish and crustaceans reproduce, protect, and grow.		3	2	1	0
6. Mangroves roots and soil help to keep water clean. They trap substances mixed in the water.		3	2	1	0

Section 7. General Information

Q.15 Birth Date (mm/dd/yy) ____________________

Q.16 Sex (M=male/F=female) __________ Q. 17 Married (Y/N) __________

Q.18 Job ____________________

Q.19 Number of years living in the area (years) ____________________

Q.20 Number of years in School (years) ____________________

Section 8. Final Comments

Q.21 We appreciate the time that you have set aside for this interview and I am happy to make a note of any of your suggestions.

____

____

____

APPENDIX B

DICTIONARY OF VARIABLES

Natural system

Land cover changes

dl Developed land

eg Evergreen vegetation

us Unconsolidated soil

dv Dune vegetation

de Deciduous

ndl New developed land

egl Evergreen vegetation losses

usl Unconsolidated soil losses

dvl Dune vegetation losses

Social system

Mangrove direct uses

firewood Cooking or heating,

conwood Beams and poles for houses, boat-building materials, fence post, furniture, and toys

artwood Poles for fish traps, fishing floats, tannins for net preservation, and fish attracting shelters.

agricul * Fodder, and green manure

foodru * Tea, condiments, and medicines

Mangrove indirect products

finfish Food, fertilizer, and bait

mamma Food, fur, observation, and sport Hunting

crust Food, fertilizer, and bait

repti Food, skin, observation, and sport hunting

mollu Food, fertilizer, bait, and shells

insect Food, honey, wax

birds Food, feathers, observation, and sport hunting

recrea Swimming, walking, sailing

Mangroves ecological benefits

promat Production of organic matter and feeding nursery

soilpro Protection of shore erosion

hurpro Protection from hurricanes and storms

nesti Habitat for nesting of birds

nurs Spawning area and protective cover

clewa Removal of nutrients, heavy metals, and other substances from the water.

Attitudes towards resource use

moral Respondent believes we have a moral obligation to protect the wetland

natura Respondent experiences satisfaction when he is in contact with the wetland

ecol1 Respondent accepts that sewage affect life in the wetlands

ecol2 Respondent recognizes limits in nature

ecol3 Respondent relates vegetation with animals.

scienc Respondent accepts the need of conservation for mangroves be studied

negat Respondent believes that only dangerous creatures live in the wetland

short Respondent preference is for short time

option Respondent accepts conservation for mangroves because of their possible future uses

equity Respondent accepts his obligation to protect the mangroves for others

exist Respondent participates in conservation with the only reason mangroves will exist in the future

extern Respondent accepts that some actions can create negative effects on others

willi Respondent is willing to sacrifice something for wetland conservation

parti Respondent say that participation in wetland conservation is not waste of time

Acceptance of regulation

lgral Respondent accepts regulation as a way to protect natural resources

lcons Respondent accepts regulation as a way to control urban development, roads, and boat landing areas

lcont Respondent accepts regulation as a way to regulate discharges in the wetland

lwood Respondent accepts regulation for wood extraction

lfish Respondent accepts regulation for fishing

lhunt Respondent accepts regulation for hunting

lreserv * Respondent accepts regulation to maintain core areas where conversion and extractive activities would be banned.

Threats to mangroves

urgro Urban growth is currently a threat for the mangrove wetland

porin Port infrastructure is currently a threat for the mangrove wetland

roads The road network is currently a threat for the mangrove wetland

garba Garbage is currently a threat for the mangrove wetland

trewa Untreated sewage is currently a threat for the mangrove wetland

oilspi Oil spills are currently a threat for the mangrove wetland

woode Wood extraction is currently a threat for the mangrove wetland

fishe Fishing effort is currently a threat for the mangrove wetland

hunte Hunting is currently a threat for the mangrove wetland

* Not used in this study

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