SATELLITE MONITORING OF COASTAL MARINE ECOSYSTEMS
A CASE FROM THE DOMINICAN REPUBLIC

Edited By

Richard W. Stoffle
David B. Halmo

Submitted To

CIESIN
Consortium for International Earth Science Information Network
Saginaw, Michigan

Submitted From

University of Arizona
Environmental Research Institute of Michigan (ERIM)
University of Michigan
East Carolina University

December, 1991

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF VIEWGRAPHS

ACKNOWLEDGMENTS

This pilot project report is the product of diligent efforts on the part of several individuals and institutions. The editors would like to extend their appreciation to CIESIN and its President, Jack Lousma, the Board of Directors and members of the consortium for supporting the research. Professors Gayl Ness and William Drake, directors of the Population-Environment Dynamics program at the University of Michigan, provided funds for initial research in the Dominican Republic that led to the idea that coral reef and coastal marine ecosystems could be monitored with satellite technology.

During the course of the research, the editors incurred the debts of many individuals. Special thanks is due to Professor William Kuhn, who directs the human dimensions of global change section of CIESIN at the University of Michigan Department of Atmospheric, Oceanic, and Space Sciences, for his tireless efforts on behalf of the project, the meteorological research section, and administrative assistance. Thanks also to Beth Lawson for her administrative guidance throughout the project.

The editors would also like to express their gratitude to Jacquie Ott and Frank Sadowski of CIESIN/ERIM and its Pilot Project Monitoring and Integration Team (PPMIT) for all of their efforts on behalf of the project. Other CIESIN staff members, too numerous to mention individually here, also provided guidance and timely advice throughout the course of the research.

We express our sincere gratitude to the administrative assistance and support provided by Contracting Officers and staff at the Institute for Social Research, University of Michigan, University of Arizona, and East Carolina University. At the Bureau of Applied Research in Anthropology (BARA), University of Arizona Dr. Carlos Velez-Ibanez, Director, Maria Rodriguez and Glenn Brown deserve many thanks for all of their support. A special thanks is due to Gerardo Bernache of BARA for the Spanish translation of Chapter One.

A special debt of gratitude is owed to the contributing scholars who participated in the research and report writing: Andrew Williams, Department of Anthropology, University of Michigan; Brent Stoffle, Department of Sociology and Anthropology, East Carolina University; Drs. Donald Portman and William Kuhn, and David Willson, Department of Atmospheric, Oceanic, and Space Sciences, University of Michigan; Joseph Luczkovich, Institute for Coastal Marine Resources and Department of Biology, East Carolina University; C. Gaye Burpee, Department of Crop and Soil Sciences, Michigan State University; Tom Wagner, Jeffery Michalek, Raymond Laurin, and support staff at the Environmental Research Institute of Michigan (ERIM). Their tireless efforts in collaborating to formulate the research, conduct fieldwork, analyze data, prepare numerous drafts of report chapters and graphics, and respond as quickly as humanly possible, given busy schedules, to countless requests and questions by the editors is gratefully acknowledged. Heck of a job, folks.

In the Dominican Republic, special thanks for their participation, ideas, and actions are due to government agency and other individuals. These are: Lic. Ivonne Garcia, Sub-Secretaria de Recursos Naturales, Secretaria de Estado de Agricultura; Narciso Almonte C., Director de Recursos Pesqueros; and Jose Martinez, Director of DIRENA, Departamento Inventario De Recursos Naturales; Rafael Castillo, Estadistica y Limite Geografico, Instituto Cartografico Militar; Lic. Venecia Alvarez, director, Centro de Investigacion de Biologia Marina (CIBIMA); Dr. Carlos Cano Corcuera, Agencia de Cooperacion Espanola; Dr. Jose Serulle Ramia, president of Fundacion Ciencia y Arte, Inc.; and Tomas Montilla, Department of Natural Resources, who worked with the CIESIN study team.

Finally, our deepest appreciation is expressed to the people of the communities of Buen Hombre and Punta Rucia, especially Tuba, Narciso, and their families. Without their kind hospitality, participation, and willingness to share their knowledge, this study could not have been undertaken.

CHAPTER ONE

EXECUTIVE SUMMARY

Richard W. Stoffle

The Human Dimensions of Global Change

Most cultures, including those of western Europe, recognized that the planet earth was both round and interconnected in special ways when Cristobal Colon (or Christopher Columbus) and his sailors landed in the Bahamas islands of the Caribbean in 1492 (Seavey 1991). It soon became obvious to the citizens of the planet who could read or who's lives were affected by Colon's voyages, that joining the old and new worlds was having major impacts on both. The term Columbian Exchange has been used to describe both the process and the results of massive planet-wide changes (Crosby 1972; Mintz 1974). There were changes in human demography, especially due to diseases (McNeill 1976); in social structure, especially deriving from a shift to industrial forms of production produced by new systems of unfree labor; in culture, especially theories of knowledge needed to incorporate the ideas and even the existence of formerly unknown peoples; in politics, especially because a few countries become dominant over the remainder of the planet; and in economics, especially deriving from the first integrated world economy. Needless to say, the Columbian Exchange also involved extensive changes in natural resources, primarily due to moving plants and animals between the old and new worlds, but also due to new types of environmental exploitation by Western European nations (Crosby 1986; Viola and Margolis 1991).

Although most people on the planet eventually became aware of some aspect of the Columbian Exchange, few people understood more than those changes that directly impacted their lives. The people of Birmingham, England, for example, knew that their town grew within a few generations from a modest community to a large industrial town by producing iron products for the African slave trade, especially the *African musket* which was essential to slave raiding and wars in West Africa (Williams 1944:82-84). The citizens of Birmingham recognized that their diet had changed because Africans slaves produced molasses and the rum from the sap of an East Indies plant now cultivated on plantations in a place called the West Indies. But few people, even the scholars of the time, understood the deep fundamental global changes that were occurring because of the Columbian Exchange. The reason for this was that no one had full access to information about these changes at the time they were occurring.

Today many people on the planet can discuss global changes as easily as they talk about Michael Jackson's music. By the mid-1960's, television satellite communications made it possible for people in most countries to watch when the first person walked on the Moon. Since then, the planet has become what some have called the *electronic village*. Data about environmental changes, such as reduction in the ozone layer or global warming, is collected and made into understandable information by the people who use satellite communications.

It can be argued that the global changes faced by the people of this planet in 1492 were greater than those faced by the people of the planet today. What is different is that we know about our global changes and can use that knowledge to stop adverse changes and encourage desired ones. Modern satellite communications make it possible for average citizens to be aware of the global implications of their individual actions. People can literally know and change behaviors that influence the entire planet. It is the challenge of our scientists, government leaders, news media persons, and educators to collect data about global change issues and to present these data as information that average citizens can translate into the global change policy of individual behavior.

This research report is about global changes in coastal marine ecosystems, especially as these are occurring on the island of Hispaniola where Columbus established his first settler communities (Wilson 1990). Through disease and warfare, Columbus and his Spanish immigrants caused most American Indian people on the island to die, thus radically altering land use patterns along the coastal marine ecosystems of Hispaniola. In general the environment was to benefit, because coastal villages, farms, and fishing activities ceased to operate as millions of American Indian people died. Today, the coral reefs of Hispaniola, like other coastal marine ecosystems around the planet, are being stressed by human activities, are being degraded, and may be faced with destruction (Bunkley-Williams and Williams 1990). When coral reefs die their surfaces become white. This produces a visual phenomena termed *coral reef bleaching*. Although the cause of coral bleaching is poorly understood, it appears to be a response to stresses from high or low water temperatures, high fluxes of visible and ultraviolet radiation, prolonged aerial exposure, freshwater dilution, high sedimentation, eutrophication due to plant nutrients and fertilizers in runoff from land, and other types of pollution (Glynn 1991). Concomitantly, humans use the natural resources of these ecosystems and their activities can have profound effects. The effects of human use activities are not well understood and the long-term effects have not been systematically documented.

It is the purpose of this research to document how and why these changes are occurring along one portion of the north coast of the Dominican Republic, so that we can better understand how to document such changes elsewhere on the planet. The research further seeks to understand how humans can become a part of the solution as well as being part of the problem, thus providing a balanced perspective on the human dimensions of global change.

Global Change Research

It is necessary to conduct applied global change research in order to understand and potentially solve problems associated with the human dimensions of global change. It has already been suggested that any study of the impacts of the Columbian Exchange is global change research, therefore much is known about global change processes and results. All such research is post-hoc, often occurring hundreds of years after the demographic, social, cultural, political, economic, and natural changes occurred. Columbian Exchange scholars and scientists who study the large scale climate and natural resource changes of the planet work with the residual evidence of events that occurred long before. Contemporary global change research is fundamentally different in that the changes under analysis are occurring on a daily basis and potentially can be monitored and solved on a day-by-day basis. This point alone makes contemporary global change research different from other types of planet-wide research of past global events.

Satellites collect the basic data for extensive geographic areas. This data can be used to understand and monitor global change problems. One limitation of satellites is that they can neither fully interpret what is observed nor explain what caused the observed global changes. *Ground truthing* is the term used to describe the activities of scientists who conduct studies on the surface of the earth to interpret what the satellite sees and what caused the observed global changes. Ground truthing is often accomplished by anthropologists, climatologists, marine biologists, and geologists. It is therefore one way to connect these discipline-specific scientists with the satellite scientists who produce earth images from space.

Global change problems are complex, so research teams should also be complex, reflecting the range of variables that may be influencing the global problem under study. There have been very few cases in which human dimensions of global change issues have been studied by complex interdisciplinary research teams using both satellite images and traditional research techniques. Therefore, applied research pilot projects are required in order to ascertain whether or not certain types of global change issues can be studied by certain types of research teams. These questions begin to be answered by analysis of single locations where global changes are occurring. Such analysis permits the detailed and organizationally complex research that is needed to take the first step. The second step is to move from the successful study of one locale to the analysis of two or more locales that are similar in most respects to the first pilot area, but contrast in ways that permit hypotheses emerging from the first study to be explored. The third step is a national or international study where smaller samples are taken from a much larger area and used to verify whether initial methods or findings have scale limitations. The ultimate goal would be to monitor representative regions of the entire planet from space, with limited ground truthing in widely separate locales to test specific hypotheses.

Global Change Theory

Theories guide the collection and analysis of data. Many of the theories that have been offered to explain global change and predict its potential impacts have been developed with information collected for other purposes. This is true for the physical as well as the human sciences. As a result, most global change theories are based on other theories generated by research focussed on other than global change issues. The challenge for scientists then, is to derive the greatest explanatory utility out of existing composite theories while applied global change research is being designed and conducted to verify or disprove composite theories.

The overall structure of global change has been modeled by the *Bretherton Wiring Diagram* (NASA 1986), which includes the category termed *human activities*, but the diagram fails to specify the key human parameters. So it is necessary to specify the human dimensions of global change so that these can be added to the prevailing Bretherton Wiring Diagram. Modeling efforts are proceeding inductively and deductively. Large conferences are being convened with hundreds of noted experts to identify the key issues and parameters associated with global change (CIESIN 1991). In contrast, the Aspen Global Change Institute brought together a few experts to produce the *Social Process Diagram* which will model the human dimensions of global change. As applied global change research pilot projects produce findings, the social process diagram will be increasingly grounded in global change data and consequently be refined deductively.

Application of Global Change Information

Once global change problems are studied and the research demonstrates that they can be understood in one location, it is important to begin to develop procedures for distributing the global change data so they become global change information and are incorporated into policy decisions to reduce or eliminate the problems. It is important to emphasize that this knowledge transfer process is as complex as the initial research itself. For this reason the knowledge transfer process should be perceived as experimental, beginning with applied research pilot projects as the basis for the experimentation. This suggests using multiple means of knowledge transfer tested at one pilot site. This permits controlled comparisons in a known environment. People that are being influenced by the observed global change should be brought into the experiment, and allowed to suggest alternative means of providing policy relevant knowledge. Like the pilot research efforts, once knowledge transfer has been found to have utility in one locale, the knowledge transfer experiments should be expanded to multiple locale experiments. Logically, the knowledge transfer experiments would follow the research steps taken by the applied research pilot projects. There would be a natural increase in both knowledge transfer wisdom and generalization from the model as the experiments proceed.

CIESIN And Pilot Research

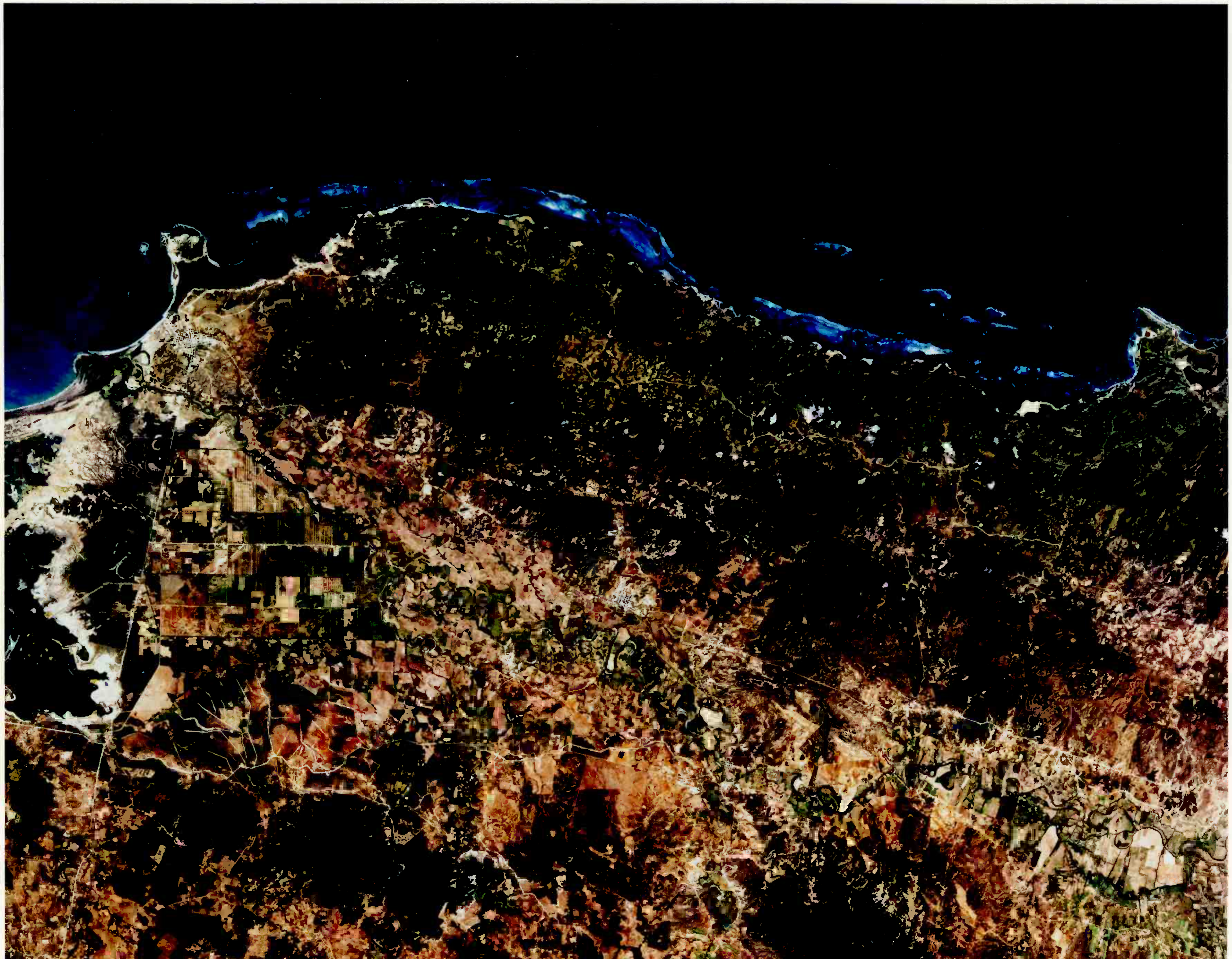
In 1990 NASA funded the creation of an organization known as the Consortium for an International Earth Science Information Network (CIESIN) (Kuhn et al. 1991). The purpose of CIESIN is to understand the human dimension of global change by increasing access to and use of earth science and related information by the international scientific and decision making communities. CIESIN will create a facility know as the CIESIN Data and Research Center (CDRC) which is to be located in Michigan. The CDRC will use global change models to develop, archive, and distribute special research products to public users as well as global change scientists. Based on these global change models, the CDRC will collect selected Earth Observing System (EOS) satellite data, as well as data sets from the physical, biological, and social sciences.

CIESIN initiated a series of nine human dimensions of global change pilot projects in 1991, to better understand how physical, biological, and social scientists must interact in order to address problems of importance to decision-makers. There is also a need to develop methodologies for merging data sets which differ on spatial and temporal scales, and indeed, to ascertain whether or not data are generally available to address specific, highly complex problems. Thus, interdisciplinary studies have been emphasized, especially those combining earth and social science. Because there has been virtually no research on the use of remotely sensed data in the social sciences of global change, this is a component of each pilot project. Pilot projects need to show how the results would be transferred to decision makers. All these elements of the pilots are to be used to inform the design of the CIESIN Data and Research Center.

The Dominican Republic Pilot Project

The Site

One of the CIESIN human dimensions of global change pilot projects is situated on the north coast of the Dominican Republic. Here the questions are (1) whether or not satellite images can be used to identify and monitor small scale changes in coral reefs and the associated coastal marine ecosystem and (2) whether or not interdisciplinary research can identify and explain the ways that humans are affecting, and being affected by, changes in this ecosystem. The study area involves a portion of a thirty-mile long coral reef, defined by the Smithsonian Marine Systems Laboratory as one of the best remaining reefs in the Caribbean. When Columbus first observed this coast he noted numerous large American Indian villages associated with extensive agricultural fields. Disease, warfare, and forced relocation caused much of the coast to be abandoned by the early 1600's. Few Spaniards ever occupied the north coast of the Dominican Republic, so it is assumed that the natural environment recovered from American Indian land use patterns over a period of three hundred years. The study area community was established in 1897 by a small group of settlers. Slowly the size of the community, which came to be called Buen Hombre, grew



until, by the late 1980s, its population was approximately 900 residents. Informal surveys of archaeological sites in the Buen Hombre area suggest that today the current village residents are living exactly where and very much like the American Indian people were at the time of Columbus. It can be argued that the coastal marine ecosystem and the local human population could exist in sustainable balance if pressures on this system only derived from the people of Buen Hombre and similar folks in other villages along the coast. This is not the case.

The future of this ecosystem is in doubt. This prediction is based on direct data and by analog. Fishermen in Buen Hombre report lower fish catches and smaller fish size over the past generation. A dive-shop operator at a neighboring international tourist hotel reports the need to take tourists to new reefs during the past five years, because the ones close to the hotel have died. Fishermen from distant towns are beginning to fish in the coastal waters of the village research site with large nets (*chinchorros*) that are both illegal and highly destructive of fish populations. The manatee have disappeared from those areas where *chinchorros* have been used. Finally, analogous coral reef areas to the west in Haiti have been characterized as *dead* and to the east in other parts of the Dominican Republic as *fished out*.

The Research Team

The CIESIN research team included David Halmo, Andrew Williams, and Brent Stoffle - cultural anthropologists; Donald Portman, David Willson, and William Kuhn - climate and atmosphere experts; Joseph Luczkovich - marine ecologist; Gaye Burpee - soil and crop scientist; Jeffery Michalek, Raymond Laurin, and Tom Wagner - remote sensing experts; and Richard Stoffle - cultural anthropologist and project director. Eight of the twelve project research team members (including a climate expert and a remote sensing expert) jointly conducted field work in the village of Buen Hombre. Information was collected so that it met the research methods and theoretical requirements of remote sensing, marine ecology, and cultural anthropology. Coordinated data collection required extensive negotiations before and during field work because sampling techniques not only differed, but often were in conflict. Separate field work was conducted in January, February, March, and during the summer of 1991. The structure and operation of the study team contributed to our understanding of whether or not complex interdisciplinary research teams can merge their analysis into one integrated study of a global change problem.

Key Findings

- Satellite imagery can be used to identify small-scale changes in coastal marine ecosystems, especially in coral reefs.

- Satellite change imagery, marine ecological and human science data have shown that changes in bottom reflectivity from 1985 to 1989 of the reef, seagrass, and mangrove ecozones are more closely tied to natural disturbances, human fishing, tourism, mining, and land use practices than to global warming.

* There are significant differences between the types of impacts that are made by local people who have a sense of ownership and inter-generational commitment to the ecosystem and the impacts of outsiders like urban fishermen and tourists who have no commitment to the ecosystem.

* Sufficient data are now available to begin to model the human dimensions of global change in coastal marine ecosystems.

* Monitoring by satellite and human science data should permit both the prediction of ecosystem stress levels and the monitoring of global changes in coastal marine ecosystems.

* Satellite images provide a unique technique for studying and planning for the protection of coastal marine ecosystems.

* Large interdisciplinary research teams can collaborate to collect data, conduct analysis, and report on global change issues, but the research process is difficult and should become the subject of methodological and epistemological study itself.

CAPÍTULO UNO

RESUMEN GENERAL

Richard W. Stoffle
Traducción: Gerardo Bernache

Las Dimensiones Humanas en el Cambio Global

La gran mayoría de culturas, incluyendo aquellas de Europa Occidental, reconocían que la tierra era redonda y que estaba interconectada por rutas especiales cuando Cristóbal Colón y sus marinos desembarcaron en las islas Bahamas del Caribe en 1492 (Seavey 1991). Pronto fue aparente para los ciudadanos del planeta que sabían leer o bien aquellos cuyas vidas eran afectadas directamente por los viajes de Colón, que la tarea de unir el viejo y nuevo mundos estaba teniendo un impacto significativo en ambos. El término Intercambio Colombino se ha utilizado para describir tanto el proceso, como los resultados del cambio mundial masivo (Crosby 1972; Mintz 1974). Hubo cambios en la demografía humana, especialmente debidos a las enfermedades (Mc Neill 1976); en estructura social, especialmente derivados de un cambio a las formas industriales de producción generadas por los nuevos sistemas de trabajo esclavo no libre; en la cultura, se necesitaba especialmente de teorías del conocimiento para incorporar tanto las ideas, como la existencia de gentes previamente desconocidas; en la política, especialmente debido a que unos pocos países se implantaron como dominantes sobre el resto del planeta; y en la economía, especialmente como un resultado de la primera economía mundial. Resulta obvio señalar que el Intercambio Colombino también involucraba cambios extensivos en los recursos naturales, debido en primer lugar a el movimiento extensivo de plantas y animales entre el viejo y nuevo mundos, pero también como resultado de nuevos tipos de explotación del medio ambiente por las naciones Europeas Occidentales (Crosby 1986; Viola y Margolis 1991).

Aunque la mayoría de la gente eventualmente se tomó consciencia de algunos aspectos del Intercambio Colombino, muy pocas entendieron mas allá de aquellos cambios que directamente impactaban sus vidas. La gente de Birmingham, Inglaterra, por ejemplo, sabía que su propio pueblo creció, en el lapso de unas pocas generaciones, de ser una comunidad modesta a un gran pueblo industrial que manufacturaba productos de hierro para el tráfico africano de esclavos, especialmente el *Mosquete Africano* que era instrumento esencial para la captura de esclavos y para las guerras de Africa Occidental (Williams 1944:82-84). Los ciudadanos de Birmingham reconocieron que su dieta había cambiado debido a que los esclavos africanos producían melasa y ron con la savia de una planta proveniente de las Indias Orientales ahora cultivada en plantaciones en un lugar llamado las Indias Occidentales. Pero poca gente, aún los académicos del momento, entendió los cambios profundos y fundamentales que estaban teniendo lugar debido al Intercambio Colombino. La razón para tal falta de entendimiento era que nadie disponía de un acceso completo a la información relativa a dichos cambios en el mismo momento que estaban ocurriendo.

Ahora mucha gente en el plantea puede discutir los cambios globales tan fácilmente como hablar de la música de Michael Jackson. Hacia la mitad de los sesentas, la televisión de comunicaciones vía satélite hizo posible que las gentes de la mayoría de países pudieran ver cuando la primera persona caminó en la Luna. Desde entonces, el planeta se ha convertido en lo que alguien ha llamado *una villa electrónica*. Los datos acerca de los cambios mundiales, tal como la reducción de la capa de ozono o el recalentamiento de la atmósfera terrestre, son recolectados y transformados en información entendible por las personas que usan las comunicaciones vía satélite.

Se puede argumentar que los cambios globales que enfrentaban los habitantes de este planeta en 1492 eran mayores que aquellos que enfrentan los habitantes del planeta en la actualidad. La diferencia es que nosotros sabemos acerca de nuestros cambios globales y podemos utilizar tal conocimiento para controlar los cambios adversos y para alentar aquellos cambios deseables. Las comunicaciones modernas por satélite hacen posible que un ciudadano promedio esté consciente de las implicaciones globales de sus accciones individuales. La gente puede literalmente conocer y cambiar las conductas que afectan al planeta entero. El desafío para nuestros científicos, los líderes de gobierno, las personas en los medios de comunicación, y los educadores es que se dediquen a recavar datos acerca de asuntos relativos al cambio global y presentar estos datos como información que un ciudadano promedio pueda traducir a una política de cambio global al nivel de su conducta individual.

Este reporte se ocupa de los cambios globales en los ecosistemas marinos de la costa, especialmente los que están ocurriendo en la Isla Española donde Colón estableció sus primeras comunidades de colonizadores (Wilson 1990). Colón y sus imigrantes expañoles causaron la muerte, por medio de la enfermedad y la guerra, de la mayoría de la población Indígena Americana, alterando así radicalmente las costumbres de uso de la tierra a lo largo de las ecosistemas marinos costeros de la Española. En términos generales, el medio ambiente se benefició, ya que las poblaciones costeras, las granjas, y las actividades pesqueras dejaron de operar debido a que millones de Indígenas Americanos morían. Ahora, los arrecifes de coral de la Española, como cualquier otro ecosistema marino costero alrededor del planeta, están siendo acosados por actividades humanas, están siendo degradados, y están enfrentando su destrucción (Bunkley-Williams and Williams 1990). Cuando los arrecifes de coral mueren, sus superficies se tornan blancas. Esto produce un fenómeno visual denominado *blanqueamiento de los arrecifes de coral.* Aunque la causa del blanqueamiento del coral no es aún bien conocida, parece ser una respuesta a presiones provenientes ya sea de altas o bien de bajas temperaturas del agua, de altos influjos de radiaciones visibles y ultravioletas, de prolongada exposición aérea, de disolución de agua dulce, de alta sedimentación, de contaminación orgánica debida al exceso de nutrientes de plantas y fertilizantes que se deslavan de las tierras, y de otros tipos de contaminación (Glynn 1991). Concomitantemente, los seres humanos usan los recursos naturales de esos ecosistemas y sus actividades pueden causar efectos profundos. Los efectos de las actividades humanas no han sido bien entendidos aún, ni tampoco se han documentado sistemáticamente sus efectos a largo plazo.

Es el propósito de esta investigación el documentar cómo y porqué estos cambios están teniendo lugar a lo largo de una parte de la costa norte de la República Dominicana, de tal manera que podamos entender mejor como documentar tales cambios en cualquier otra parte del planeta. Esta investigación busca además entender como los seres humanos pueden convertirse en parte de la solución aun siendo parte del mismo problema, proporcionando así una perspectiva equilibrada de las dimensiones humanas del cambio global.

La Investigación del Cambio Global

Es necesario realizar investigación relevante al cambio global con el fin de entender y resolver potencialmente los problemas asociados con las dimensiones humanas del cambio global. Se ha indicado ya que cualquier estudio de los impactos del Intercambio Colombino se puede considerar como parte de la investigación relativa al cambio global, por lo tanto es evidente que se conoce ya mucho acerca de los procesos de cambio global y sus resultados. Toda esa investigación es posterior a los hechos, a menudo tiene lugar cientos de años despues de que los cambios demográficos, sociales, culturales, políticos, económicos y naturales han ocurrido. Los estudiosos del Intercambio Colombino y los científicos que estudian los cambios de gran escala en el clima y en los recursos naturales del planeta, trabajan ahora con la evidencia residual de los eventos que ocurrieron con mucha anterioridad. La investigación contemporánea del cambio global es fundamentalmente diferente en que los cambios bajo estudio están ocurriendo a diario y potencialmente pueden ser monitoreados y resueltos en una base diaria. Tan solo este punto convierte a la investigación contemporánea del cambio global en algo diferente de otros tipos de investigación mundial de los eventos globales del pasado.

Los satélites pueden recolectar información básica de áreas geográficas extensas. Esta información puede ser utilizada para entender y monitorear los problemas del cambio mundial. Una limitación del uso de satélites es que ellos no pueden ni interpretar completamente lo que se observa, ni explicar que causó el evento observado de cambio global. La *confirmación de campo* es el término usado para describir las actividades de científicos que conducen estudios en la superficie terrestre para interpretar tanto lo que ven los satélites, como lo que ha causado los cambios observables. La confirmación de campo es a menudo realizada por antropólogos, climatólogos, biólogos marinos, y geólogos. Esta es, por lo tanto, una forma de conectar a tales científicos especializados con los científicos de satélites que producen imágenes terrestres desde el espacio.

Los problemas del cambio global son complejos, por lo que los equipos de investigación deben también ser complejos, deben representar el rango de variables que pueden influenciar el problema global bajo estudio. Ha habido muy pocos casos en los que las dimensiones humanas de los problemas de cambio global han sido estudiados por equipos complejos de investigación interdisciplinaria que utilicen tanto imágenes de satélites como técnicas de investigación tradicional. Por lo tanto, se necesitan proyectos piloto de investigación aplicada con el fin de evaluar si ciertos tipos de problemas de cambio global pueden ser estudiados por ciertos tipos de equipos de investigación. Esas cuestiones empiezan a ser estudiadas por los análisis de lugares singulares donde están ocurriendos los cambios globales. Tal análisis permite la investigación compleja y detallada que es necesaria para dar el primer paso. El segundo paso es pasar del estudio exitoso de una localidad, al análisis de dos o más localidades que son similares en la mayoría de aspectos a la primer área del estudio piloto, pero que contraste en formas específicas que permitan explorar las hipótesis que derivaron del primer estudio. El tercer paso es un estudio nacional o internacional donde muestras más pequeñas son tomadas de un área de estudio mucho más extensa y son utilizadas para verificar si los métodos iniciales y/o los resultados tienen alguna limitación de escala. La meta última sería monitorear, desde el espacio, regiones representativas del planeta entero con un limitado trabajo confirmación de campo en localidades completamente separadas para evaluar hipótesis específicas.

Teoría del Cambio Global

La teorías guían la recolección y el análisis de datos. Muchas teorías que se han ofrecido para explicar el cambio global y para predecir sus impactos potenciales han sido desarrolladas con información recolectada inicialmente con otros fines. Esto es cierto tanto para las ciencias físicas como para las ciencias humanas. Como resultado, la mayoría de las teorías de cambio global están basadas en teorías generadas por investigaciones enfocadas en otros problemas y no en los del cambio global. El desafío para los científicos es, entonces, derivar la mayor utilidad explicativa de las teorías compuestas existentes mientras que la investigación aplicada del cambio global está siendo diseñada y realizada para verificar o descartar tales teorías compuestas.

La estructura general del cambio global ha sido modelada por el *Bretherton Wiring Diagram* (NASA 1986), que incluye la categoría denominada *actividades humanas*, pero el diagrama por sí mismo no puede especificar los parámetros humanos más importantes. De esta manera, es necesario especificar las dimensiones humanas del cambio global de forma que éstas puedan ser añadidas al vigente Bretherton Wiring Diagram. Los intentos de modelaje están desenvolviendose tanto inductiva como deductivamente. Se han organizado grandes conferencias donde cientos de expertos reconocidos han tratado de identificar los problemas centrales y los parámetros asociados con el cambio global (CIESIN 1991). En contraste, el Aspen Global Change Institute (Instituto de Cambios Globales Aspen) reunió a unos pocos expertos para producir el *Social Process Diagram* (El Diagrama de Procesos Sociales), el cual modelará las dimensiones humanas del cambio global. En tanto que los proyectos piloto de investigación aplicada del cambio global generan resultados, el diagrama del proceso social será cimentado firmemente en datos de cambio global y consecuentemente será refinado deductivamente.

Aplicaciones de la Información del Cambio Global

Una vez que los problemas del cambio mundial son estudiados y que la investigación demuestra que pueden ser entendidos en una localidad, es importante empezar a desarrollar los procedimientos para distribuir los datos de cambio global de forma que éstos se conviertan en información de cambio global y sean incorporados en las decisiones políticas para reducir o eliminar los problemas. Es importante enfatizar que esta transferencia de conocimientos es tan compleja como la investigación inicial en sí misma. Por esta razón, la transferencia de conocimientos debería entenderse como un proceso experimental, empezando con proyectos de investigación aplicada como la base para la experimentación. Esto implica usar múltiples medios de transferencia de conocimientos que han sido comprobados en una localidad piloto. Esto permite la comparación controlada en un ambiente conocido. La gente que está siendo influenciada por los cambios globales observados debería incorporarse al experimento y permitírsele sugerir medios alternativos para proveer conocimientos relevantes para la toma de decisiones políticas. De la misma manera que los esfuerzos de investigación piloto, una vez que la transferencia de conocimientos ha sido de utilidad en una localidad, los experimentos de la transferencia de conocimientos deberían extenderse a múltiples localidades experimentales. Lógicamente, los experimentos de transferencia de conocimientos seguirían los mismos pasos tomados por los proyectos piloto de investigación aplicada. De esta manera habría un incremento natural en sabiduría de transferencia de conocimientos y en la generalización del modelo al timepo que los experimentos se están desarrollando.

CIESIN y la Investigación Piloto

En 1990 la NASA patrocinó la creación de una organización conocida como el Consortium for International Earth Science Information Network (CIESIN, El Concorcio para la Red Internacional de Información de las Ciencias de la Tierra) (Kuhn et al. 1991). El propósito del CIESIN es que tanto la comunidad científica internacional, como aquellas comunidades que necesitan tomar decisiones puedan entender la dimensión humana del cambio global al incrementar su acceso a y su uso de las ciencias de la tierra y demás información relevante. El CIESIN creará una organización conocida como el CIESIN Data and Research Center (CDRC, El Centro de Investigación y Datos del CIESIN) que estará localizado en el estado de Michigan. El CDRC usará modelos de cambio global para desarrollar, archivar y distribuir los productos de investigaciones especiales para un público usuario así como para los científicos del cambio global. Con base en estos modelos de cambio global, el CDRC colectará datos selectos del sistema de satélite Earth Observing System (EOS, El Sistema de Obervación Terrestre), así como también bases de datos de las ciencias físicas, las biológicas y las ciencias sociales.

CIESIN inició una serie de nueve proyectos piloto para investigar las dimensiones humanas del cambio global en 1991, con la meta de entender cómo los científicos físicos, los biólogos, y los científicos sociales deben interactuar para responder a problemas importantes para aquellas personas que toman decisiones. También existe la necesidad de desarrollar metodologías para reunir bases de datos que difieren en las escalas temporal y espacial, y para poder definir con certeza si hay o no, de manera general, datos disponibles para responder a problemas específicos de gran complejidad. Así, se han enfatizado los estudios interdisciplinarios, especialmente aquellos que combinan las ciencias de la tierra y las ciencias sociales. Debido a que virtualmente no ha existido investigación en el uso de datos de sensores remotos en las ciencias sociales dedicadas al estudio del cambio global, éste es un componente de cada proyecto piloto. Los proyectos piloto necesitan mostrar cómo los resultados serían transferidos a los que toman las decisiones. Todos estos elementos de los estudios piloto se utilizarán para guiar el diseño del Centro de Investigación y Datos del CIESIN.

El Proyecto Piloto en la República Dominicana

El Lugar

Uno de los proyectos piloto del CIESIN en relación a las dimensiones humanas del cambio global está situado en la costa norte de la República Dominicana. Aquí las preguntas básicas son (1) evaluar si las imágenes de satélite pueden ser utilizadas o no en la identificación y monitoreo de cambios a pequeña escala en los arrecifes de coral y en el ecosistema marino costero asociado al arrecife, y (2) evaluar si la investigación interdisciplinaria puede o no identificar y explicar las formas en que los seres humanos están afectando, y siendo afectados por, los cambios en este ecosistema. El área de estudio comprende una porción de un arrecife de coral de treinta millas de longitud, definido por el Smithsonian Marine Systems Laboratory (Laboratorio de Sistemas Marinos de la Smithsonian) como uno de los mejores arrecifes que existen en el Caribe. Cuando Colón observó por primera vez esta costa, él notó que las numerosas y grandes villas de los Indígenas Americanos estaban asociadas con extensos campos agrícolas. Sin embargo, las enfermedades, la guerra, y la relocalización forzada causaron el abandono de casi toda la costa hacia principios de los años 1600. Muy pocos Españoles apenas si ocuparon la costa norte de la República Dominicana, de esta manera se puede asumir que el ambiente natural se recobró, por un período de más de trescientos años, de los sistemas de uso de la tierra característicos de los Indígenas Americanos. La comunidad en el área de estudio fue establecida en 1897 por un pequeño grupo de colonizadores. Poco a poco el tamaño de la comunidad, que vino a llamarse Buen Hombre, creció hasta que su población llegó a unos 900 habitantes para finales de los años 1980s. Un reconocimiento informal de los sitios arqueológicos en el área de Buen Hombre nos indica que los actuales habitantes del pueblo viven hoy en condiciones similares y exactamente en el mismo lugar donde vivían los grupos Indígenas Americanos al momento de la llegada de Colón. Se podría argumentar que el ecosistema marino costero y la población humana local pueden coexistir en un equilibrio sostenible si las presiones sobre el sistema viniesen sólo de la gente de Buen Hombre y de sus pueblos vecinos a lo largo de la costa. Pero, desafortunadamente, este no es el caso.

El futuro de este ecosistema está en peligro. Esta predicción se basa tanto en datos directos como en la analogía. Los pescadores de Buen Hombre reportan decrementos en la captura de peces, así como peces de un tamaño más pequeño que los que capturaban en la generación pasada. Un operador de excursiones de buceo en un vecino hotel de turistas internacionales reporta la necesidad de llevar a los turistas a arrecifes nuevos porque durante los cinco años pasados aquellos cercanos al hotel han muerto. Los pescadores de pueblos distantes están empezando a pescar en las aguas costeras del pueblo donde tiene lugar nuestra investigación con grandes mallas (*chinchorros*) que son tanto ilegales, como altamente destructivas de las poblaciones de peces. El manatí ha desaparecido de esas áreas donde los *chinchorros* han sido utilizados. Finalmente, las áreas de arrecifes de coral análogas que se localizan al oeste en Haití han sido caracterizadas como *muertas* y aquellas al este en otras partes de la República Dominicana se han declarado como *pesquerías agotadas*.

El Equipo de Investigación

El equipo de investigación del CIESIN incluyó a David Halmo, Andrew Williams, y Brent Stoffle --antropólogos culturales; Donald Portman, David Willson, y William Kuhn -- expertos en clima y atmósfera; Joseph Luczkovich -- ecólogo marino; Gaye Burpee -- científico de suelos y cosechas; Jeffrey Michalek, Raymond Laurin, y Tom Wagner -- expertos en sensores remotos; y Richard Stoffle -- antropólogo cultural y director del proyecto. Ocho de los doce miembros del equipo de investigación (incluyendo al experto en clima y a uno de los expertos en sensores remotos) participaron en el trabajo de campo en el pueblo de Buen Hombre. La información fue recabada de manera que cumpliese con los métodos de investigación y los requerimientos teóricos de los sensores remotos, la ecología marina y la antropología cultural. La recolección coordinada de datos requirió de negociaciones extensas antes y durante el trabajo de campo debido a que las técnicas de muestreo no sólo eran diferentes, sino que a veces incluso estaban en mutuo conflicto. Trabajo de campo complementario fue realizado en enero, febrero, marzo y durante el verano de 1991. La estructura y operación del equipo de estudio contribuyó a de una manera definitiva a nuestro entendimiento de si los equipos de investigación interdisciplinaria pueden o no conjugar su análisis en un estudio integrado del problema de cambio global.

Principales Resultados

* Las imágenes de satélites pueden ser utilizadas para identificar cambios a pequeña escala en ecosistemas marinos costeros, especialmente en arrecifes de coral.

* Los datos de cambio en imágenes vía satélite, en la ecología marina, y en las ciencias humanas han demostrado que cambios en la reflectividad del subsuelo marino de 1985 a 1989 en el arrecife, en los pastos marinos y en las ecozonas

del manglar están más cercanamente influenciadas por los disturbios naturales, la pesca humana, el turismo, la minería y las prácticas de uso de los suelos que por efectos del recalentamiento de la atmósfera terrestre.

* Existen diferencias significativas entre los tipos de impactos que puede crear la gente local que tiene un sentido de propiedad y de un compromiso inter-generacional con el ecosistema cuando se compara con el impacto de los fuereños tales como los pescadores urbanos y los turistas que no tienen compromiso alguno con el ecosistema.

* Existen suficientes datos disponibles actualmente para comenzar a realizar un modelaje de las dimensiones humanas del cambio global en los ecosistemas marinos costeros.

* El monitorear, por medio de datos vía satélite y datos de las ciencias humanas, debería permitir tanto la predicción de los niveles de presión que sufre el ecosistema, como la medición de los cambios globales en los ecosistemas marinos costeros.

* Las imágenes de satélite nos proveen de una técnica única para el estudio y la planeación de protección para los ecosistemas marinos costeros.

* Grandes equipos interdisciplinarios pueden colaborar en la recolección de datos, en la realización del análisis y en reportar los problemas del cambio global, pero el proceso de investigación es difícil y debería convertirse, en sí mismo, en un objeto de estudio metodológico y epistemológico.

CHAPTER TWO

REMOTE SENSING APPLICATIONS IN THE COASTAL ZONE

Thomas W. Wagner, Jeffrey L. Michalek, and Ray Laurin

This chapter documents specific aspects of this program with respect to the remote sensing technology and its several applications. Consequently, it is divided into seven sections. The second section provides a brief overview of the role of remote sensing in monitoring coastal environments and lists the data sets used and the information products created. The third section illustrates the use of human image interpretation in obtaining land use information from aerial photos and Landsat images. The fourth section describes preparation of a satellite derived bathymetric image-map for this portion of the Dominican Republic coast. The fifth section describes preparation of two different types of satellite images showing changes in the coastal environment over a 14 year period. The sixth section summarizes this project's conclusions with respect to CIESIN's three areas of interest: (1) integrated science, (2) information technology, and (3) knowledge transfer. The final section explores some communication and policy-related considerations to which this study contributes. It attempts to provide a general framework for thinking about the appropriate information products and how people may use the information with respect to global change issues.

Coastal Surveys with Remote Sensing

Historically, resource surveys of coastal environments use aerial photographs, topographic and nautical charts (where they exist), and on-site field observation and sampling. While suitable for small and relatively unchanging areas, this procedure has limited utility for assessing remote, extensive and dynamic areas. As in this case, maps and aerial photos are often old and out of date and may be limited in their availability and the features that they show. Field surveys are labor-intensive and time consuming and, therefore, are costly and usually cover only small areas. In short, traditional survey techniques are not keeping pace with the requirements to monitor changes occurring in most coastal environments.

The possibility of using remote sensing to improve coastal bathymetry and marine hazard mapping was first addressed by ERIM in 1970 (Polcyn et al. 1970) and further defined for modern satellite sensors in the late 1970s and 1980s (Lyzenga 1978; Tanis and Hallada 1984; Tanis and Byrnes, 1985; Nordman et al. 1990).

Remote sensing is a tool that complements direct observation and knowledge by extending it in space and time. Remote sensing data alone have little utility for decision making, but in combination with ground observations and/or local knowledge, they result in information that is both useful and compelling. When combined with data from other sources, the information derived from remote sensing can provide increments of knowledge substantially greater than that provided by the individual data alone.

A Human Analogy

Our perceptual systems place high value on monitoring change. Rapid changes indicate movement within our field of view, and our mind notes such movement almost to the exclusion of non-changing backgrounds.

Much of human perception involves learning and using the visual edge-detection and motion-detection processes that characterize the eye-brain system. Through analysis and processing of remotely sensed images, we create technological analogs to the visual images we see with our eyes--images that convey important spatial and temporal information about the world around us.

Remote sensing adds to our visual capabilities. It allows us to extend our horizon to space altitudes using otherwise invisible forms of energy. It provides us with detailed permanent records of large and remote areas and highly complex spatial relationships. Remote sensing data may be up-to-date or allow us to go back in time. Given their common formats, comparisons of data from different dates document the physical changes that have taken place.

For this project, we created three different information products of the Buen Hombre area. Each combined in different ways local knowledge with the same remote sensing data. These products and procedures demonstrate both the great flexibility in using remote sensing data and their dependance on ancillary or *ground truth* information.

We visually interpreted aerial and space images to produce maps of nine land use classes for the immediate Buen Hombre area. We processed and displayed seven water depth classes for the coast. We highlighted small but significant physical changes in the near shore environment. These examples contribute to the Buen Hombre data base and may be significant for other marine coastal environments as well.

Remote Sensing Data

Remote sensing data are data obtained at a distance from the object or condition being observed. They are the product of non-contact sensing and are based on a record of the energy, usually electromagnetic energy, used to convey the data from the object or condition of interest to the remote sensor.

We used four types of remote sensing data for this project: (1) aerial photography, (2) satellite imagery, (3) GPS signals, and (4) sonar depth measurements. The former two are historical and were obtained from existing data sources. The latter two sets of data we obtained in specific support of this study. Table 2.1 lists these data.

TABLE 2.1. List of Remote Sensing Data

SENSOR	DATE	RECORD	DESCRIPTION
Aerial camera	2/16/83	Pan film	9" contact prints, 1:43,000 scale, 60% overlap
Landsat MSS	2/06/75	CCT	Path/row: 9/46 ID 20015-14332
Landsat TM	2/02/85	CCT	Path/row: 8/46 ID:50338-14384
Landsat TM	1/04/89	CCT	Path/row: 8/46 ID:42364-14403
GPS satellites	2/18-3/2/91	Field notes	latitude/longitude +/- 15 meters
Scubapro sonar	2/18-3/2/91	Field notes	water depth

Aerial Photography

Aerial photography has been taken of the Buen Hombre coast and other areas of the Dominican Republic for several decades (Hudson 1991). But we were not successful in locating aerial photos older than 20 years. The aerial photos used for this project were recorded on 16 February 1983.

Twelve 1:43,000 scale 9 inch panchromatic prints show the Buen Hombre coast. Each print covers approximately a 36 sq. mile area on the ground. The discernable resolution is a couple of meters--roads and trees are evident but individual structures are difficult to pick out. The original negatives may show more detail. There is a 60% overlap between adjacent east-west pictures for stereoscopic viewing. These photos are typical of those collected for general purpose topographic mapping and resource inventory.

Landsat Data

The primary image products for this study were created from Landsat data obtained in 1975, 1985, and 1989 (Viewgraph 1). The 1975 data consisted of computer compatible tapes (CCTs) of four Multi-Spectral Scanner (MSS) bands. The 1985 and 1989 data consisted of CCTs of seven Thematic Mapper (TM) bands. Table 2.2 summarizes the parameters of these sensors (after Tanis and Hallada 1984). The individual band designations are used throughout this report.

TABLE 2.2. Landsat Sensor Parameters

SENSOR	SPECTRUM	BAND	RESOLUTION (meters)	WAVELENGTH (micrometers)	DIGITAL LEVELS
MSS	Green	MSS1	83	0.5-0.6	128
	Red	MSS2	83	0.6-0.7	64
	Near IR	MSS3	83	0.7-0.8	64
	Near IR	MSS4	83	0.8-1.1	64
TM	Blue	TM1	30	0.45-0.52	256
	Green	TM2	30	0.52-0.60	256
	Red	TM3	30	0.63-0.69	256
	Near IR	TM4	30	0.76-0.90	256
	SWIR	TM5	30	1.55-1.75	256
	Thermal IR	TM6	120	10.4-12.5	256
	SWIR	TM7	30	2.08-2.35	256

The TM data have greater spectral and spatial resolutions than the MSS data. For our study the number digital levels (bits) recorded by MSS1 and by TM1, TM2, and TM3 were of significance. Differences between low and high signal values are on the order of 14 digital counts. These visible bands have the greatest marine water penetration capabilities and, therefore, were used to observe and map underwater features and calculate water depths.

Viewgraph 1: Landsat Data

GPS Data

Sea truth data collected in the Buen Hombre area provided reference information used for some of the image processing tasks. We recorded geographic location, water depth and predominant bottom type for approximately 50 near shore marine sites during a three week field trip in February, 1991.

A hand-held Global Position System (GPS) was used to obtain precise locational information for the sites. GPS involves a new system of polar-orbiting satellites operated by the U.S. Navy to provide direct position information to receivers on the ground. At the time of the field trip, 14 GPS satellites with very precise orbits were broadcasting signals that were received on the ground.

When three or more simultaneous signals were received from the GPS satellites, the ground receiver calculates and displays the precise latitude and longitude of its location. Elevation information is also available with signals from four satellites.

We used the Magellan NAV 1000 PRO unit to determine all position fixes during the marine survey. This light weight, hand-held, water-proof portable receiver provided autonomous positioning accuracies of 15 meters or less within several seconds of acquiring signals from three GPS satellites. Because the GPS satellite constellation was incomplete at the time of the survey, only certain parts of the day were available for the reception of GPS signals.

Sonar Data

In most parts of the world, shipboard sonars have long replaced tedious *lead and line* methods for measuring water depths. Recently low-cost, battery operated hand-held sonars have become available for rapid water depth or distance measurements.

We obtained water depths with a Scubapro Personal Dive Sonar (Viewgraph 2). This hand operated remote sensing device is capable of sound transmission distances from 2 to 260 feet and of under water operations down to 300 feet. We took our readings just below the water surface by either holding the unit over the side of the boat, or using it while floating at the surface near the boat. The five to ten readings obtained at each site were averaged to compute a final depth. We obtained the readings after the boat was anchored to minimize variations due to drift. A single 9 volt battery powers this unit.

Information about shallow water bottom types was obtained by direct observation via SCUBA diving and snorkeling. Chapter Five contains a complete description of the methods used to obtain biological data for this study. Chapter Six describes fully the ethnographic study conducted to collect sociocultural and economic data.

Viewgraph 2: Sample Sites and Sea Truthing

Remote Sensing Information Products

The products consist of written tabular information, such as the sonar water depth and GPS location information that are used in combination with other field-recorded and remotely sensed data, and various types of images and maps.

Table 2.3 lists the image/map products that were created principally with remotely sensed data for this project.

TABLE 2.3. List of Buen Hombre Image/Map Products

DATE	IMAGE PRODUCT	SCALE(s)	DESCRIPTION
1989	Landsat TM natural color print	1:25,000 1:50,000 1:100,000	Land area 60% cloud covered, water area clear.
1985	Landsat TM natural color print	1:50,000 1:266,000	Geo-corrected, restored image, no clouds.
1985	Color bathymetric image/map	1:50,000	Seven color-coded depth classes.
1975	Landsat false color print	1:250,000	Vegetation appears red, no clouds.
1983	Land use map of Buen Hombre area	1:43,000	Anderson level 3 classes based on aerial photos
1985	Land use map of Buen Hombre area	1:50,000	Based on 1985 Landsat TM natural color image.
1985-75	TM1/MSS1 B&W change		Continuous grey tones indicate degree of changes.
1985-89	TM1/TM1 B&W change image	1:50,000	Continuous grey tones indicate degree of changes for five selected coastal areas.
1985-89	TM1/TM1 color change image	1:50,000	Change areas red & magenta, background B&W for five selected areas

Geometric Correction of Landsat Data

The initial field work in Feburary/March 1991 used uncorrected 1989 Landsat images. This fieldwork produced both maps and photographs and observations for geometrically correcting the Landsat data. The 1985 Landsat TM data were resampled and registered to the Universal Transverse Mercator (UTM) projection with a 25.0 meter grid. Eight well distributed control points were located and digitized from the 1:50,000 scale topographic maps of this area. Geometrically corrected Landsat data were used for all subsequent Landsat image products.

The image data was resampled using ERIM's restoration method. This resampling method helps recover losses (blurring) of pixels and produces a clearer, sharper image than that produced from other resampling methods. The 1985 TM image was resampled using the calculated transform yielding sub-pixel accuracies. The standard error measure in the North-South direction was 12.8 meters and the standard error in the East-West direction was 19.7 meters.

Subsequently, we registered the 1975 and 1989 Landsat data sets to the 1985 TM geo-coded product. Matching the three data sets to the same projection and grid size allowed their analysis and comparison. These geometrically corrected data sets provided the basis for the land use, bathymetric, and change image products.

Land Use Maps

Mapping Land Use

The spatial aspects of human endeavor are such that it's useful to categorize and map land uses within a given geographical setting. Land use maps provide a basis for decision-maker knowledge about land practices, land capabilities, and land values. Their creation requires that certain features of the land be imaged by remote sensors and translated into mapped information by human interpreters. Planners and decision makers consider such map-based information to provide a legitimate basis for land use planning and for local and regional decision making.

We prepared two different land use maps of the same portion of the Buen Hombre coast as part of this study. One map was based on the 1983 aerial photos and the other, on the 1985 natural color Landsat TM image (Viewgraph 3). Preparation of both maps used the knowledge and skills of an experienced interpreter who had general knowledge of this environment.

The objective of this activity was to determine the feasibility of substituting Landsat TM images for more traditional aerial photos in deriving land use information. Traditionally, the preparation of land use maps is a three step process involving:

Viewgraph 3: Land Use and Land Cover Categories

1) selection or creation of a land use classification scheme that both reflects the land use classes of interest and the elements observable with the available data;

2) preparation of a line map through examination and drafting of the image data by a human interpreter; and

3) refinement or verification of the map units, if possible, from direct field observation (or *ground truth*).

This is an iterative process where by step 1 determines the specific requirements for information that, in turn, influence steps 2 and 3. Step 2 is the key process of integrating with the image data, ancillary information -- the experience and knowledge of the human interpreter. This step is person-dependent; its execution varies with different skills of the human interpreter. Step 3 modifies both step 1 and step 2 until a land use map of appropriate quality is produced.

In the absence of other guidelines for specific land use information that may be useful for the Buen Hombre area, we used the Anderson classification, created for the use with remote sensing data by the late James Anderson of the United States Geological Survey (USGS). The Anderson land use/land cover classification system is a multilevel system consisting of nested categories of decreasing generality (Anderson 1978). Level I is the most general. It has nine basic (Level I) land use categories: Urban or Build-up Land, Agricultural Land, Rangeland, Forest Land, Water, Wetland, Barren Land, Tundra and Perennial Snow and Ice. A single digit number is assigned to each category. Subsequent levels down to Level IV provide a framework for adding more detailed categories. Categories can be presented at any level, if they can be aggregated at the next higher level to maintain compatibility.

Land use maps may have categories at the different levels. Where very general categories are required, a Level I map will be produced. For detailed mapping of certain categories, a map that includes Level III or Level IV categories may be produced.

In selecting Anderson classification levels, one must keep in mind the issue of the time and cost to produce the map, and the transient nature of the information. Level III or Level IV land use data take more time and therefore, are more expensive to compile; they also become out of date more quickly because of minor use changes in the landscape.

The flexibility of the Anderson classification system allows it to be adapted to specific cases and for users to define low level categories that reflect their needs and the local land use conditions.

Land Use from Aerial Photos

Visual interpretation was used to analyze the panchromatic (black and white) aerial photos. The basic photo attributes such as tone, texture, size, shape and pattern, provided the basis for the interpretation. Mapping units were delineated based on their size, homogeneity, separability and interpretability. The categories were mutually exclusive. However, several categories graded into each other at their limits. In other cases where differentiation of two or more categories became too tedious, map complexes comprising several units were delineated.

The 3-dimensional stereo effect obtained by overlapping of adjacent photos provided a useful element for the interpretation in this topographically variable environment. Below is a description of the photomap units with their Anderson land use classification numbers in parentheses (Viewgraph 4):

Agriculture (2). Agricultural lands are recognized by their small rectangular shapes. On the photographs, they are generally light gray and have a uniform texture.

Rangeland/grazing land/savanna (3). The concept of land for grazing livestock is rather broad. Within the project area, this category includes several units that have different appearances. For example, small pastures may appear as agricultural land. Woody savannas are frequently used for grazing and may be mapped as degraded forests. On the photos, this category appears in slightly darker tones and less uniform texture than the active agricultural fields.

Forests (4). The forested lands are characterized by a coarse texture and a tone ranging from dark to medium. Five subunits were interpreted: dense forests, light forest, degraded forest, cactus forest and dry forests on the western portion of the study area.

Dense forests (41). Dark tones and medium textures characterize areas of dense forest. They occasionally grade into the thin forests (42).

Thin forests (42). They appear more open on the photo. The tone is consistently lighter than the dense forests.

Cactus (43). Coarse or grainy textures and medium tones characterize this map unit.

Degraded forests (44). These units appear very open, and occur on topographically rugged or eroded terrain. Sometimes they are associated with the badlands unit (72).

Dry forest (45). The coarse texture of this unit is similar to that of the dense forests, but the tone is somewhat lighter.

Wetlands (6). We identified only one wetland mapping unit. It is mangrove and extends along the shore next to the ocean. On the photos, this unit appears as a dark uniform band along the coast.

Viewgraph 4: Aerial Photos and Land Use Cover Map

Barren/Non-Productive Lands (7). This category has two subclasses. Sand beaches and badlands.

Sand beaches (71). These appear as bright white, smooth patches along the coast.

Badlands (72). This unit is steep to very steep and is severely eroded. It is a mixture of dark and light tones, strongly textured.

Land Use from Satellite Images

We interpreted the satellite color image in the same manner as the panchromatic photos except that a single image covered the entire area. Map units were identified and separated based on color, tone, texture and pattern. However, two limitations affected interpretation of this image: the lack of stereo coverage, and the coarse spatial resolution of the sensor. As a result, the satellite image did not provide the same level of categorization as the aerial photos.

Terrain relief and shadowing further complicated the satellite image interpretation. Rugged terrain and oblique sun angles at the time the data were collected created shadows that made portions of the landscape facing away from the sun appear darker regardless of land use. We observed two distinct image tones or colors for the same category. The shadowed darker tones were easily confused with dense forest, which is normally dark even in sunlight. Shadows also are evident on the panchromatic aerial photos but are more easily interpreted because of the available stereoscopic information. Description of the Landsat map units is given below with their Anderson land use classification numbers in parentheses:

Bare soils (1). Bare soils appear as small isolated or clustered light brown and tan patches.

Agricultural and range lands (23). We could not consistently separate these two map units; they were mapped as a single unit. On the image they appear as smooth, light green patches with small inclusion of brown representing bare soils.

Forest (4). Forested areas appear as dark green and very dark units; these units are also strongly textured due to their occurrence on hilly terrains.

Wetland/mangrove (6). This unit corresponds to the mangrove formation. We recognized two subclasses within the project area.

Mangroves (61). On the image, this unit appears as smooth green units; it probably corresponds to the permanently submerged mangrove stands.

Drier mangroves (62). On the image this unit appears as small brown patches within the green background of the typical mangrove units. They probably correspond to areas subjected to sporadic emergence and submersion.

Barren/non-productive Land (7). This unit includes 2 subclasses, Sand beaches (71) and Badlands.

Sand Beaches (72). These are bright white, smooth patches along the coast of possible interest for recreation.

Badlands (72). This unit has steep to very steep slopes that are often eroded. This unit is usually textured with strongly contrasting dark and light tones.

Map Comparison

The aerial photographic and satellite maps are different in a number of ways. While they make use of the same classification system, the details they show are different. The map patterns are in general agreement, but different levels of terrain detail were obtained from the different images.

Certain trade-offs occurred when using satellite images in contrast to traditional aerial photos. The multiband digital format allows a range of enhancement possibilities not available with aerial film. However, satellite images sacrifice the high resolution and stereo-imaging capabilities of aerial photos.

The maps were prepared without supporting ground truth or specific map information requirements. Therefore, neither is considered to be a final product. Their utility and accuracy should be assessed by the local residents. The accuracy may be assessed by selecting a number of sample points on the maps and determining their identity in the field. A classification error matrix is then used to recognize where and why errors occur.

The U.S. Geological Survey has established an accuracy level of 85% for land use maps prepared through interpretation of high altitude aerial photos at a scale of 1:100,000. Procedures for statistically testing the accuracy of thematic maps prepared through interpretation of remote sensing data are described in some detail by Van Genderen et al. (1978).

The view with Landsat data is more generalized than the view with aerial photos since many features (small parcels of land) are not observable with space-based sensors.

The satellite data provide greater spectral and temporal resolutions that allows us to identify large areas with greater certainty and monitor changes that take place between the acquisitions of two data sets. For example, the satellite data allowed differentation of two Mangrove units in contrast to the one for the aerial photography. The change information is valuable in a land use planning since they allow to make decisions concerning the rates and nature of landscape changes.

Bathymetric Image Map

The 1985 Landsat TM data were used to estimate and map water depths along the Buen Hombre coast. Although the 1989 data set is more recent, the data contain many clouds and cloud shadows over the study area, including portions of the water. For this reason the 1985 data were selected for creating the bathymetric image-map (Viewgraph 5).

Prior to computer processing for depth estimation, we smoothed the input data to reduce the effects of random image noise and image striping. We used a low-pass filter with a 3x3 pixel box size for this purpose. Pixel area averaging filters of this type are effective for reducing random noise (Lillesand and Kiefer 1987).

The physical basis for this activity is that the light that penetrates the water surface and reflects off the ocean bottom is attenuated to different degrees by the water column through which it passes. All other conditions being equal, a decrease in surface water radiance observed by the satellite corresponds to an increase in water depth. Thus water depths were mapped to where the light reflected off the bottom no longer was great enough to produce a significant signal compared to the background noise of the sensor -- approximately 50 feet in this case.

The depth to which a wavelength of light penetrates a water column before it is entirely absorbed depends on its intensity and on the water's attenuation characteristics at that wavelength. For this purpose we calculated a relationship between the sensor signal and the factors that affect the sun's radiation as it passes through the atmosphere and the water column, and reflects off the ocean bottom and back to the sensor. That portion of the signal resulting from reflection off the bottom provided the water depth information (Michalek 1991).

We considered the three different regression models and algorithms for calculating water depth from spectral data that are described in Tanis and Hallada (1984). These algorithms vary with the number of spectral bands and the amount of ancillary information needed to make them work. These algorithms are (1) a three-band TM hybrid depth algorithm, (2) a two-band ratio algorithm, and (3) a single-band algorithm.

The three-band TM hybrid depth algorithm was not implemented for this project. The algorithm uses bands TM1, TM2, and TM3, but TM3 (red band) has only modest depth penetration capabilities. The algorithm is most useful for mapping shallow water depths where a discrete number of bottom types are identified and mapped. This method requires the most detailed *sea truth* information (Nordman et al. 1990; Michalek 1991) including control points for which precise geographic position, water depth, and bottom type are

Viewgraph 5: TM Color-Coded Bathymetric Image recorded. Both the spatial complexity of the Buen Hombre marine ecosystem and our limited *sea truth* data discouraged opportunities for using this method.

We attempted to use a two-band ratio algorithm. This method seeks to minimize the effects of changing bottom types by using a ratio of radiances in TM1 and TM2 to calculate the water depth. This method assumes that different bottom types will have the same relative radiance differences between the two bands and that the ratio value is primarily a function of depth (Marshall 1988). The maximum depth for which calculations may be made is limited by the sensitivity and the light attenuation in the water column of the longer of the two wavelength bands (TM2).

The two-band ratio algorithm appeared to work well for water depths up to 20 feet but showed block striping in the deeper areas. The striping may be due to a detector noise artifact in TM2. The ratio method was not used to generate a bathymetric map for this reason.

We used the single-band algorithm to generate a provisional depth map for this study. The single-channel method requires the least amount of spectral and ancillary information and works best where the bottom reflectances and attenuation coefficient are fairly constant. The main advantage of this method is its simplicity and relative insensitivity to random noise. However, survey data are required to estimate some input parameters. Also, marked variations in bottom types and water attenuation (turbidity) may introduce significant errors (Marshall 1988). The following equation was used to calculate the water depths:

$$(1) \quad Z = -1/2k \ln(V - VS) + 1/2k (\ln V0)$$

where, Z = depth (ft), V = the observed signal radiance, VS = portion of signal resulting from scattering of radiation in the atmosphere, water column, and water surface, k = water attenuation coefficient (ft-1), V0 = sensitivity factor consisting of contributions from solar irradiance at the surface, the bottom reflectance, atmospheric transmission, and sensor equipment (ft-1).

VS was estimated from the satellite image data and the terms k and V0 were estimated from a linear regression analysis between known depths and transformed radiance values for a sample of pixels. We used the filtered TM1 data from the 1985 scene. A large group of pixels over a known deep water region was selected to estimate the portion of the TM1 signal that results from scattered radiation in the atmosphere, water column, and at the air/water boundary. A mean value and standard deviation for the deep water signal were determined from this training set. The training set mean minus one standard deviation was used as our estimate of VS.

The k and V0 terms were estimated using a linear regression analysis with depth as the dependent variable. But first the pixel radiances to be used as the independent variables needed to be transformed. This transformation included subtracting the VS estimate from the radiances and then taking the natural logarithm of this difference.

We used fourteen points of similar bottom types in the regression. These points had depths that ranged from 2.0 feet down to 33.8 feet (uncorrected for tidal variations). The regression yielded the following statistics:

slope = -7.966065
constant = 31.763236
correlation coefficient (r) = -0.83

The slope is related to the attenuation coefficient k, (slope = -1/2k) and the constant is related to the sensitivity factor V0, (constant = ln V0/2k) for the band 1 data. The values for k and V0 were then computed:

k = 0.0628 ft-1
V0 = 53.9093 ft-1

At this point, the single-channel method could be applied to estimate depths for the study area using the band 1 values as the input data, and a predetermined TM5 (SWIR) threshold pixel value to establish land/water boundaries.

The output file from the single-channel depth processing is a 1-byte file with pixel values that represent integer depths in feet. This file was again smoothed using a 3X3 low-pass filter and converted to a 3-band color file with the following codes:

Black: Land
Gray: 1 - 5 ft.
Red: 6 - 10
Yellow: 11 - 15
Light Green: 16 - 20
Dark Green: 21 - 25
Cyan: 26 - 45
Dark Blue: > 45 (Deep Water)

The intervals of this code suggest the increasing difficulty in discriminating depth intervals at greater than approximately 25 feet. In other words, at greater depths very small recorded sensor signal differences represent relatively large water depth differences. On the image-map the intermixing of the latter two categories, 26-45 feet (cyan) and >45 feet (dark blue) suggests that the limit for this discrimination was reached at about 45 feet.

This bathymetric map is a provisional product. While our comparison of this map with the depths at known references points and with the 1983 aerial photography appear to provide a good correlation for the area of interest, its accuracy is not known.

Our *sea truth* data indicate that detailed water depth variations are not represented on this image-map. Both the pixel smoothing and the selection of large depth class intervals, mitigate against a high level of small area detail. More detailed depth information for the shallow areas may be available in the data than is shown here.

Turbid water areas outside our study area show anomalous depths. Indeed, remote sensing data from turbid sea coasts have been used for mapping that variability as a function of the concentration of suspended materials. However, water turbidity was not a problem for mapping water depths in the clear coastal waters near Buen Hombre.

To date, we have not checked this product in the field. A field evaluation would likely result in some adjustments of the depth category intervals, but the pattern of the bathymetric contours compared with those on the 1:50,000 topographic map appears accurate.

In general terms a remote sensing product such as this bathymetric image-map, that uses site-specific data for calibration of the algorithms used in its production, should be field checked and modified as needed before it is used as a basis for decision making.

Monitoring Change

We directed much attention to using remote sensing technology to record and measure environmental changes to the Buen Hombre coast, especially the near-shore coral reef systems. We analyzed multi-date combinations of Landsat data from 1975, 1985 and 1989. The objective was to produce image products that helped to identify and delineate areas of change that were considered detrimental to the coastal ecosystems (Viewgraph 6).

Data Registration

Several processing steps are involved in the simultaneous analysis of multidate data sets. One step was the geometric correction, resampling, and registration of the all the data to 25 meter pixels. Another key step is the radiometric calibration of these data.

Radiometric Calibration of TM Data

Analysis of the single date histograms of pixel values showed a slightly greater radiometric range for the February 1985 TM data than for the January 1989 TM data. These differences varied for the different spectral bands. Such differences are common for multispectral data obtained of the same area on different dates and may be due to actual scene changes between the two dates, differences in the sun elevation, or to Landsat sensor variations. Based on these histograms, we wanted to modify the radiometry of the 1989 data to closely match the dynamic range of the 1985 data.

Viewgraph 6: TM Ration and TM Vector Threshold Change Images

The same geographical areas were then examined for both dates using the video display. Several pixel radiance values in each of three selected areas were recorded for TM bands 1 through 5 and for TM-7 for both data sets (Table 2.4). The areas selected included (1) deep water, (2) mangrove forest, and (3) bare soil. These areas were selected because they appeared similar in the natural color images for the two dates. The pixel values from the two dates were plotted separately for each band to verify the linear relationships between the radiances in the different bands.

Because linear relationships occurred in all bands, computations of gain (slope) and offset (intercept) coefficients needed to modify the 1989 data were made using a calculator. The coefficients are presented in Table 2.5. Subsequently a file containing these coefficients was used with ERIM's radiometric balancing software to modify the 1989 TM data set.

Table 2.4. Coefficients to radiometrically correct 1989 TM data to 1985 TM data.

TM Band	Offset	Gain
1	1.0410	1.0524
2	-0.7910	1.1643
3	-1.0024	1.1338
4	-0.9955	1.1447
5	-0.5713	1.1635
7	-2.3652	1.1720

Measuring Amplitudes of Change

Two different continuous tone change images were prepared, one for the 1975 to 1985 data and one for the 1985 to 1989 data. These change images were derived from the ratio of single bands of data: [2], TM2 (1985)/MSS1 (1975) and [3], TM1 (1989)/TM1 (1985).

The ratio between the 1985 and (radiometrically balanced) 1989 TM data sets was created using TM1 (blue) from both dates. In this image the brighter areas represent blue radiance increases from 1985 to 1989, and darker areas show a radiance decrease. The intermediate gray pixels are areas unchanged or only slightly changed.

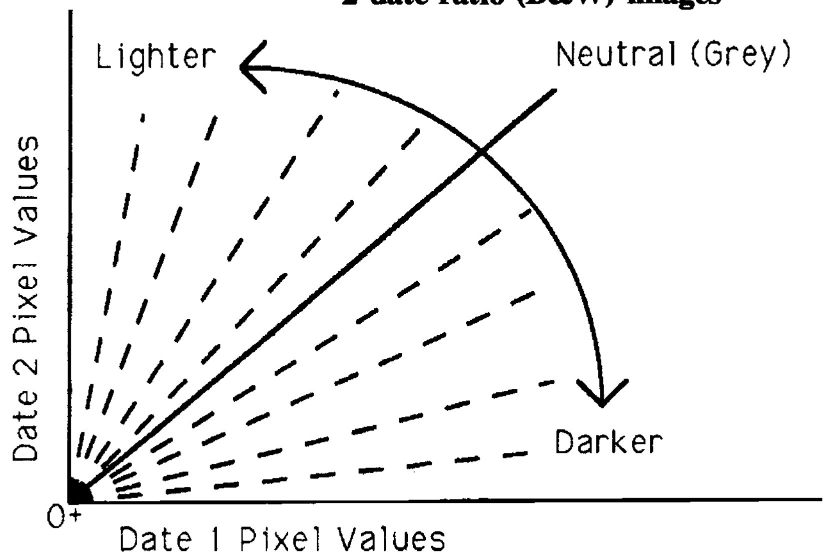
Similar processing was performed to create a ratio image between the 1975 MSS and 1985 TM data sets. TM2 (green) and MSS1 (green) were used. These data sets did not have the same geographical boundaries and the extreme eastern portion of the study area is not covered by this image. There was also a difference in the spatial resolution of the original data from which this image was made. Again, brighter areas in this image indicate radiance increases and darker areas indicate radiance decreases.

Table 2.5. TM pixel radiance values used in regression analysis to compute radiometric balancing coefficients for bands 1-5 and 7

Terrain	Image	2 FEBRUARY 1985						4 JANUARY 1989					
Area	Row,Col	B1	B2	B3	B4	B5	B7	B1	B2	B3	B4	B5	B7
Deep	612,1216	73	17	14	6	4	2	69	16	13	9	4	5
Water	613,1216	74	18	14	7	5	4	68	16	13	7	3	6
	614,1216	71	18	14	7	5	1	68	15	13	7	6	6
	614,1215	74	18	14	8	4	4	67	17	14	7	4	4
	614,1214	74	18	14	8	5	5	68	16	15	7	4	1
	612,1214	73	19	14	7	5	3	64	16	13	7	5	4
	611,1214	74	19	14	8	5	1	66	16	12	7	6	4
	611,1212	71	19	14	8	5	3	69	16	14	7	3	6
	609,1212	72	19	15	8	6	3	67	17	13	7	5	4
	608,1208	73	19	15	8	6	3	67	17	12	7	4	4
Man-	1209,1476	67	24	22	41	21	7	65	22	21	38	20	9
grove	1210,1476	70	23	22	45	23	10	67	21	21	43	21	11
	1211,1476	69	23	22	47	23	7	65	21	21	44	23	10
	1212,1476	67	24	22	50	24	7	64	22	21	44	22	8
	1213,1476	65	24	23	55	25	7	65	22	21	48	21	6
Bare	2012,1792	122	71	96	82	174	105	120	61	83	73	144	89
Soil	2012,1793	127	70	97	84	167	102	119	63	90	72	151	91
	2013,1793	133	76	104	88	175	103	121	64	91	77	149	90

The nature of these images may be conceptualized from Graph 2.1. This is a comparison of the values for the same pixel on two different dates.

Graph 2.1. Representation of image tones for 2-date ratio (B&W) images



The pixels values that have not changed from date 1 to date 2 fall on or close to a line that extends in a 45 degree angle through the origin of the graph, i.e., their values are highly correlated. Because the 1975 MSS data were not radiometrically balanced with the 1985 TM data, the line representing *no-change* may have an angle different from 45 degrees. However the image tones are similar to that of the 1985 TM and 1989 TM image. Low values (dark features) appear close to the origin; high values (bright features) are some distance from the origin. This 1:1 ratio value is portrayed as a neutral medium grey tone on the ratio image. Despite whether a feature on the ground appears light or dark to the sensor, it will be represented as medium grey if there is very little or no radiometric change. Thus, the marked contrasts between land, water and bare areas disappear on ratio images.

Pixel values that deviate from the 45 degree line indicate change. Specifically, pixel values that are greater on the later date than the earlier date have higher ratio values (> 1) and are lighter in appearance on the image. Pixel values that are lower on the later date appear darker in the ratio image. The extent of the deviation from the 45 degree line is a measure of the relative amount or rate of change. For example, a small amount of change will produce a light or dark grey tone, and a large change will appear as black or white on the image.

Analysis of the 1975-1985 ratio image and the 1985-1989 ratio image, in combination with ground truth data, indicate several types of change. Some changes are likely to be significant; some, ephemeral. Only certain changes are of interest within the context of this environmental monitoring activity. There are six types of changes evident in these images:

1) *Clouds and cloud shadows*. The most ephemeral change, but one that frequently plagues multidate imagery, is that of clouds and cloud shadows on one date or another. The clouds that covered major portions of the land area in the 1989 Landsat image are evident as high ratio values (bright) and the cloud shadows as low ratio values (dark) in the ratio image (Viewgraph 7).

2) *Surf zone and water depth*. Another type of ephemeral change is related to different wave conditions. The surf zones on the windward sides of the coral reefs and on unprotected shorelines show dark linear tones indicating reduced areas of surf in 1989. It's interesting that the windward surf zones are evident on the change images but the actual reefs are not. Those portions of the shoreline that are protected from waves do not indicate change. The slight difference in water depth associated with the different tidal states may have enhanced (lightened) the appearance of very shallow areas on the ratio images.

3) *Mangrove and other vegetation changes*. The reduction or removal of dark vegetation appears as a significant light tone on the change images. Several mangrove and forest areas that were harvested between 1985 and 1989 are clearly shown. Similarly, several agricultural areas and irrigation canals show up as dark because of the revegetation and addition of water that has occurred between the two dates. In particular, crop rotations, in which fields are cultivated and fallow on alternate years, are evident in this type of image. Some of these vegetation changes represent long term changes to the ecosystems; others do not.

4) *Marine bottom type/condition changes*. Of primary concern for this study is any evidence that multidate remote sensing data can highlight bottom type changes. As far as we know, destructive bottom type changes involve radiometric changes from dark to light. Bleaching, abrasions of corals, losses of seagrass, and disturbances of sand or algae are all likely to result in higher bottom reflectances. Therefore, light tones or patterns for water areas on the ratio images are suggestive of marine ecosystem disruption. Most of the light toned change areas are small and localized on or near the coral reefs -- several pixels representing less than an acre. However, one 20 acre oblong patch of shallow sea bottom just offshore from a location known as *Punta Juanita* appears very light. Because this area was not visited, we do not have a good explanation for this evident large area change. One conjecture is that it may coincide with the location where local inhabitants have reported the complete loss of fishing habitat and the possible removal of corals by *outsiders* (see Section 5.2 below).

5) *Water sediment patterns*. Optical changes in the water caused by terrestrial runoff are evidenced in the extreme eastern and western portions of the Landsat imagery, but did not affect the Buen Hombre coast.

6) *Sea state*. The ratio images provide some suggestion that the sea state beyond coral reefs was different between 1985 and 1989. A uniform but slightly lighter tone

Viewgraph 7: TM Vector Threshold Change Image of Sand Key and *Punta Juanita* suggests that the open ocean had somewhat different wave patterns that resulted a different appearance, perhaps due to sun glint. This is in contrast to the darker tone, protected near-shore areas that show little or no change.

Recording Types of Change

Not all changes show up well in any one TM band or a ratio of two TM bands. Change Vector Analysis allows the detection of all radiometric changes in any number of spectral bands. This empirical approach computes pixel direction and magnitude changes for multiple input bands. Bands TM1, TM2, and TM3 from the 1985 and 1989 image pair were used in the processing.

The TM visible bands were used to create images that show a certain type of change from dark to light between the 1985 data and the 1989 data. Visible wavelengths (TM1, TM2, and TM3) were used because the primary areas of interest were the shallow water and coastal mangrove regions. The Change Vector Analysis method (Virag and Colwell 1987) was used.

The initial output image from the Change Vector Analysis processing was a 2-byte file where channel 1 shows the direction or *sector code* and channel 2 shows the magnitude of the change. Because the analysis considered two directions (+ or -) and, in this case, three input bands, there were 23 or 8 possible sector codes. For instance, sector 1 includes pixels where a decrease in the pixel value occurred between date 1 (2-Feb-85 data) and date 2 (4-Jan-89) in all three channels processed. Sector 8 indicates pixels where an increase occurred between the two dates for all three channels. All possible sector codes are indicated in Table 2.6.

Table 2.6. Two-date change codes

	Landsat Change		
Sector Codes	TM1	TM2	TM3
1	-	-	-
2	-	-	+
3	-	+	-
4	-	+	+
5	+	-	-
6	+	-	+
7	+	+	-
8	+	+	+

+ indicates an increase in pixel radiance value from date 1 to date 2.
- indicates a decrease in pixel radiance value from date 1 to date 2.

Date 1 = 2 February 1985 TM data
Date 2 = 4 January 1989 radiometrically modified TM data

Sectors 7 and 8 were of interest because they represented areas where the threshold change magnitude was met due to total radiance increases in TM1 (blue) and TM2 (green) but not in TM3 (red), or due to increases in all three bands. It was thought that any shallow areas of coral, algae or seagrasses that had been damaged or destroyed may appear brighter in the second date in the three visible bands, or possibly only in TM1 and TM2 since TM3 has a reduced ability to penetrate the water column and is less effective, especially in deeper water.

The total magnitude of the change per pixel was computed by equation 2.

$$\sum_{i=1}^{n} sf_i \left((x2_i - x1_i)^2\right)$$

where i = TM spectral band
$x2$ = date 2 pixel radiance for band i
$x1$ = date 1 pixel radiance for band i
sf = scale factor for band i

In this processing, a scale factor of 5 was used for each TM band.

After the 2-byte change vector analysis, change images were produced to show the locations and types of changes of interest. Pixels were categorized by sector code when the magnitude of the change was equal to or greater than a threshold value. These pixels were assigned a single color and were overlaid on a black and white background image.

Forty (40) was the selected threshold value. This value was chosen by examining areas in the natural-color composites where severe changes appeared to be occurring and recording the scaled change magnitude for these pixels from the change image. Several iterations of the change image processing occurred before arriving at a threshold that represented significant changes but avoided changes due to image noise. Two images were prepared using band 1 of either date 1 or date 2 as the background. One image included sectors 7 and 8 changes as magenta and red respectively, and the second image showed sector 1 changes as yellow.

Note that the colored pixels do not represent all pixels where changes have occurred between the two dates, only areas of substantial difference. Several suspected areas showed sector 7 and 8 changes. Among these areas was one large oblong area southeast of Sand Key, near Punta Juanita. According to local people, this area was a coral reef that was most productive for fishing and is now destroyed. They suggest that corals may have been physically removed from this area at one time.

Several smaller shallow water regions showed sectors 7 and 8 changes in the study area. These areas include: the near shore area on the northwest portion of Sand Key; some small patch reefs just north of the Punta Rucia beach region (Viewgraph 8); and another near shore region that is several kilometers west of the Buen Hombre village and immediately west of a large mangrove region, where several sand chutes between aquatic vegetation appear to have increased in size. Also, some shallow coral reef and lagoon areas both east and west of Buen Hombre had small groups of pixels that met the selected change threshold. The marine areas that showed change were almost exclusively in shallow water areas.

Sectors 7 and 8 changes were also of interest because any areas of the mangroves that had been cleared also might be detectable. The sectors 7 and 8 change image did detect a portion of mangrove known to be cleared along the shoreline just west of Punta Rucia.

Sector 1 changes were of interest because they are areas where the threshold change magnitude was due to radiance decreases in TM1, TM2, and TM3 between 1985 and 1989. Any large areas of growth at the edges of a mangrove, or even portions of coral reefs and seagrass/ algae beds might be located. No such areas were detected from this processing.

The sector 1 change image showed the surf effect change along the north sides of the shallow coral reefs noted in the previous section. These may be due to larger wind-driven waves in 1985 than 1989. If the 1989 wave action was reduced from that of 1985, these areas would appear darker in all bands than in 1985 -- sector 1 changes.

Tide levels at the time of the satellite passes also may make a difference. A calculation of tidal levels was done using a table of predicted high and low water levels published by the National Oceanic and Atmospheric Administration. The nearest reference station was at Puerto Plata some 60 kilometers from this location. Based on this reference, a difference in water levels at the two times was only 0.08 feet (+0.93 feet for 2 February 1985 and +1.01 feet for 4 January 1989). Thus, this artifact may result in a negligible scene difference. Both vector threshold change images show ephemeral changes due to the presence of clouds and cloud shadows on date 2.

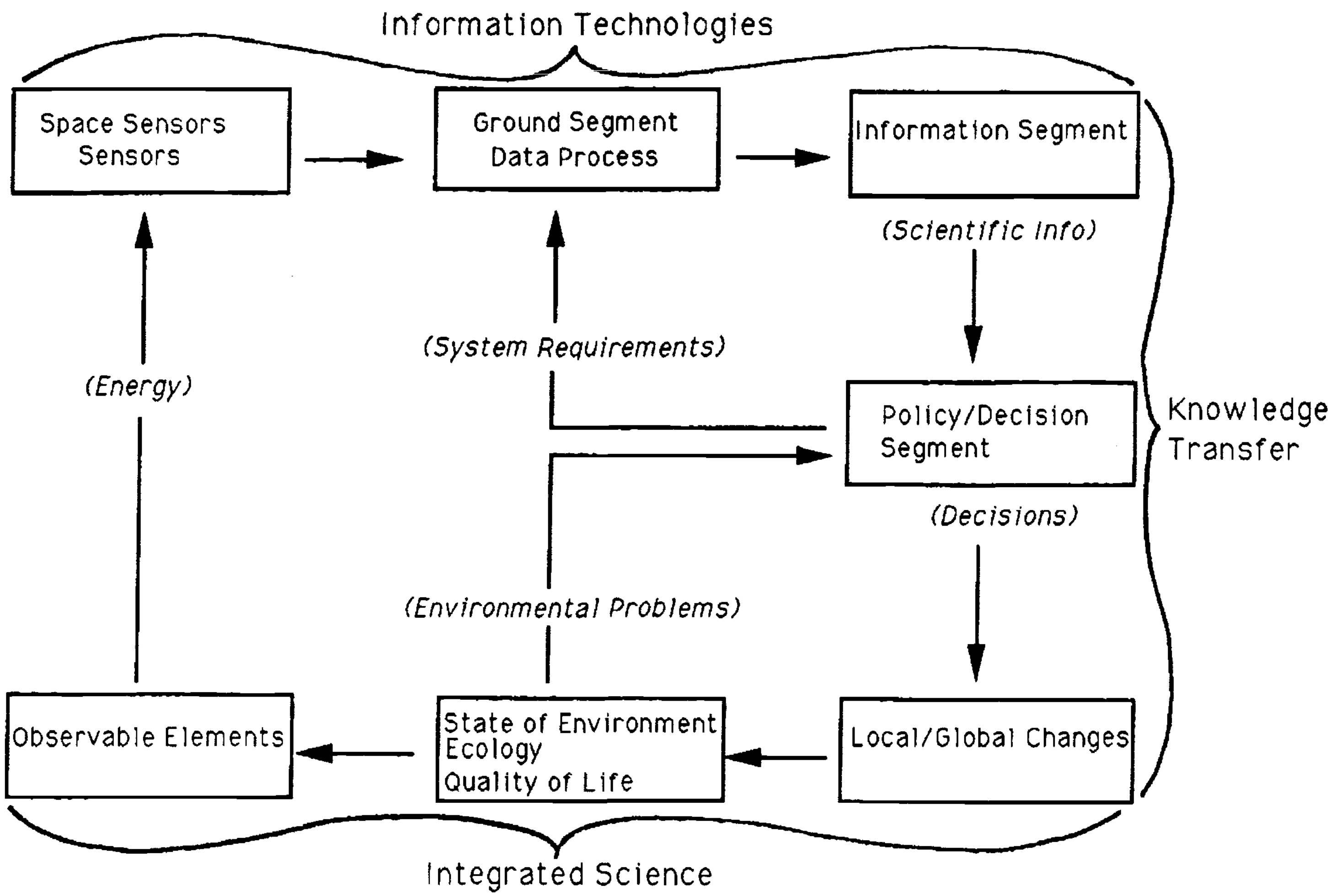
CIESIN Issue Summaries

This CIESIN pilot project is concerned with utilizing remotely sensed data as indicative of the possible uses of future EOS-data in roles of information, policy, and decision making. The following diagram may help to conceptualize the relationships of the three processes (integrated science, information technology, and knowledge transfer) that CIESIN has identified as being central to this process. CIESIN is organized to respond to issues raised by the pilot projects in these three areas.

In this section, we attempt to create a conceptual model of that process and to generalize within the context of that model, some to the things that we have learned in the Buen Hombre study.

Viewgraph 8: TM Vector Threshold Changes Along Coast Near Punta Rucia

FIGURE 2.1. DIAGRAM OF THE EARTH OBSERVATIONS/GLOBAL CHANGE SYSTEM



From this diagram, it may be noted that uses of remote sensing in connection with issues of global change involve a cyclical process of interactions between science, information technology, knowledge transfer processes. However, the ultimate concern of all of these is the *state of the global environment* -- its ecology and the quality of life that it affords to its human inhabitants.

The state of the environment may be partly characterized by a set of observable elements that can be recorded by remote sensors. However, many important aspects of the environment do not have physically observable elements or have elements that are not accessible to remote observation. They are beyond the capabilities of remote sensing to record and monitor directly. Many of these aspects fall into the domains of the natural and the social sciences.

Some of the physical data that are recorded by remote sensors may be processed into products that convey information. The appropriateness of the products is determined by the requirements of the knowledge transfer and decision-making processes. In principle, decision-making or policy processes directly or indirectly promote changes in the state of the environment. Some changes are anticipated and intentional; others may be unintentional.

The integrated science issues are those that describe the linkages between the bottom three boxes: local/global changes, state of the environment, and the observable elements at the earth's surface.

The information technology issues are those that implement the linkages between the observable elements, the space segment, the ground data processing segment, and the information segment. It includes the technological processes of creating information from the large quantities of data available through the remote sensing technology and from many other sources.

The knowledge transfer issues are those that link the information segment with the policy/decision segment and the policy/decision segment with changes in the environment. This view allows us to see the connections between integrated science, the information technology, and knowledge transfer as part of a cyclical process -- one in which the entire process is non-functional without each element being in place.

An example of the interactions of this model is to start with the empirical observation that tropical coral reefs around the world are under stress and are declining in biological productivity and decreasing as protective barriers to severe storms. As a result, both the livelihoods and the physical security (well-being) of those that depend on tropical marine ecosystems are at risk from this decline. Integrated science studies tell us that destruction of coral reefs is accompanied by a physical condition known as *bleaching*. The death and decay of colored coral animals result in exposure of highly reflective calcium carbonate reef substrata to view and a general *bleaching* or whiting of the reef. On a large scale, this bleaching is an *observable* that may be recorded by remotely sensed satellite data. Our knowledge of the light transmission properties of water helps us select blue and green wavelengths of light for observing this change.

On a single date many areas of coastal zone may have features as light in tone as a bleaching reef system, such as sand or salt flats. However, infotec provides us with the multidate data collection and processing tools to compare the radiance differences between two different dates and to convert the digital values of Landsat data to information about the areas of change in a coral reef. The end product of this process is either the black-and-white, two-data ratio image or the change vector image. One shows environmental changes as continuous greytones and the other clearly identifies those areas of substantial change that exceed a certain threshold level.

Knowledge transfer is the process of informing those concerned with specific reef systems of the location and spatial extent of the changes taking places and over what period of time. This involves displaying and transferring the change information in ways that are accurate and easily comprehensible to the *user*. In this case we coded the threshold change information red and overlay it with a single data, natural color image. The natural color background serves to place the change information into a comprehensible spatial context.

The final but most important step in this cycle is the decision or policy process. The *bleaching* information provided by the images, if properly understood, may influence the behavior of people at local, regional, and national levels and prompt actions that change the processes that caused the *bleaching*. This pilot project suggests such actions which include restrictions on tourism and fishing by non-local residents. Our findings may lead to establishing protected areas and to greater regulation of the coral reefs. These actions are expected to change the appearance of the environment and we expect these changes can be monitored by remote sensing devices.

In some sense this is a cybernetic system in which feedback loops help promote its functioning. Information concerning the state of the environment, particularly the perceived problems, helps to drive the decision making processes. The policy/decision-making process in turn, prompts man-induced changes to the environment.

While this diagram shows data and information coming from the space remote sensing technology, it's equally valid to consider the policy and decision processes as driving the demand for information. Therefore, in a broader context, the requirements placed on the ground and space segments are, or should be, derived from decision making requirements for information.

If the feedback loops are broken or ignored, the system as a mechanism for effecting environmental change breaks down -- *runs open loop* as we say. Democratic processes that respond to environmental problems are subverted; massive space and data processing systems get designed and costly engineering works get built without clearly identifiable social and/or environmental functions.

Integrated Science Issues

Within the integrated science domain, remote sensing is a diagnostic tool -- a tool for recording and measuring surface *observables* that are a functions of environmental parameters of interest. The effectiveness of the subsequent remote sensing record is dependent on our scientific understanding of the links between the environmental parameter of interest and the surface-observables and the link between the surface-observables and the sensor record.

We have organized our knowledge of this marine coastal system into different scales of processes which roughly correspond to the categories of the USGCRP. Specifically, we have identified different orders of processes and the patterns that connect them.

First-order processes relate to the global setting of the island of Hispaniola. This setting is governed by geological-oceanic-atmospheric processes that implement its tropical maritime climate and the geobiology of the Island Republic. The prevailing climatic conditions are governed by the nature of global atmospheric processes. Some processes, such as the number of plant and animal species and the land area/boundary ratio, are governed by this insular nature.

Second order processes are governed by the linear features of coastal zones. Many important parameters change gradually or abruptly along this 3-dimensional linear zone -- the most significant being the aquatic-terrestrial boundary itself. The coastal zone may be thought of as a membrane, an ecotone that both retards and directs exchanges of enery and materials between the land and the sea. Transects orthogonal to the coastline provide some of the most useful data regarding the spatial variability of this landscape. Vertical (topographic and bathymetric) as well as horizontal gradients are of significance.

Third order processes are natural processes that contribute to breaks in the coastline linear structure. These are indicated by variations in biota and substrate. They include streams and channels that dissect the terrain and local geographic variations that result in locally distinct micro-climates and ecological *patches*.

Fourth order processes are those imposed by human interactions with the environment. Agriculture, fishing, and habitation result in certain patterns that are superimposed on the natural environment.

Fifth order processes are human socio-cultural and technological differences that allow one group or another (resident fishermen, foreign fishermen, farmers, tourists), to exploit the coastal zone in different ways and, therefore to impose different patterns on the landscape.

* While few areas of Buen Hombre have changed significantly between 1975 and 1989, the remote sensing data provide early indications of environmental stress due to human factors (fishing and tourism).

* Both the natural color TM image and the Landsat bathymetric map provide second order linear and third order pattern information. The third order ecological information is especially useful for understanding the physical characteristics and constraints of this coastal zone.

* The land use maps provide fourth order pattern information. The satellite-derived map does not substitute for the detail provided by the aerial photos, but it may be sufficient for certain purposes.

* The fifth order change images demonstrate the different changes (damages) that are occurring to this fragile marine environment. There are indications that the local Buen Hombre fishermen are having the least impact, while *chinchorro* fishermen from outside the area and the newly developing (Western) tourism industry are having moderate to severe impacts.

* Understanding complex human interactions with the coastal zone environment requires an integrated science approach which accounts for both physical and social processes and the patterns that connect them.

Information Technology Issues

Information technology involves remotely recording the observable elements and turning that record into information products. This is an inexact science. Since the remote sensing data seldom provide all of the data that are necessary to produce an information product, the infotech process must identify, archive, and integrate many different types of data from many different sources.

What did we learn about processing and using the aerial photography, the Landsat data, the GPS data, and the sonar data in this study? What were the other types of data that were required to create the information products? How good is each information product, i.e. how accurately does it represent the parameter(s) of interest -- land use, water depth, physical change?

* Remote sensing and associated data processing technologies provide us with the opportunity to obtain land use and bathymetric information concerning coastal environments --information that is impractical to obtain by other procedures.

* Several remote sensing technologies (satellite and aerial imagery, GPS, sonar) used in combination provided more useful information than any one individually.

* Generalized land use information of the coastal zone is available from satellite data, but aerial photography and ground observations still are necessary to obtain detailed, small area information.

* Approximate water depth information may be obtained from remote sensing data, but mapping differences related to bottom type remain illusive.

* All of the remote sensing technologies required integration of at least some non-remote sensing data to produce a useful information product.

* Spatial data registration was a crucial component of the comparison and use of multidisciplinary data sets.

Knowledge Transfer Issues

Within the knowledge-transfer domain, remote sensing products are media of communication -- i.e. the information products [reports, images, maps, tables, descriptions] intended to convey information to decision/policy makers.

What are the links between our information products (maps and images) and the decision makers? What other types of information are necessary in order to make decisions using these products? Finally, what are the links between decision processes and change in the local or global environments?

Specifically, what do the information products communicate and how well do they do it? Are they or will they be understood? Do they convey the right information -- the information needed in order to make a decision. What is the evidence that the products affect decisions?

* There is a large and growing demand for information concerning coastal zone environments. The demand comes from local, regional, and national leaders; from both the private and public sectors; and from the local and the international community. Coastal zones represent less than 7% of the land surface of the earth but will be the focus of almost half of the world's development funds.

* Remote sensing imagery is an effective means for conveying environmental information and for *legitimizing* environmental action.

* Local farmers and fishermen had no difficulty in understanding the information content of the natural color satellite images of their area.

* Local inhabitants that make daily use of the land and sea resources are in the best position to interpret the information content of remote sensing products and their utility.

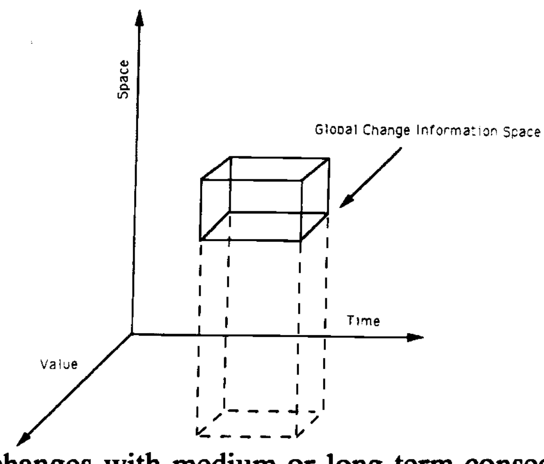
Policy-Relevant Information

This section provides a level of generalization that does not derive directly from the experience of this pilot project but rather from an attempt to put the results of this pilot project within the context of an existing perception or philosophy. We interpret our observations within this broader framework because they are easier to understand, but not be possible to prove. Such a framework derives from a lifetime of experiences and all we can do is cite the evidence from this study and others to support our assertions. Others, viewing the same evidence, may draw different conclusions.

Global Change Information

This report describes several information products that are intended to precipitate and address environmental issues in the Buen Hombre environment. The global change information that is relevant within the broad realm of human decision making is quite specific and selective. Such information may be defined by its spatial, temporal, and social context as suggested by the following diagram:

FIGURE 2.2. DIAGRAM OF GLOBAL CHANGE INFORMATION SPACE



Only physical changes with medium or long term consequences (probably measured in decades) and operating on regional or international scales are of interest. However, it is important to distinguish between these long term, large area consequences and, perhaps, the short term and small area observables and indicators of change. Small area or changes that happen quickly may be important precursors or indicators of global change and therefore, are of interest. Thus, there may be two or more spatial scales and temporal scales of interest. Confusing the sets of scales leads to differences of opinion about what kinds of issues are appropriate for global change research.

While in this study we are concerned with processes that are generic to large areas and have likely been going on for a long time, the observable physical effects may be small in a areal extent and the result of short-lived events. If these small area changes have high social values, such as concentrations of environmental toxicity, or are indicators of large scale future changes, such as declining fish catches, they are of interest for global change research.

To command attention, the effects should be of a significant value in human or social terms. Ultimately, we are concerned with decisions that affect the productivity of major ecological zones -- in this case, tropical marine coastal zones.

Many decisions of the farming and fishing residents of Buen Hombre, and of neighboring people and government officials, have high value (survival within that environment), have long term (perhaps irreversible) consequences, and are large enough to be observed by satellite sensors. These types of decisions may be replicated in coastal zones throughout the tropical world. They relate to the exploitation and management of fragile coral reefs and fishing grounds and to the intensive use and cultivation of marginal agricultural land.

Learning Styles

An important element of CIESIN pilot projects is exploring the different learning styles of people. Learning styles relate to the fact that different types of people (scientist and non-scientists alike) have preferred ways and media for learning and communicating. The preferred learning styles of different occupational groups and professions has been the subject of much educational research (Kolb 1984; Gardener 1983; Armstrong 1987).

Preferred learning styles have profound implications for the kinds of products that an information system produces. To be successful, it must produce products that convey appropriate information in ways that are compatible with the different ways in which people learn. These products may not necessarily be scientifically detailed or technically sophisticated, but they should "speak" to the learning style(s) and living conditions of the intended audience.

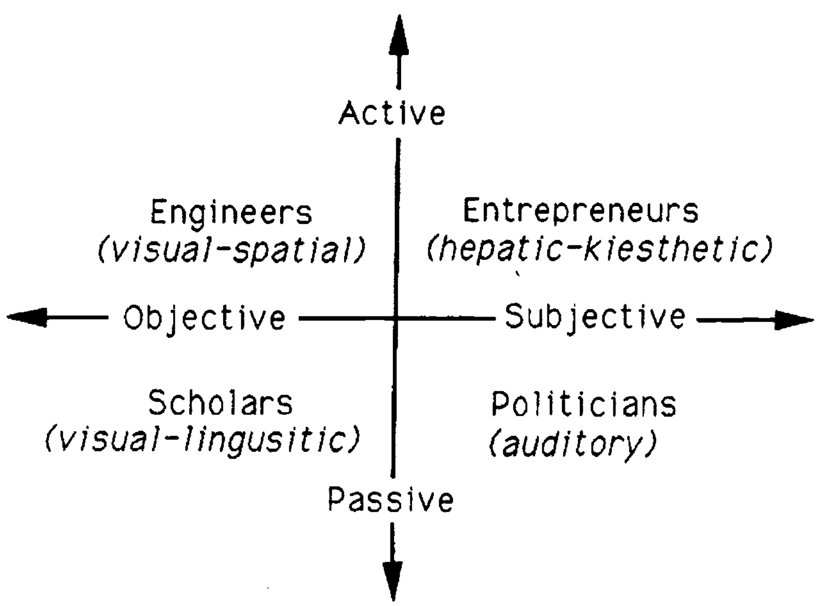
As described by Dohmen (1990), there are three main sensory channels by which we get information into our brains: (1) vision, (2) hearing, and (3) kinesthetic sense, also known as haptic awareness. The dominant channel--or channels, as is often the case--by which people most efficiently take in information define their learning style. It helps determine which kinds of information products will be most useful for them.

The North American-European culture has a very strong visual-linguistic orientation. Written agreements, for instance, are considered real while oral ones are often ignored. TV occupies several hours of an average American's day. The visual learning channel has two main subdivisions: (1) visual-linguistic and (2) visual-spatial. The former provides learning primarily from written language, and the latter from images, pictures, and diagrams. Less than fifteen percent of the people in our culture are auditory learners--the ones who hear the words in their heads when they read.

To date, remote sensing products have been created by people who have a strongly visual-spatial orientation. They communicate most effectively with those who have this same learning style. Few remote sensing products are intended for visual-linguistic, auditory, or haptic-kinesthetic learners. Haptic-kinesthetic learners learn best by doing, by hands-on experience. This style is dominant in many cultures that do not have a long literary tradition. This learning style often characterizes cultures where skilled physical labor and less formal schooling is the norm.

In Figure 2.1, the scientists that are concerned with integrated science often have the *scholar's* learning style--visual-linguistic. The *engineer's* learning style characterizes many of the people who are involved with modern information technology--visual-spatial. The self motivated *entrepreneur* provides the hepatic-kinesthetic learning style of those seeking opportunities to translate information needs into products and to bring information products to the marketplace. Finally, the auditory learners, who deal in verbal analogy and metaphor, are often social scientists and politicians. Figure 2.3 illustrates the generally preferred learning styles of different professions, although clearly each person employs each of the learning styles to different degrees. This illustration is placed on a vertical axis representing personal activity level (active-passive) and orientation (objective-subjective).

FIGURE 2.3. Illustration of Learning Styles (after Samples).



This illustration may be superimposed on Figure 2.1, since people with different learning styles gravitate to different professions (as the labels imply). The most difficult and often least successful communication usually occurs between those most opposite in learning style. For this reason, influence of one group with the other is often "taken on faith," based on the development of mutual trust rather than by actual exchanges of information. For example, politicians often accept the judgement of engineers they have known for a long time rather than seek to understand the nature of information.

Likewise, different societies assign primary value to certain kinds of learning. Western society values primarily linguistic and logical-mathematical intelligences. Among the fishermen in Buen Hombre, on the other hand, where skillful navigation is needed daily, the visual-spatial and kinesthetic intelligences are highly valued. They readily understand the visual-spatial information of the Landsat images and are highly motivated by the hepathic-kinesthetic activity of *ground truthing*.

As illustrated by the Buen Hombre pilot project, the spatial aspects of the ethnographic and marine biological research were considerably enhanced by access to the remote sensing technologies. Local and national decision makers, who for the first time used these remote sensing products concerning territories and resources of specific interest, came away excited about their information content and their ability to convey information to interested, and often conflicting, parties.

Differences in learning styles, unless recognized, may impede communication; the most effective information products may not be communicated. A global information system must create a variety of products and distribute them through different communication channels. The Buen Hombre pilot project experience also indicated that we have a long way to go in understanding the requirements of the users and in devising appropriate products and mechanisms for making these products useful. In particular, learning the analogic and metaphorical *language* of the decision makers and developing different products is a key to that process.

CHAPTER THREE

CLIMATE HISTORY OF BUEN HOMBRE

Donald Portman, David Willson, and William Kuhn

This chapter presents an analysis of the climatic history, in terms of annual precipitation, of the north coast of the Dominican Republic. The purpose of the chapter is to reconstruct as accurately as possible the history of and variations in climate using available historic precipitation records.

Climate change has been the focus of much of the research on global change (Clark 1987). Some concerns focus on global warming and its potentially disastrous effects on world ecosystems and production activities. Crises in global agriculture, evidence of rises in temperature and sea levels, drought, famine, and atmospheric pollution have driven national and international research funding initiatives directed at investigating causes of climate change, formulating new policies to solve emerging problems and reverse current trends. Analyzing the role of human *forcings*, or activities that contribute to environmental change and degradation is one area of concentration among researchers.

The present analysis is driven by an interest in the extent to which climatic patterns and fluctuations have influenced (1) the biological condition of coastal marine ecozones and their resources, and (2) changes in human patterns of use of certain ecozones and resources. In other words, this chapter examines potential causative phenomena in terms of natural, or climatic, processes, that have resulted in changes in Buen Hombre's ecosystem and the patterns of adaptation in human natural resource use in the community.

The analysis of climate history was also stimulated by oral testimony of elders in the community of Buen Hombre concerning the early cultivation, and later abandonment, of rice and bananas, two significant subsistence crops. According to elders, Buen Hombre was settled at a time when rainfall was abundant. During this period, rice and bananas were cultivated. The two crops were abandoned in the 1940s, according to elders, because precipitation had decreased. Coconuts also were once plentiful on the beaches east of the village, but they, too, have disappeared.

Methods and Assumptions

Villager recollections of agricultural change attributed to a change in the climate prompted researchers to examine whether or not there had been a significant shift in local climate between 1897 and the 1940s. Based on discussions with research team meteorologists and the crop and soil scientist, a conclusion was reached that precipitation was the key variable, rather than temperature and solar radiation. Meteorologists at the University of Michigan conducted a search for available historic precipitation records and reports for Hispaniola, the Dominican Republic, and Haiti, with a focus on data reported for stations on the north coast of the Dominican Republic.

In addition, the crop and soil scientist collected information on the *climate space*, or minimum requirements in terms of precipitation, temperature, solar radiation, and the interaction among these variables, for the survival of crop plants and animals. The objective is to determine, as closely as possible, whether climatic change had contributed to the abandonment of rice and banana crops, or whether the change was due to social, political, and economic factors (policies, incentives, practices such as deforestation), or other environmental factors such as crop disease episodes. The roles of climate and political economy in historic agricultural change in the village of Buen Hombre are discussed more fully in Chapter Four. Inferences regarding climatic change on the north coast of the Dominican Republic and Buen Hombre in particular, drawn from analysis of precipitation data, are presented below.

Buen Hombre Average Annual and Monthly Rainfall

Rainfall patterns in the Dominican Republic, as in many other tropical locations, are the product of complex influences of geography and topography on a wide range of scales of atmospheric circulation. Climatic zones range from humid tropical in the central upland valleys to semi-arid, subtropical as one moves from east to west along the northern coast. The Samana peninsula, as an example, receives over 2000 mm of rain annually. In stark contrast, the northwest coast receives, on average, less than a third of that.

Buen Hombre is on the semi-arid northwest coast. Apparently, there had been no rainfall measurements there before a gauge was established by our research team in 1991. There are no local data, consequently, to verify the perception that rainfall has significantly decreased for the last two or three decades. Available rainfall records from the nearest recording stations can be used to estimate Buen Hombre's rainfall history. It is well-known, however, that tropical rainfall, particularly in mountainous regions, is highly variable in both space and time.

The following text summarizes some considerations necessary to estimate Buen Hombre's rainfall from available data in the vicinity. The specific goal is to obtain, for the past several decades, estimates of (l) Buen Hombre's average annual rainfall, (2) its average seasonal variation (month by month) and (3) the interannual variability in the region.

Average Annual Rainfall

Average annual rainfall patterns for the entire island of Hispaniola have been published by Fassig (1929), Alpert (1941), Portig (1976) and perhaps by others. Portig's map is reproduced in Figure 3.1. A rectangular area, about 80 by 100 km, has been marked on the map to define a region around Buen Hombre for which most of the rainfall data presented in this chapter are examined. Figure 3.2 is a map of the height contours of this region and shows, also, the average annual precipitation for a number of stations. The contours were copied from a 1:250,000 scale Dominican Republic road map (U. S. Army Map Service, 1961) and the rainfall data were taken from Wernstedt (1961).

The nearest station to Buen Hombre that might be expected to have comparable rainfall is Monte Cristi (19 degrees, 51 minutes North latitude and 71 degrees, 39 minutes West longitude, elevation 15 meters). It is near the coast and about 25 kilometers west of Buen Hombre. By a special request sent to the director of the Monte Cristi weather station, the monthly rainfall record from April 1933 to January 1991 was obtained from the National Meteorological Office. The 57 year period (1934 to 1990, inclusive) gave an average of 667 mm.

All three rainfall maps cited above indicate that Buen Hombre annual precipitation is likely to be more than that of Monte Cristi. The Fassig and Alpert maps have isohyets at 20-inch intervals and Portig's map at 500 mm intervals (20 in. = 508 mm). A casual inspection of the three maps gives the following average annual rainfall amounts in millimeters:

	Monte Cristi	**Buen Hombre**
Fassig (1929)	Between 500 and 1000	1000
Alpert (1941)	1000	Between 1000 and 1500
Portig (1975)	Between 500 and 1000	Between 1000 and 1500

Alpert lists the data used for his map. For Monte Cristi it was 1181 mm for an unspecified 7-year period, almost twice the 1934-1990 average of 667 mm. Neither Fassig nor Portig gave details describing the data for their maps. From Portig's text, however, one may deduce that most, if not all, of his data were taken from the extensive tabulations of Wernstedt (1961). The latter lists a 23-year annual rainfall average of 639 mm for Monte Cristi. It is close to the value of 633 mm for the 23-year period 1934 to 1956, inclusive, and not greatly different from the 1934-1990 average of 667 mm.

The unusually high 7-year average used by Alpert was used also by Mather (1961) in an analysis of the average climatic water balance of North America. Further consideration of the validity of this record is given in the section on interannual variability.

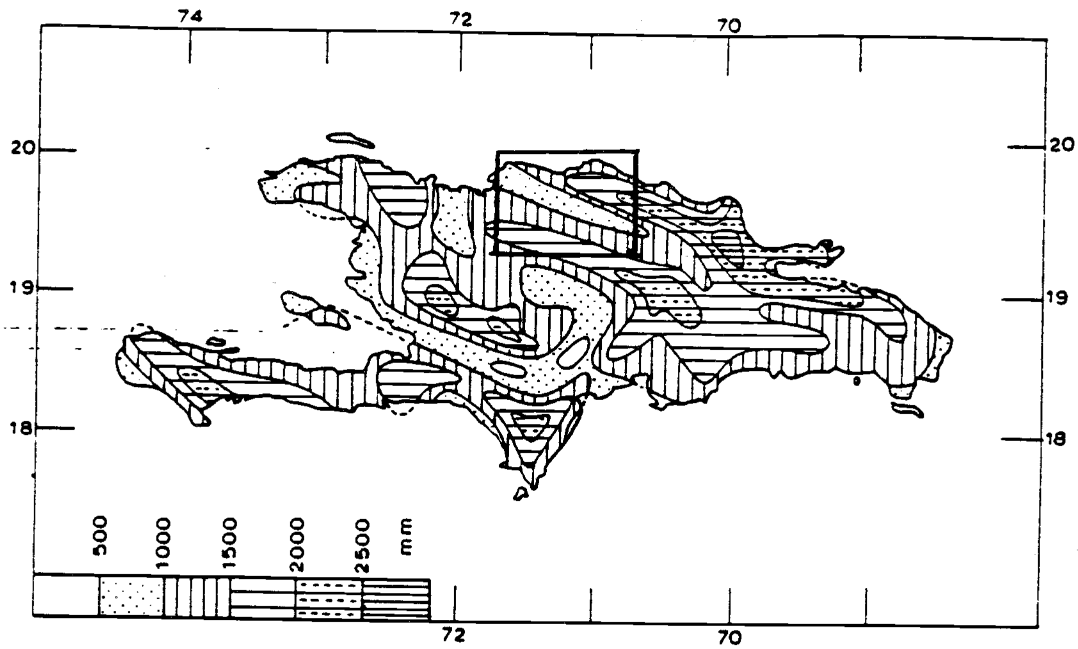


Figure 3.1 Average annual rainfall pattern for Hispaniola. (From Portig, 1976.)

As noted above, the average annual rainfall along the Dominican north coast decreases from east to west. Cap Haitien, Haiti, on the coast 60 kilometers west-southwest of Monte Cristi, however, has an average rainfall of more than 1500 mm. Variation along the coast is shown in Figure 3.3 in which data available from Wernstedt (1961) have been plotted according to longitude. Buen Hombre's location in this pattern gives it an average annual rainfall of nearly 1000 mm, in general support of the analyses of the three cited rainfall maps. The Cap Haitien value shows, however, that such interpolation may be highly unreliable without consideration of coastal and highland configurations in relation to precipitation-producing circulation patterns.

The station of Villa Isabel, currently known as Villa Vasquez (19 degrees, 44 minutes North latitude, 71 degrees, 27 minutes West longitude) is only 15 kilometers south-southwest of Buen Hombre. At an elevation of 16 meters, it had an average annual rainfall of 638 mm for an 18-year period according to Wernstedt (1961). It is situated in the broad valley of the Rio Yaque del Norte which is generally parallel to the coast in the Buen Hombre region, but separated from it by the hills of the northwestern extension of the Cordillera Septentrional (Figure 3.2). Between Villa Isabel and Buen Hombre the terrain is generally above 200 meters with at least two passes between 100 and 200 meters elevation. Because of the intervening terrain and with the assumption that most rainfall in the area is associated with onshore flow, one may expect Buen Hombre's rainfall to be more than that of Villa Isabel.

Two other stations in the Yaque del Norte valley, Valverde and Santiago, with annual averages of 762 (10 years) and 950 (23 years), respectively, show the effect of the rain shadow of the Cordillera Septentrional, if it is assumed that rain occurs primarily with onshore flow from the northeast quadrant. The mountains in this region are above 1000 meters in places and the range is more than twice as broad as it is in the Villa Isabel-Buen Hombre area. Santiago's annual value is about 55% of Puerto Plata's across the range at the coast and Valverde's about 60% of Luperon's, similarly across the range and at the coast. Portig shows the valley rain shadow area as having an annual rainfall of 500 to 1000 mm while the coastal area across the range is shown as a region of 1000 to 1500 mm.

The estimate of about 1000 mm for Buen Hombre made on the basis of Monte Cristi's 667 mm and the somewhat systematic variation along the coast is not unreasonable if Villa Isabel's 638 mm represents a rain shadow effect like those of Valverde and Santiago. In other words, in the Valverde-Santiago area the higher and broader mountain range results in the coastal rainfall being 70 to 85% greater than that in the valley. Between Villa Isabel and Buen Hombre, on the other hand, where the mountains are much lower and narrower, a coastal value of 1000 mm corresponds to a 50% increase of that over the valley.

Both interpolation in the coastal pattern and extrapolation in the rain shadow pattern give, perhaps fortuitously, a value of Buen Hombre's average annual rainfall of 1000 mm. Although the value is compatible with the three maps cited above, its reliability should not be accepted without an examination of the nature of atmospheric conditions and circulation

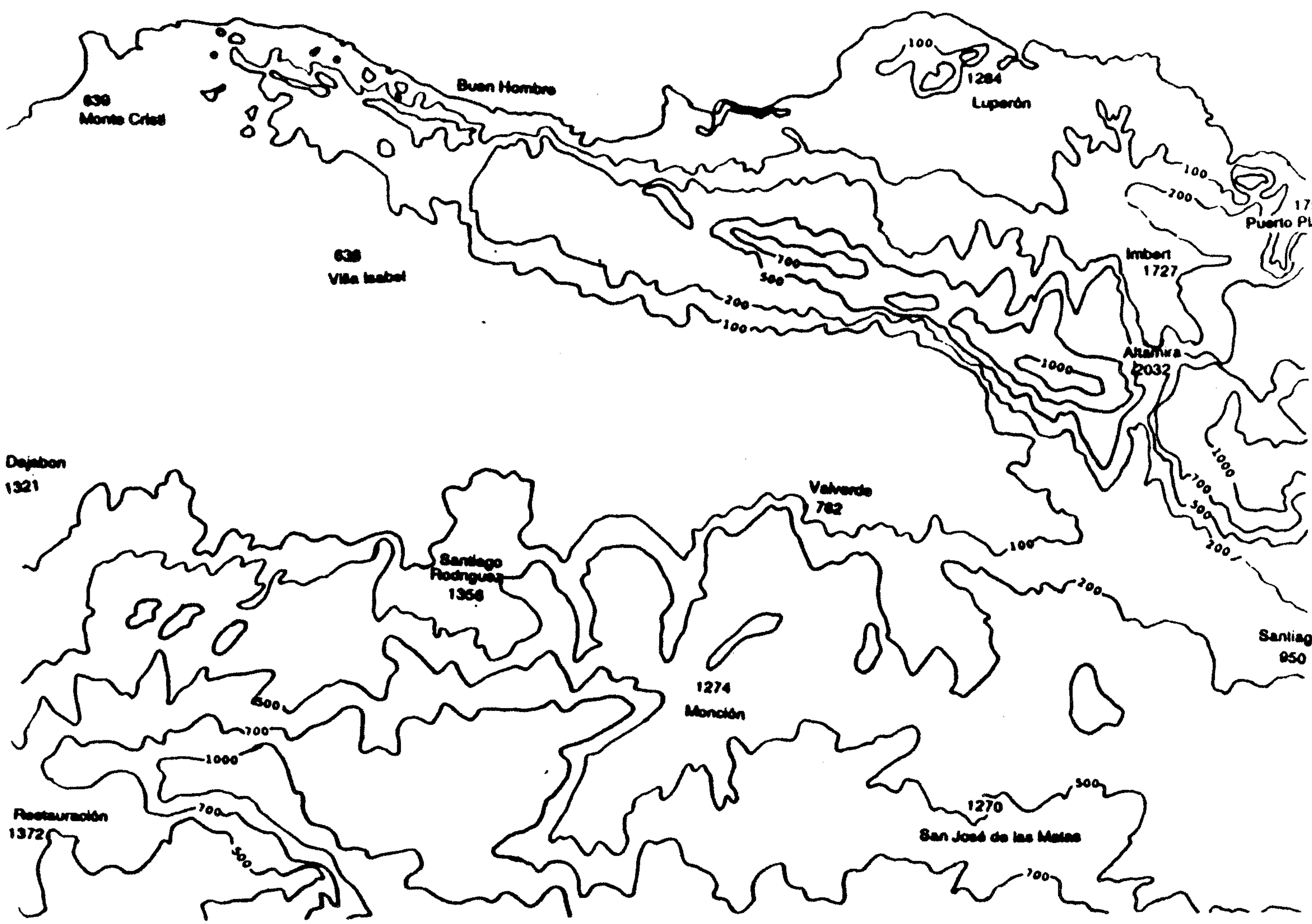


Figure 3.2 Topography and average annual rainfall, Dominican Republic northwest coastal region. Rainfall in millimeters, height contours in meters. (Note unequal contour intervals.)

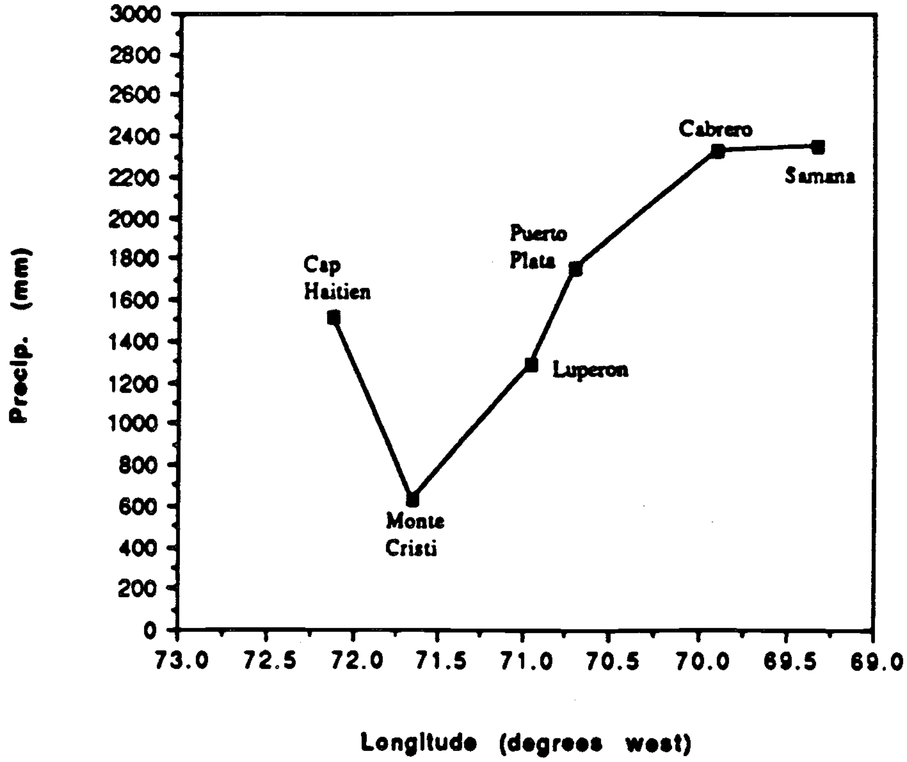


Figure 3.3 Longitudinal variation of average annual rainfall along the north coast of Hispaniola.

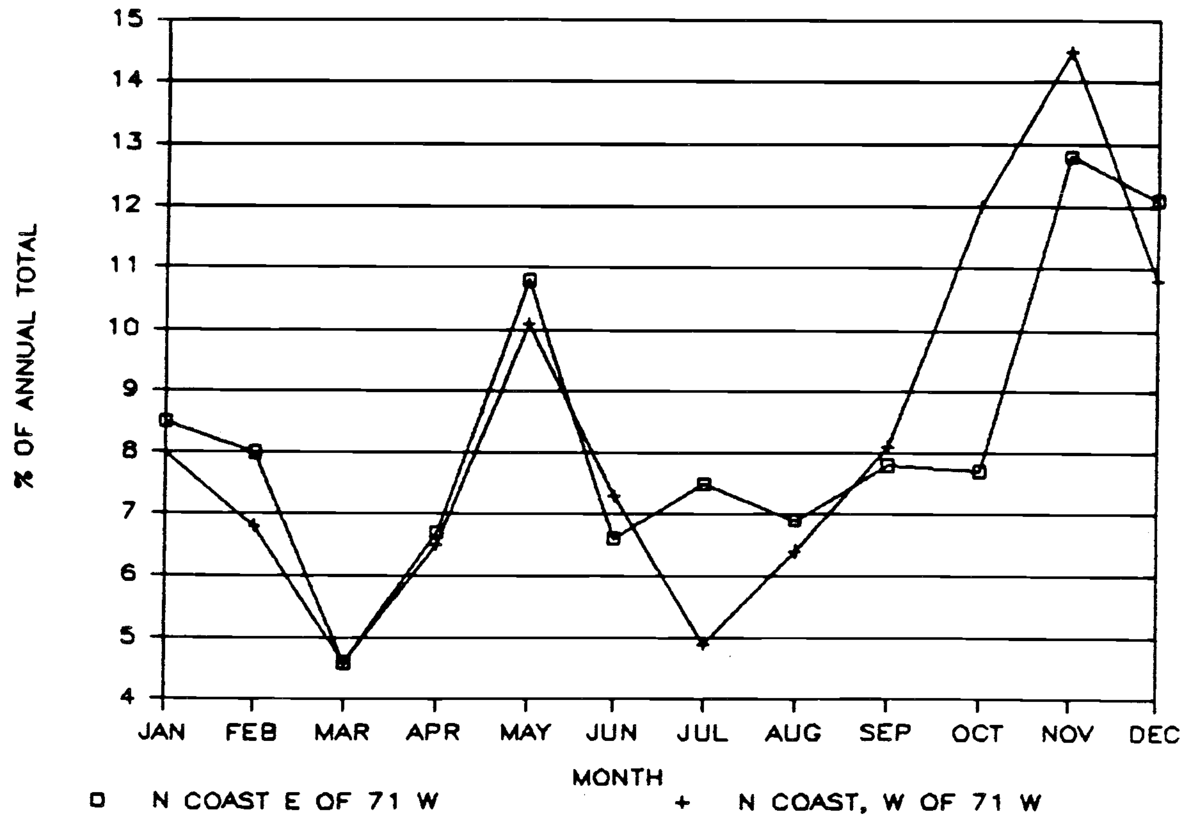


Figure 3.4 Monthly rainfall in percent of annual total, north coast regions, Hispaniola. (From Portig, 1976.)

patterns responsible for precipitation in the area. In the following sections many of these are examined in order to describe both average monthly patterns and interannual variability.

Mean Monthly Pattern

Figure 3.4 shows the mean monthly rainfall for the north in terms of percent of mean annual amounts. It was constructed from data given by Portig (1976) for all but the easternmost part of the island's north coast. He divided this region according to two rainfall regimes, one east of 71 West longitude and the other west. If the latter represents the mean monthly regime at Buen Hombre and if, as estimated above, a mean annual value of 1000 mm is assumed, the ordinate scale on the diagram represents the mean monthly rainfall, in millimeters, at Buen Hombre.

For comparison, the 57-year record for Monte Cristi is shown in Figure 3.5 and the 18-year record for Villa Isabel in Figure 3.6. It is quite likely, of course, that these records figured prominently in Portig's analysis. The data shown here, however, represent a period significantly longer than that for the data he used if, indeed, they were from Wernstedt's 1961 tabulation, as presumed above.

All three figures show strong bimodal monthly distributions. A marked maximum occurs in November and minima occur in March and July or August. The secondary maximum is in May.

Many regions in the tropics have bimodal monthly rainfall patterns. In many cases they can be associated with the twice-yearly passage of the intertropical convergence zone (ITCZ), a band of low pressure discontinuously and variably encircling the earth in the tropical regions. It separates the northern and southern hemisphere semi-permanent subtropical anticyclones, i.e., high pressure cells, occupying the low latitude oceanic areas most of the time. Because circulation around an anticyclone in the northern hemisphere is clockwise and that in the southern hemisphere is counterclockwise, the flow tends to converge (horizontally) in equatorial regions. Convergence results in upward motion and, if adequate moisture is present, condensation, cloudiness and precipitation.

These large-scale circulation features are the result primarily of the rotation of the earth and the decrease in solar heating with increase in latitude. In the annual swing of the earth around the sun, of course, the north pole tilts toward the sun in June and away in December. This causes the subtropical anticyclones to shift latitudinally and, at the same time, the ITCZ to *follow the sun*. That is, it shifts into the summer hemisphere. If a station is near the equator, therefore, it may experience two visits a year of the ITCZ. Stations at the limits of the tropics, however, can expect only one, but somewhat longer, period of lower pressure, cloudiness, and precipitation. This relatively simple picture in the tropics would seem to provide an equally simple pattern of precipitation. The size, shape and distribution of continents, however, create a major distortion in both the flow and precipitation patterns. In the region of the Dominican Republic, for example, the average seasonal

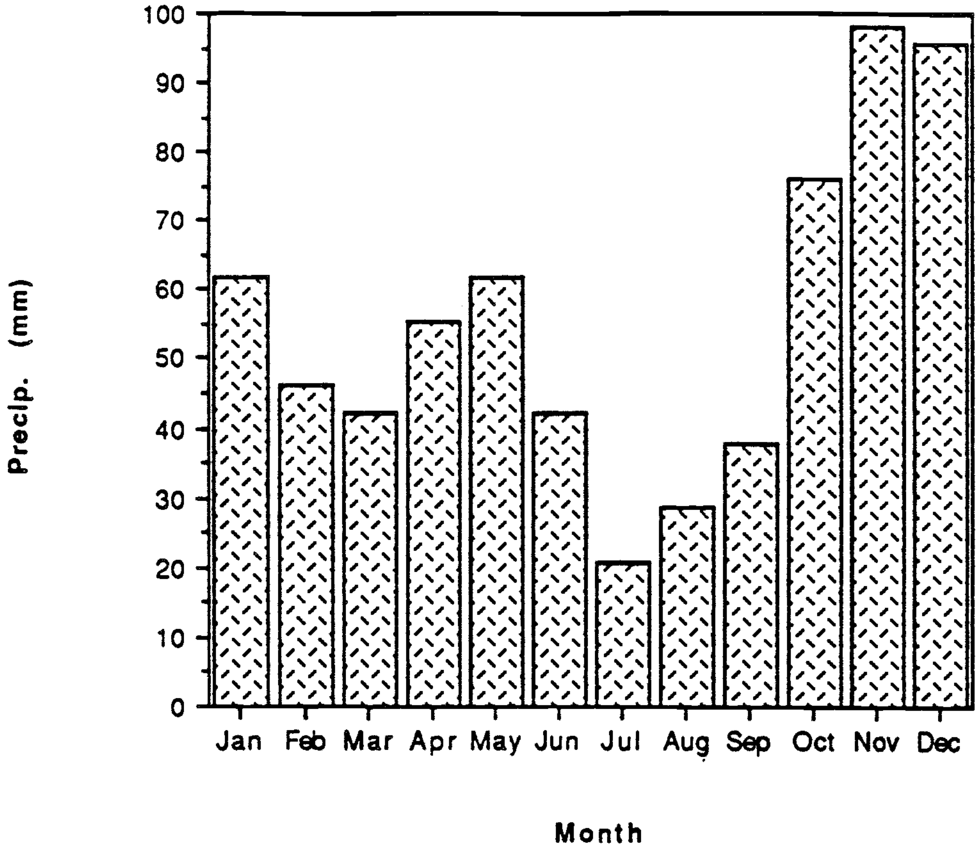


Figure 3.5 Monte Cristi mean monthly rainfall, 1934 to 1990.

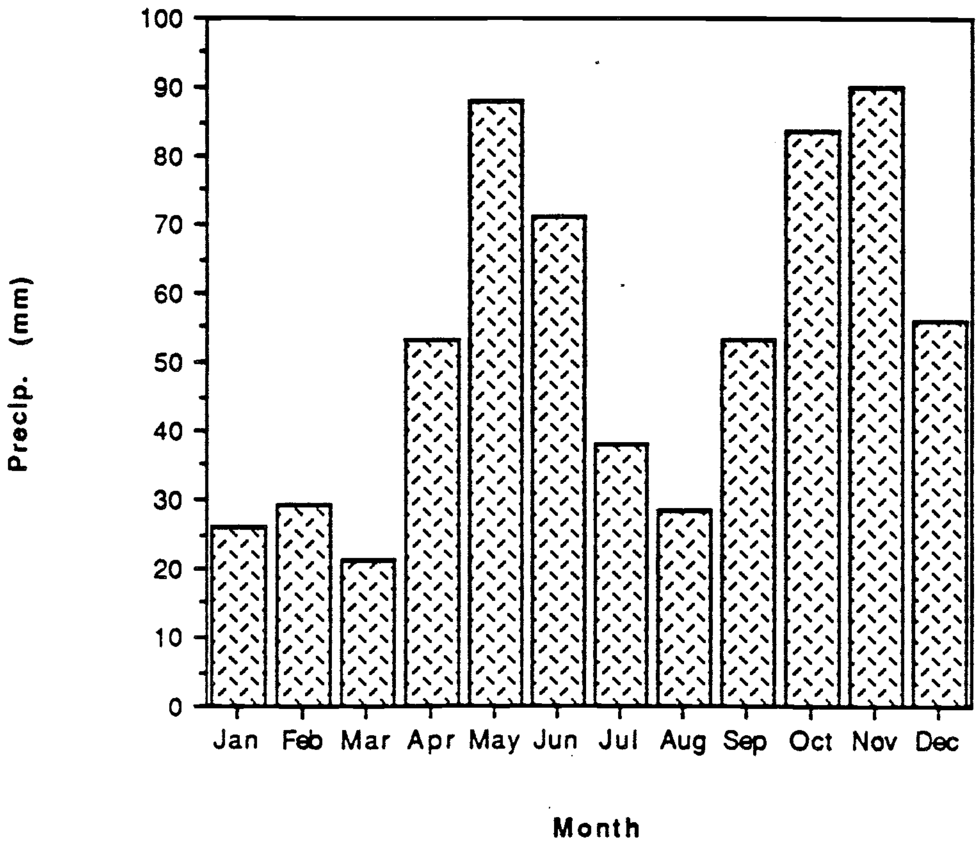


Figure 3.6 Villa Isabel mean monthly rainfall, 18 year record. (From Wernstedt, 1961.)

swing of the ITCZ is only from the equator to about 5 degrees north latitude. In fact, from near the Dominican Republic westward to 160 degrees West latitude, Riehl (1979) shows the average position to remain north of the equator all year.

The seasonal north and south movements of the ITCZ, furthermore, lag behind that of the zenith sun. If the zone's influence were felt as far north as the northern coast of the Dominican Republic it would be in August or September, a period, in fact, near the precipitation minimum. It is clear that the low pressure associated with the ITCZ, in its simplest form, cannot be responsible for the observed seasonal rainfall pattern that has a marked summer dry period.

The pronounced November maximum in precipitation observed along the northern coast is equally difficult to explain. Caribbean tropical storms occur most frequently in September. Alaka (1968) gives statistics for tropical cyclone occurrences for the period 1901-1963 for this region. In 42 of the 63 years no tropical cyclones were reported in November, in 20 of the years there was one reported in each November and in one year there were 2. In September, on the other hand, only one year had no tropical cyclone reports while one year had as many as 7. Altogether, total occurrences for the 1901-1963 period were as follows:

June	33
July	34
August	100
September	173
October	110
November	21

Tropical cyclones in this context are low pressure areas with cyclonic circulation (counter-clockwise in the northern hemisphere) that develop in the easterly flow (wind from the east) between the high pressure areas of the semi-permanent subtropical anticyclones and the equator. They vary in size from 100 to 1500 km in diameter and generally move slowly westward. If they develop into hurricanes (i.e., have winds greater than 73 mph) they often ultimately move out of the tropics and then eastward in the mid-latitudes. Rainfall may be abundant and extensive regardless of whether or not such a storm reaches hurricane stage.

Antecedent flow patterns for tropical cyclones are often *easterly waves.*" They appear as low pressure troughs on the equatorward sides of the semi-permanent subtropical anticyclones in well-developed easterly flow. They travel westward at about 8 degrees longitude a day (Riehl 1979). Showery precipitation is associated with the cyclonic flow region in the eastern section of such a trough. They may generate in Africa, move across the Atlantic to the Caribbean over a period of many days and may or may not develop full cyclonic circulation. The associated rainfall as well as their overall development depend strongly on the nature of the upper-air wind pattern. Neither the ITCZ nor the occurrence of tropical cyclones and easterly waves appear to account directly for the seasonal distribution of rainfall along the north coast of the Dominican Republic.

Seasonal shifts in both surface and upper-air wind patterns are associated with the above-described large-scale phenomena. They include a variety of flow characteristics throughout the atmosphere. Included are regions of wind shear, changes in vorticity, and shifting patterns of low-level divergence associated with the anticyclones. Their influence on rainfall is felt through their enhancement or inhibition of the upward motion necessary for precipitation.

Divergence associated with the subtropical anticyclones produces a significant characteristic of the middle troposphere in the tropics. It is the temperature inversion associated with the easterly, or *trade* winds that occupy the region between the subtropical high centers and the ITCZs. Diverging air in all quadrants of an anticyclone creates a large area of subsidence, i.e., sinking air, which warms at the higher pressures of lower elevations. The resulting increase of temperature with height, or inversion, at the base of the subsiding layer inhibits the localized upward motion required for the development of showers characteristic of tropical precipitation. Variations in the position and intensity of the subtropical anticyclones can, therefore, be a major controller of precipitation patterns.

Shifting flow patterns at all levels in the atmosphere, which may enhance or inhibit the upward motion required for precipitation, have to be considered along with associated lower-atmosphere wind direction in relation to the orientation of orographic features. Lahey (1973) has carefully examined seasonal changes in wind patterns up to 30,000 feet in the southern Caribbean in order to account for the arid climate along the north coast of South America. He maintains that easterly winds parallel to such an east-west coast are significantly divergent because of the increased resistance offered by the land area as compared to that of the sea. This causes the wind over land to turn away from the sea, creating a band along the coast in which the air subsides, thus counteracting the upward motion required for precipitation. The change in wind direction resulting from such a cross-wind change in friction can be considered the result of a decrease in coriolis force (relative to the horizontal pressure gradient force) due to the friction-induced decrease in wind speed.

His wind pattern analysis for various levels in the atmosphere, unfortunately, do not extend to the region of the Dominican Republic in detail sufficient to delineate significant seasonal changes. His surface wind patterns, however, suggest a wind direction nearly parallel to the Buen Hombre coastal area in July. The patterns for the other three months he shows (January, April, and October) appear to have east-northeast winds in this area. The coastal resistance-divergence hypothesis appears to be well-founded and, indeed, responsible for the aridity along the north coast of South America. It has been applied to other regions, also (Bryson and Kuhn 1961), and may partly account for the late spring and summer rainfall minima along the north coast of the Dominican Republic.

When the wind is from the northeast or east-northeast the rainfall pattern in the Dominican northern coastal regions is likely to be dominated more by orographic lifting than by coastal divergence patterns. The foothill and mountain ranges running generally west-northwest to east-southeast are then approached by a more nearly perpendicular flow. The rainfall pattern should show, as it does, a characteristic increase in amount with increase in elevation on the windward side of the range and a decrease on the leeward side. Thus the mean monthly rainfall pattern at a given location can be expected to be influenced not only by seasonal shifts in large-scale circulation patterns, but also by the local topography orientation in relation to seasonal changes in wind direction.

Taken all together, available information on local topography, nearby rainfall records, local and large-scale atmospheric flow patterns and their seasonal variations, is essentially inadequate to estimate with confidence the average monthly pattern for Buen Hombre. It is likely, however, that it is much like that for most of the north coastal area so that, with 1000 mm average annual value estimated above, Figure 3.4 can be used to represent Buen Hombre's average monthly pattern until more information becomes available.

Interannual Variability

Hastenrath (1984) has examined the interannual variability of climate and circulation in the tropical Atlantic Ocean area. He concludes that

> For most of these regions, rainfall anomalies tend to be associated with departures in the large-scale atmospheric and oceanic fields that correspond to the pattern changes in the annual alternation of dry and rainy seasons. The interannual variability of climate and circulation thus appears largely as enhancement and reduction of the annual cycle (Hastenrath 1984:1097).

As he points out, however, there is little utility in this conclusion for anticipating future rainfall regimes because of the lack of understanding of the relevant general circulation mechanisms.

An example of the interannual precipitation variability in the Caribbean is shown in Figure 3.7, the annual rainfall record for Port-au-Prince, Haiti, covering the years 1888 to 1950. The average for this period was 1345 mm and, as can be seen, the greatest annual amount, 1938 mm, occurred within 3 years of the smallest, 859 mm, a range of 80% of the average. There appears to be no systematic trend and, in fact, a 25-year average for the period 1761-1786 for Leogane, on the coast, about 20 km west-southwest of Port-au-Prince, was also 1345 mm (Reed 1926). This record supports the commonly-held view that interannual variations in tropical precipitation are large and that long-term trends are difficult to discern.

In an earlier study of interannual variability in the Caribbean area, Hastenrath (1976) made an extensive analysis of rainfall records at 48 stations from southern Mexico through

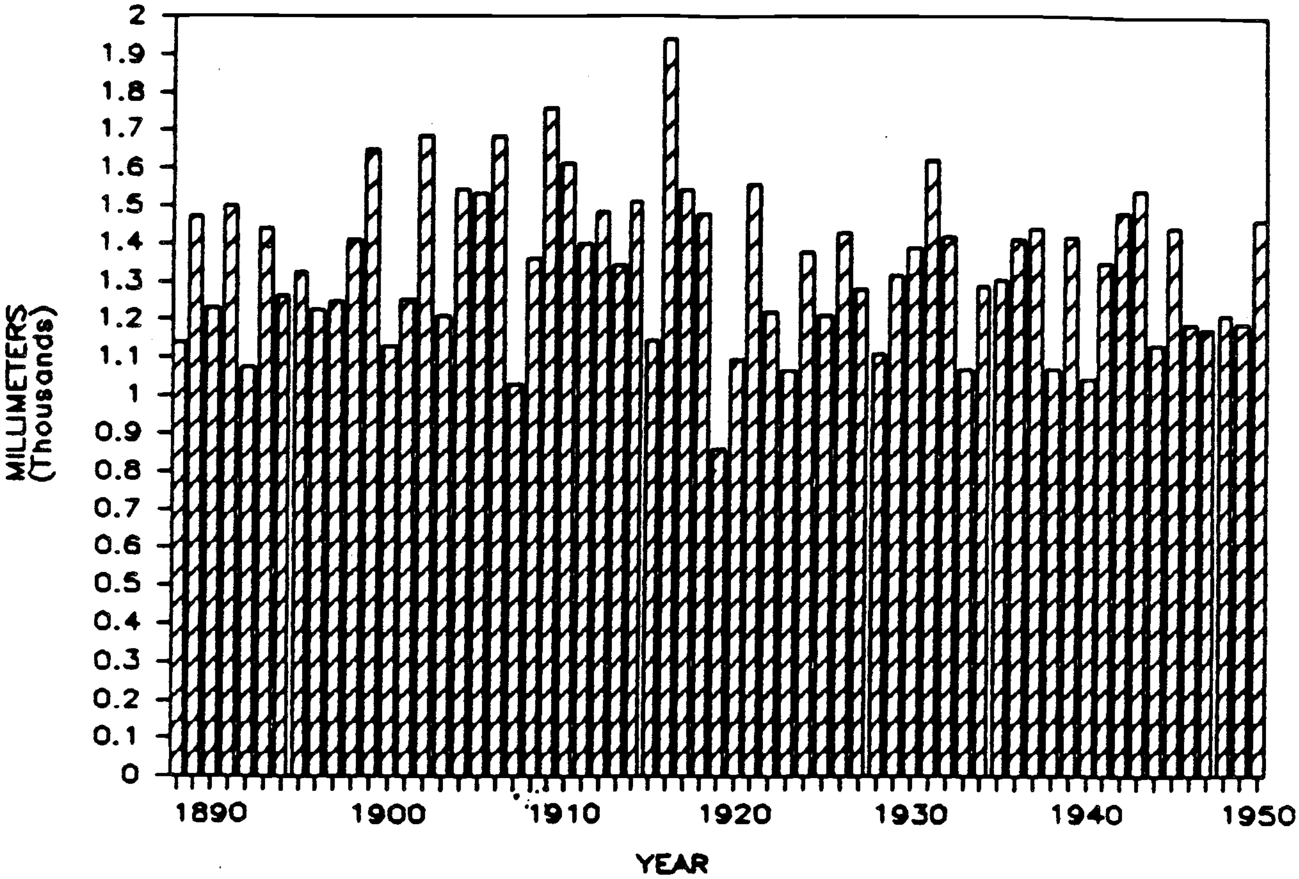


Figure 3.7 Port-au-Prince, Haiti, annual rainfall, 1887 to 1950.

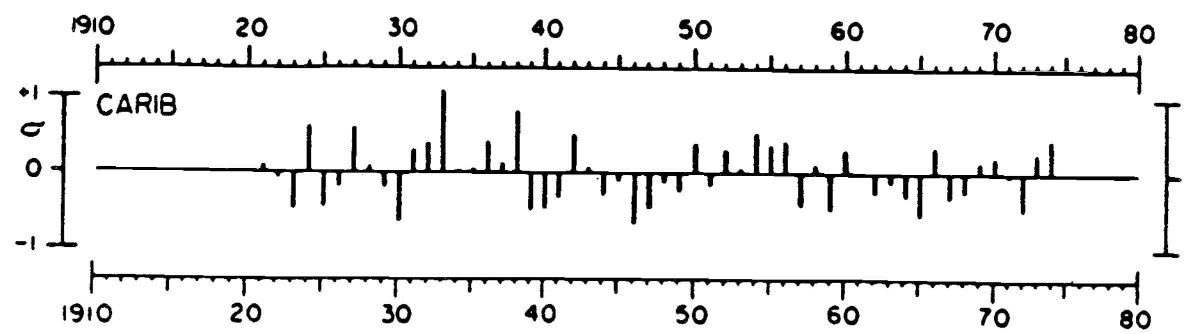


Figure 3.8 Average standard deviation for each calendar year, 1921 to 1974, for 48 stations in Central America, northern South America and the Caribbean. (From Hastenrath, 1985.)

Central America and the Caribbean to northern South America for the period 1921-1974. Figure 3.8 is a reproduction of Figure 8.7:1 that appeared in Hastenrath (1985). It shows the yearly values of the standard deviation of calendar-year annual rainfall totals averaged for all stations. The positive values indicate above average and the negative values below average values for the entire period.

Extreme values appear to occur in sequences of several years. For example, the years 1931 to 1938, inclusive, all had above normal rainfall while the years 1944 to 1949, inclusive, had below normal amounts. The Monte Cristi record, 1934 to 1990, is shown in Figure 3.9. It has a large interannual variation but only weak correspondence with Hastenrath's analysis. The fact suggests that Hastenrath's results, if used to estimate interannual variability at Buen Hombre, should be done with caution.

The 7-year average for Monte Cristi listed by Alpert (1941) as noted above, is nearly twice as large as the 1934-1990 average. In order to help assess the validity of this large value, the 7-year running averages for Monte Cristi's 57-year record are shown with it in Figure 3.10. It is seen that the nearly 1200 mm value is almost 50% greater than the highest 7-year average recorded in this period.

It is possible that the anomalous 7-year average was the result of one or more tropical cyclones within a 7-year interval. Such an occurrence seems more likely than the occurrence of other atmospheric conditions causing increases of nearly twice the 1934-1990 average. To examine the history of tropical cyclones in the Monte Cristi-Buen Hombre area in relation to annual rainfall amounts, yearly maps of North Atlantic Tracking Charts published by Neumann et al. (1978) were reviewed. The number of tropical cyclones (tropical storms and hurricanes) occurring each year in an area 2 1/2 degrees longitude by 2 1/2 degrees latitude, centered approximately at Monte Cristi, were tabulated for the period 1934 to 1975. Each year having one or more storms is indicated in Figure 3.11, a plot of annual rainfall for Monte Cristi. From this figure it is difficult to see an important influence of tropical cyclones in the local area on the interannual variability of rainfall amounts. This record does not, of course, establish that the 7-period with the high rainfall average was not caused by one or two tropical cyclones before 1934, but it further reduces the likelihood of the reality of the anomalous 7-year average.

In an appendix to this report, 20-year rainfall records for Puerto Plata, Santiago, Monte Cristi and Cap Haitien are displayed in a variety of graphical forms. They are for the two decades 1951 to 1970 and there are data from other periods for comparison. In general, these data show the nature of the interannual variability to be expected in this region. It is difficult to find in these graphs, however, any suggestion of the kind of variability required to produce an anomaly as large as that found in Portig's data for Monte Cristi.

Our assumption and inference that the record reflects true rainfall in Monte Cristi, and by extention Buen Hombre, therefore, seems to be a logical one. The assumption is

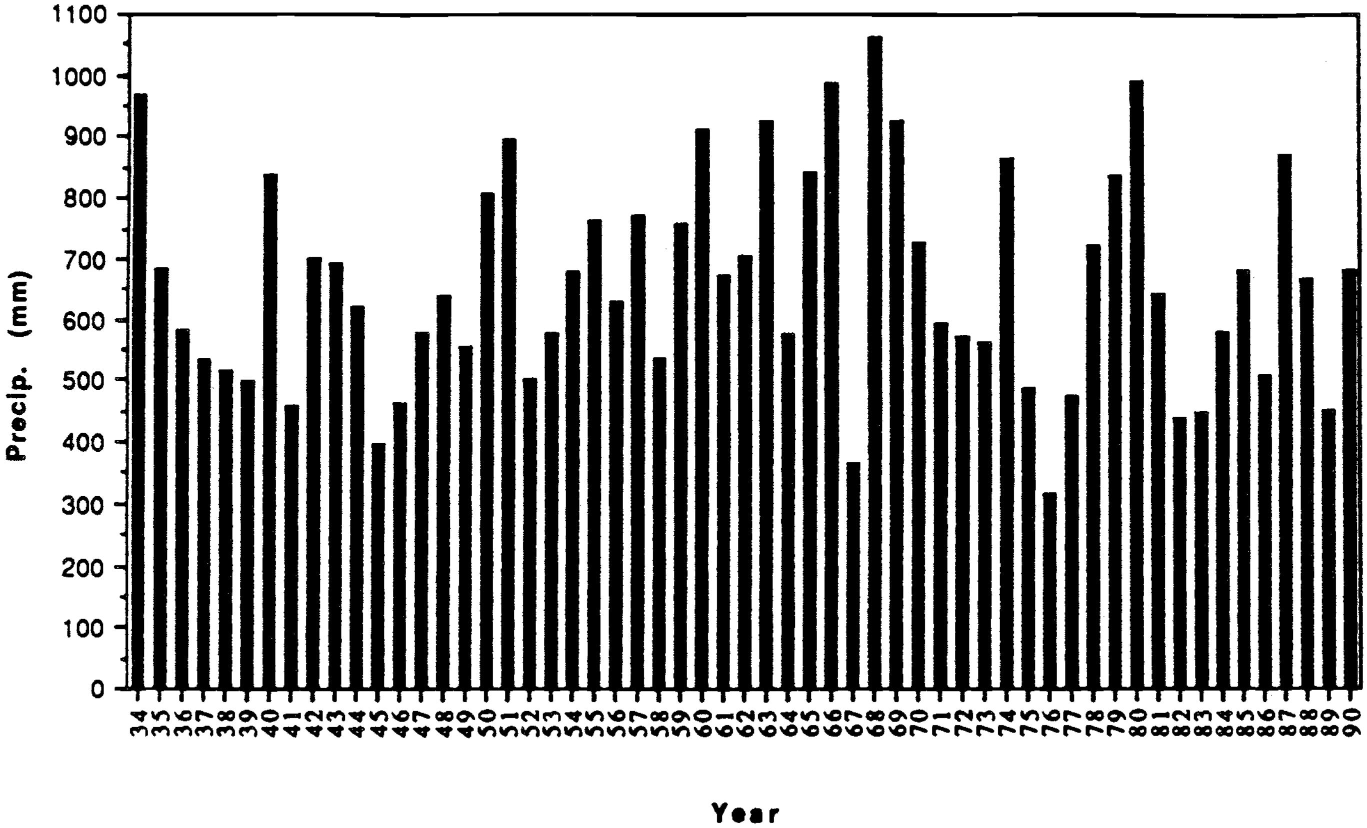


Figure 3.9 Monte Cristi annual rainfall, 1934 to 1990.

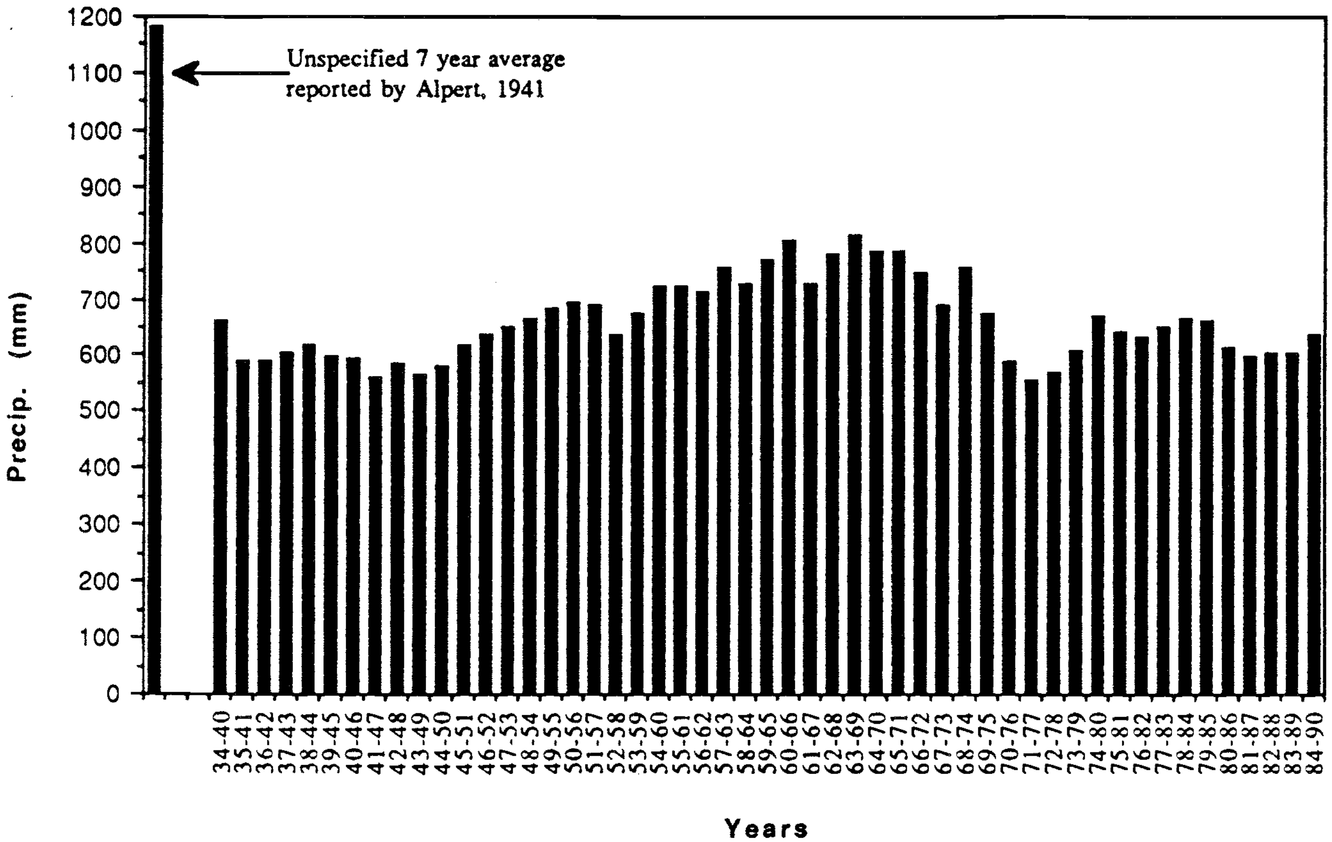


Figure 3.10 Monte Cristi 7-year running-average annual rainfall.

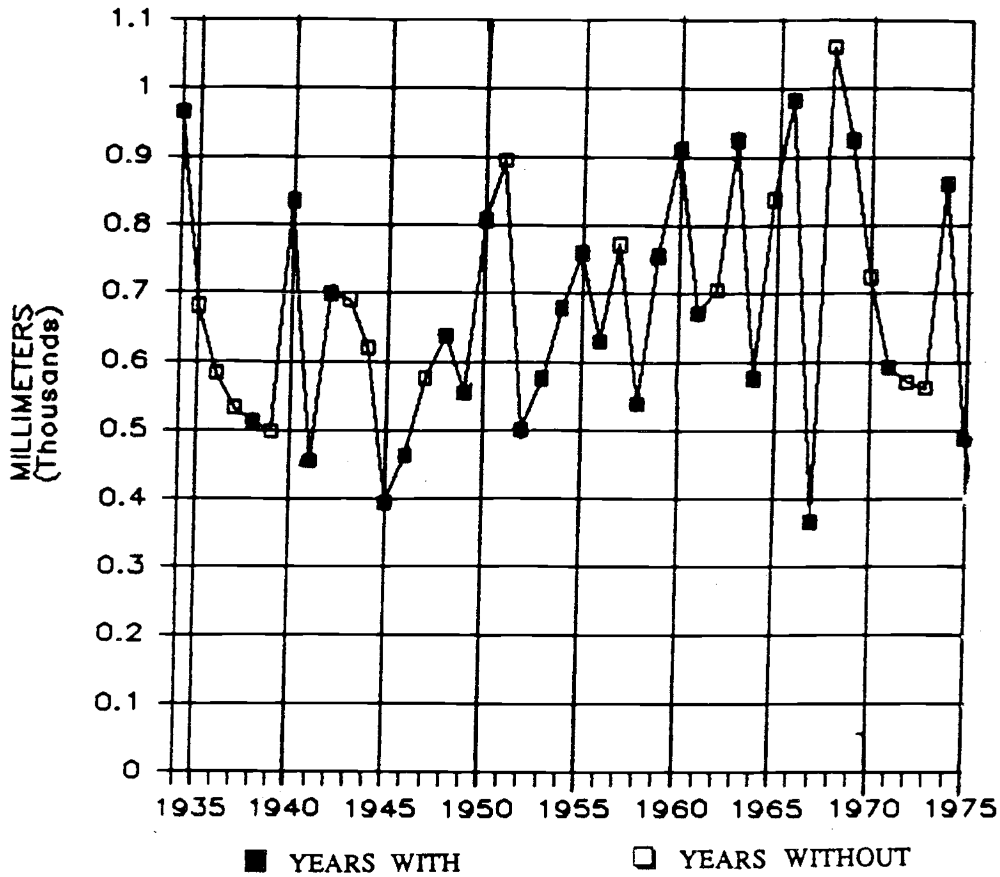


Figure 3.11 Monte Cristi annual rainfall, 1934 to 1975, showing years having one or more tropical cyclones in the vicinity.

strengthened by ethnographic data, especially given the oral testimonies gathered from village elders that corroborate the record (see Chapter Four).

Conclusion

Previous ethnographic studies (Stoffle et. al 1990) and this CIESIN research project document that various aspects of climate directly influence how the people of Buen Hombre use their land and associated marine resources. Rainfall reduces the amount that people fish, but increases the growth of their crops. Colder than normal weather reduces both the amount that people fish and crop growth. Colder weather also increases biological stress on people and livestock, causing both to have various sicknesses, and this results in people gathering more wild medicinal plants from the mountain sides and their need for more cash to purchase medicine for the seriously ill. Long term fluctuations in either temperature or rainfall results in major modifications in the productivity of people's fishing and farming adaptive strategies. A recent three year drought resulted in almost total crop failure and very heavy fishing pressure on prime cash-producing seafood species. A number of people moved out to other areas during the drought, while villagers from even harder hit agricultural villages over the mountain came to the Buen Hombre coast to cut trees on the mountain sides to make charcoal and to swim out from the shore to collect seafood along the inner reefs.

This chapter's analysis of weather patterns over the past few generations suggest another type of climatic pressure, derived from an apparent significant reduction in annual rainfall. Villagers say that lower rainfall caused certain crops to be eliminated from their fields and surface water to become less available. These two changes in farming have resulted in less flexibility in their economic activities and a greater dependency upon the external market economy to provide basic food and water. The marine resources of the village have become the major source of cash to solve this dependency upon the national market economy. Therefore, it is apparent that by knowing selected aspects of the regional climate of Buen Hombre we have a robust predictor of how they and other people from the region will use the marine and land resources.

CHAPTER FOUR

ETHNOHISTORY OF BUEN HOMBRE

David Halmo, Andrew Williams, C. Gaye Burpee, and Brent Stoffle

This chapter summarizes the history of population-environment interactions on the north coast of the island of Hispaniola in general, and in the community of Buen Hombre in particular. The purpose of this chapter is to highlight historical patterns of natural resource utilization and significant human ecological trends from the founding of Buen Hombre to the present.

Researchers sought to reconstruct the history of Buen Hombre to the extent possible using the scientific method known as *ethnohistory*. In our view, as has been argued elsewhere (Dobyns 1978), an ethnohistorical perspective of populations affected by development and change is a crucial component in informing policymakers and government administrators as to the long-term temporal adaptations employed by local peoples in response to historic alterations in their environmental conditions. Such a perspective can significantly contribute to enhancing the potential of developing human resources, in contrast to perpetuating wasteful conditions which frequently result from uninformed transfer of technological hardware so characteristic of development interventions (Dobyns 1978:104).

Methods

Ethnohistory

The first part of the chapter is based on data gathered from the ethnohistorical literature, other secondary sources, and oral history interviews. Ethnohistory combines the analysis of historical documents, traveler's reports and archeological data with interpretations deriving from ethnographic research. These data sets are combined in order to *triangulate*, or verify from three independent data sources, the research findings. Ethnohistory of a study area sets a cultural and historical frame for understanding contemporary conditions.

Oral History

The reconstruction of the ecological history of Buen Hombre from 1897 to the present is almost entirely dependent upon verbal testimonies from key community leaders and elders. Both individual key expert interviews and focus group interviews were conducted to elicit information. Formal, in-depth oral history interviews were conducted in 1990. Five community elders were selected by fisherman, farmer and women's association members during focus group meetings. These individuals were identified as being knowledgeable about the long-term social, economic and environmental history of the community of Buen Hombre from the earliest days of settlement to the present day.

Native American Occupation of Hispaniola

The dynamics of population-environment interaction on the north coast of the Dominican Republic are not recent in origin. Further, many current patterns of natural resource utilization have been significantly influenced by indigenous patterns. It is thus necessary to devote some space to briefly summarize the patterns of population-environment interaction characteristic of the indigenous Taino culture. Besides placing contemporary trends in their historical context, such a summary will also provide an invaluable comparative data base.

The island of Hispaniola has been occupied by humans for thousands of years. Native Americans arrived on the island by at least 5,000 BC, and its pristine environment would never be the same. As Indian people settled the island, they expanded in numbers and modified the natural environment. The Taino, speakers of an Arawakan language, had arrived on the island which they called Hayti or Quisqueya by at least 5,000 BC (Black 1986:13; Wilson 1990:1). The Taino were descendants of indigenous South Americans who had migrated into the Caribbean throughout the final centuries BC. In a span of fifteen hundred years they expanded to inhabit nearly all of the Caribbean from Trinidad to the northern Bahamas. In the process they replaced or incorporated smaller groups of indigenous island inhabitants (Wilson 1990:2).

The Indian population probably rose steadily from 5,000 BC until about 800 AD. During this time they increasingly modified the environment as they became increasingly sophisticated at hunting and gathering. With the adoption of corn, beans, and squash as well as other tropical cultigens, horticulture became the economic base upon which the population expanded until it was among the densest and socially most complex in the Caribbean. Extensive environmental use by dense native populations probably reached the apex in terms of environmental alteration well before 1492. Based on analogy with other American Indian populations in the New World, it can be assumed that American Indian people in Hispaniola had recognized the limits of the natural environment to support their people and had developed a wide range of conservation measures long before 1492.

On the north coast of Hispaniola, Indian people combined horticulture with the intensive use of marine resources. In the Buen Hombre area, for example, numerous sherds of stylized, decorated ceramics and heavy concentrations of conch shells in middens and mounds observed in the hillslope fields surrounding the village attest to the presence of a permanent American Indian community. The thick layers of black soil are likely anthropogenic black soils (*terra preta*) like those described for the Amazon basin (Smith 1980) and elsewhere.

Long before the arrival of Europeans, indigenous Caribbean societies evolved elaborate and complex sociopolitical institutions. The Taino were organized politically into several provinces, composed of numerous villages, led by a *cacique* or chief as the ultimate authority within each. Caciques were elite politico-religious officials, separated from lower status, commoners. While land tenure and use was communal in nature, the cacique directed both the production and distribution of food and goods in his chiefdom, or *cacicazgo* (Wilson 1990:4).

The Taino practiced a mode of intensified agricultural production called conuco. The predominant feature of Taino agriculture throughout the Caribbean was the intensive cultivation of such crops as manioc, sweet potatoes, peppers, peanuts, and maize. Aboriginal agriculture was practiced using the slash and burn method of clearing and firing vegetation to create fields and plant crops. Native farmers also used sharpened sticks and polished stone axes (Black 1986:13; Wilson 1990:93).

The Taino also engaged in intensive utilization of marine resources such as a variety of fish, shellfish, turtles and manatee. Fishing technology consisted of wooden spears which were thrown from dugout canoes.

Discovery and Colonization by Europeans: The North Coast

The island of Hispaniola was the first Caribbean island to be colonized, the north coast being the location of the first Spanish colonial settlements. It was from here that the Spanish empire was governed. It remained the most important base of operations for thirty years.

During Cristopher Columbus' first voyage, he sailed along the north coast of Hispaniola. His journal entries document a dense Taino population that combined horticulture with the intensive use of marine resources:

> This big island appeared to be very high, not encircled by mountains but level like beautiful fields. It appears to be all cultivated, or at least a large part of it, and the crops look like wheat in the month of May in the vicinity of Cordoba... (Fuson 1987:127).
>
> There must be a lot of people in this region, since I have seen so many canoes. Some of them are as large as a rowboat with fifteen benches for the rowers (Fuson 1987:129).

By January 4, 1493 Columbus began to explore what is the modern-day northwest coast of the Dominican Republic. His journal entries contain a rich description of the Monte Cristi area near Buen Hombre in the late 15th century:

> All this country near the mountain is low, forming a lovely plain...Beyond the mountain, 18 miles to the east I saw a cape which I named Cabo del Bezerro. Between Monte Cristi and the cape the reef extends seaward for six miles, although it seems to me that there are channels by which one could enter...To the east of Monte Cristi, toward Cabo de Bezerro, the twelve miles is all beach, the land is very low and beautiful. The rest of the land is very high, with beautiful and well cultivated mountains...as well as very large valleys that are green and possess many rivers (Fuson 1987:165-166).

La Villa de la Navidad, founded on Christmas day in 1492 or January 3, 1493 by the Gregorian calendar (Fuson 1987:231; Woodbury 1959:104), was the first European settlement in the western hemisphere. The settlement was established as a result of the wrecking of the Santa Maria near this area. The site of Navidad was a viable Indian village under the leadership of Guacanagari, a Taino cacique. After the decision to establish a settlement at the site, Columbus left nearly four dozen men behind to build fortified structures and remain there until he returned (Fuson 1987:231). When he returned to the site in 1494 during his second voyage, Columbus found that the settlement had been destroyed and abandoned.

Exactly what caused the demise of this colony is unknown. Ewen (1988:41) suggests that the Taino massacred the settlers and destroyed the buildings. Indian leaders who did not tolerate the capture of village women by Spanish colonizers occasionally succeeded in mobilizing enough force to rebel against the captors (Black 1986:14). The desire for gold also may have led the European settlers to explore further inland.

Columbus made no effort to re-establish La Navidad. He and his crew established a second settlement in 1494, which they named Isabela in honor of the Spanish queen. The settlers established farms planted with melons, wheat, and sugarcane. For the most part, however, the search for gold, which Indians indicated had been present in the Cibao valley became the focus of their time (Black 1986:15). The settlement of Isabela was also short-lived. Conflict among the colonists escalated such that, by 1496, Columbus' brother in charge of the colony, migrated to the south coast and established a new colony on the Ozama river, accompanied by most of Isabela's population. With a population of nearly 300 in 1498, the settlement was named Santo Domingo (Black 1986:16).

Other Spanish settlers continued to colonize the Navidad region in the early 1500's. Their goals were to establish settlements and subjugate the native population (Ewen 1988:41). One of these settlements was Puerto Real, which grew to be a sizable town that was a center for cattle ranching, hide production, and the illegal smuggling system known as the *rescate* operated by French, English, and Portuguese traders. The mountain topography prevented easy access to other major settlements and the acquisition of necessities and luxury items from the established colonial market on the south coast (Ewen 1988:42).

Mining and sugar cane cultivation and processing were the primary economic activities of the colony. During the next twenty years following the establishment of the first settlement, colonists had built seaports, towns, fortifications, and opened up new gold mines while engaging in agriculture and stock raising. Native woods, cotton, sugar and gold were exported. This rapid development stimulated a wave of new colonists migrating to the settlement. There was a total of 17 towns on the island by 1513 (Woodbury 1959:104).

The cattle that Columbus imported on his second voyage rapidly increased in population on the vast open ranges and provided settlers with abundant meat and hides (Ewen 1988:44). The populations of pigs and dogs also increased such that, by 1506, settlers hunted them as game animals (Woodbury 1959:106).

Despite the importation of a wide variety of Old World plants, trees, cereals, and seeds by Columbus on his second voyage, and the development of large scale cotton and sugar cane enterprises, the focus on gold mining resulted in the colonies having to import food from Spain to feed the rapidly growing population of settlers (Woodbury 1959:108).

Demographic Impact of Colonization: Population Collapse

The Indians of Hispaniola were the first in the New World to experience the overwhelming military superiority of the Spanish colonizers and the devastating array of diseases they carried. Thus the Taino represent one of the first New World populations to be quickly and completely eradicated as a consequence of the European discovery (Wilson 1990:2).

Pre-conquest population estimates for the island of Hispaniola vary. Angel Rosenblat (1976) made a conservative estimate of over 100,000. Eyewitness accounts led Bartolome de las Casas to estimate the population at 3,000,000 (Thornton 1987:16). Based on a detailed examination of documentary sources, two distinguished historical demographers (Cook and Borah 1971:I:379-410) estimated the indigenous Native American population to be as high as 8,000,000 in 1492.

The Columbian discovery drastically altered the population density and land use practices on the island. Indian populations suffered heavy mortality from warfare and slavery, but it was Old World pathogens such as smallpox that decimated Native American inhabitants (Crosby 1972; Dobyns 1983; McNeill 1976; Purdy 1988). Aboriginal American populations had no immunity to this and other Old World diseases.

Cook and Borah calculated that the native population collapsed from an estimated 8,000,000 in 1492 to 3,770,000 in 1496 (cf. Dobyns 1983:257). The first recorded outbreak of smallpox originated on Hispaniola in December of 1518 (Dobyns 1983:259), and from there began the first hemisphere-wide pandemic. Between 1496 and 1518, a span of just 22 years, the population of Hispaniola fell from an estimated 3,770,000 to only 15,600 (Cook and Borah 1971:I:401). Only 3,500 remained in 1538 (Cripps 1979:47). Vazquez de Espinosa (1942:39) noted that all American Indian people were gone from the island before he arrived in 1612.

Because of American Indian population collapse and Spanish failure to repopulate the island, environmental recovery probably began in 1492 and lasted until at least 1612. After this time, hispanic people slowly began to reestablish a population that would be as dense and as extensive as that of the American Indians before 1492.

American Indian inhabitants of the area surrounding present day Buen Hombre surely must have suffered heavy mortality. Indeed, Buen Hombre lies 45 kilometers to the west of Columbus' first New World settlement of La Isabela and about 75 kilometers east of the settlement established at La Navidad (in contemporary Haiti). These settlements contained small hispanic populations. On the north coast of Hispaniola, the hispanic population did not begin to establish itself until the late 1800s. Consequently, in the Buen Hombre area the natural environment may have undergone as much as 250 years of recovery before being redisturbed by humans.

In summary, the Spaniards did not conquer a *virgin land* comprised of pristine ecosystems. Rather, in the words of two eminent ethnohistorians (Jennings 1975:15; Dobyns 1976; 1983:8), they *widowed* an already occupied and extensively altered natural environment. Because of aboriginal depopulation by the early 17th century and slow hispanic repopulation, the natural landscapes and seascapes underwent hundred of years of regeneration before being extensively disrupted again in the late 19th and early 20th centuries.

Ethnohistory of Buen Hombre

The village of Buen Hombre is situated along the arid northwest coast of the Dominican Republic. The people of Buen Hombre look north to the sea and south to the mountains. The community is located in a cove between an extensive coral reef zone and the flanks of the Cordillera Septentrional mountain range. A deep break in the coral reef and a shallow lagoon are two more of the community's natural resource assets.

As mentioned, archeological evidence suggests that the region was not always uninhabited. Great numbers of sherds of stylized, decorated ceramics and heavy concentrations of conch shells in middens and mounds in the hillslope fields surrounding the village clearly attest to the presence of a significant and sedentary Taino community in the Buen Hombre area. The journal entries of Columbus, as noted above, also document a heavily populated region.

According to elders interviewed in 1990, the community of Buen Hombre was founded around 1897 by a family of thirteen Cuban refugees fleeing their homeland during the second War of Independence (1895-1899). These early settlers found an uninhabited ecosystem characterized by fertile soils, regular rainfall, and dense secondary forest.

While data are scarce, it can be argued based on the comments of elders that the coastal area was at most very sparsely populated in 1897. Taino populations in this region would have likely suffered heavy mortality. The contemporary village of Buen Hombre is only 45 kilometers from the first permanent New World settlement of La Isabela. This area would have been in close proximity to the more significant settlements like Puerto Real. Disease, exploitation and massive exodus into the interior were significant reasons behind depopulation. The north coast area likely continued to experience outmigration of Spanish colonists, who shifted their colonization efforts southward to the more fertile and mineral rich interior. Consequently, the north coast was gradually but steadily abandoned.

This historical pattern of colonization, in combination with the decimation of the aboriginal population, meant that the entire north coast of the Dominican Republic remained sparsely populated. It is not clear whether there were any short-lived settlements in the immediate vicinity of Buen Hombre during the colonial period. It would seem unlikely, as a coastal community would have had difficulties in evading Spanish authority. Consequently, the ecosystem of Buen Hombre may very well have experienced as much as a 250 year *fallow* period before being rediscovered by a group of Cuban refugees.

During the Haitian occupation of 1822-1844, there was a Haitian fishing community about three kilometers to the west of the current site of Buen Hombre. They relied predominantly on cage or corral fishing. Buen Hombre elders suggested that there was another Haitian community on the east side of Buen Hombre on the Playa de Coco. The beach received this name because of the large number of coconut trees in the area. The Haitian communities were forced to flee the country when Dominicans liberated their country from Haitian domination.

Early Agriculture

The founding settlers of Buen Hombre cleared tracts of land near the lagoon and established a diversified agricultural system that included the cultivation of such crops as plantains, cassava, maize, beans, potatoes, peas, tomatoes, bananas, and rice. The cultivation of both rice and bananas on the leeward side of the mountains suggests that precipitation was more regular and reliable during this period. Families also raised a variety of animals including donkeys, horses, pigs, goats, sheep, chickens, and cattle for transportation, traction, and food. Their initial stock of animals was probably acquired from the town of Villa Vasquez and other villages over the mountain slopes.

Climate and Crop Changes. Oral history indicates that prior to 1950 agricultural production in Buen Hombre was abundant. There was sufficient rain to produce many crops, including bananas and upland rice. However, villagers say that since the 1940s rainfall has decreased, and agricultural production has changed both in types of species planted and in decreased overall production. Neither rice nor bananas has been cultivated in the village since the 1940s. Precipitation data from this geographical region in the Dominican Republic have been analyzed to evaluate the accuracy of villagers' retrospective perceptions of rainfall amounts (see Chapter Three). A key question is that if decreases in rainfall actually occurred, were the decreases enough to cause cultivation of rice and bananas to cease, as villagers have stated, or is it possible that factors other than precipitation might have caused changes in the agricultural activities of the village?

Part of the answer lies in the climatic requirements of these two crops. Rice is a semi-aquatic plant. It grows in standing water, though standing water is not required. Rice grown in flooded paddies or basins is usually called paddy, wetland or lowland rice, while rice grown in well-drained, unflooded, rainfed soils is termed upland or dryland rice. Upland rice, therefore, is cultivated at the ecological limits for the species in terms of water requirements. Climate, especially precipitation, is a key variable in the productivity of upland rice. Yet rainfall is the most variable and least predictable agroclimatic factor (Gupta and O'Toole 1986). Because rice is so sensitive to stress due to lack of water, daily rainfall distribution is more critical than monthly or seasonal distribution. In areas of low rainfall, drought stress at critical growth stages is the main factor limiting yields. Chandhary and Rao (1982) report that adequate total annual rainfall for rice production ranges from 1,100 to 2,000 mm per year, but low to moderate yields can be obtained with annual precipitation amounts between 700 and 1,100 mm.

In Latin America, where dryland rice requires 1,000 mm of rain per year and 200 mm per month during the growing season, it has been shown that 100 mm per month distributed evenly is better for the rice crop than 200 mm a month falling within a two to three day period (Da Mota 1980). Upland rice cannot be supported in areas with annual rainfall amounts under 700 mm, as occurred in Monte Cristi, just west of Buen Hombre, between 1951 and 1970. If total precipitation in Buen Hombre was similar to that reported for Monte Cristi during those two decades, statements by villagers that rice production was not possible during those years would be supported by rainfall data alone. Annual precipitation data for Monte Cristi in the early 1900's is unknown, but a 7-year average for a seven-year period sometime between 1905 and 1926 was reported at approximately 1200 mm annually. This was enough to produce greater than moderate rice yields during those years and is strong evidence of support for villagers' statements of greater rainfall amounts prior to 1950, as compared to after 1950. The relationship between precipitation and upland rice production is direct (Stansel 1980). As precipitation decreases, yields decrease.

Bananas require even greater quantities of precipitation than rice. For maximum productivity bananas need 2,000 to 2,500 mm of rain annually (Daniells 1986). In areas where maximum precipitation is only 500 to 1,300 mm per year, irrigation is necessary (Soto 1985). On a monthly basis bananas are seriously short of water with less than 100 mm of rain per month. 200 mm per month is an adequate amount on all but the most porous soils (Simmonds 1966). Therefore, 100 to 180 mm of monthly rain meets the precipitation requirement for bananas (Soto 1985). This indicates that although precipitation records are patchy for Monte Cristi prior to 1950, 1,200 mm of mean annual precipitation could have supported bananas in the region. It also indicates that either the data for the 7-year average annual precipitation of 1,200 mm was lower than most years prior to 1950 or that in areas where bananas were grown, they were grown on fine-textured soils with high water-holding capacity. The majority of the agronomic soils in Buen Hombre are in fact fine-textured and currently have moderate levels of organic matter, which enhance water-holding capacity and the soil's ability to store water.

Temperatures in Monte Cristi and Puerto Plata, to the west and east of Buen Hombre, respectively, fall within the optimum range for growth and development of both rice and bananas. Bananas are usually cultivated in areas where temperatures vary between 21 and 29.5 C (70 to 85 F) with average annual temperatures at 27 C (80.6 F). The minimum acceptable temperature is 16 C (60 F), the maximum is 38 C (100 F) (Simmonds 1966; Soto 1985). Average annual temperatures for Puerto Plata range from about 24 to 26.5 C, which is within the optimum range.

Rice is rarely produced in areas where average annual temperatures drop below 20 C or where daily temperatures fall below 15 C or go above 30 to 35 C (Da Moto 1980). The first domesticated rice plants originated in a region where mean monthly temperatures ranged from 23 to 28 C (Huke 1976). Buen Hombre temperatures fall within the optimum range for rice.

According to Huke (1976) the period between 1890 and 1945 contained the most benign world climate of the last thousand years. This period encouraged man to extend cultivation of rice into areas that had not previously produced rice crops. Rice, which is grown under more diverse environmental conditions than any other food crop, was expanded from transitional climatic zones for rice production to climates previously beyond the outer limits for rice production. A strong possibility exists that Buen Hombre received unusually high amounts of precipitation during this benign period. Though rice and bananas were produced during these years, after 1950 world weather patterns changed for the worse (Huke 1976). If there were accompanying decreases in precipitation in Monte Cristi, as our data indicate, the decreases would have been disastrous for rice and banana production in the region. As precipitation went from marginal to unacceptable levels for these two cultivars, villagers were forced to cultivate species requiring less water, such as the tobacco, pigeon peas and cotton now farmed.

In summary, the analysis of precipitation data for Monte Cristi and other north coast stations seems to support statements made by villagers that annual precipitation has decreased since the 1940s. Furthermore, precipitation decreases alone are in fact enough to explain why rice and bananas are no longer produced in the village. Other factors also may have contributed in some degree to the change in crop regimes, but historical meteorological data support village oral historical accounts.

Marine Resource Use

Historic data on the early use of marine resources is still somewhat sketchy. It seems likely that these early settlers would have utilized the beach and mangrove ecozones in gathering shellfish and conch. Community elders recalled that by 1937 there was a large fish market on the beach front. By the mid 1940s they indicated there was a substantial increase in the use of marine resources.

Salt Ponds, Policy, and Mangrove Expansion. According to community elders, there was intensive mangrove growth between 1910 and 1944. Through time the mangrove has grown from Buen Hombre to La Pasa de la Posa. Behind the mangroves were a series of salt water lagoons or pools. These pools often dried up in the summer months of July, August and September and were utilized as a source of salt for domestic consumption. Both the utilization of this natural supply of salt and the rapid growth of the mangrove came to an end during the early stages of the Trujillo dictatorship. In 1944 he opened up the mangrove forest and the surrounding hills to large-scale timbering and prohibited Buen Hombre residents from utilizing their natural salt supply. In 1950, however, the timber company involved ended its contract and large-scale cutting ceased. Community members up until very recently had used mangrove wood in the construction of their homes. This is now prohibited. By 1958 the salt lagoons had disappeared as a result of the mangroves expanding into these areas.

The early economy of Buen Hombre eventually expanded to consist of two interdependent economic systems, one centered on fishing and the other on agriculture. Such a relationship fits a common pattern of coastal fishing communities supplying interior agricultural communities and towns with marine products.

Village elders stated that there was a substantial increase in the use of marine resources by the mid 1940s. They recalled the period as being one in which the coral reef and tidal shore provided an abundance of fish, large lobster, conch, octopus, and manatee. Fishing in these earlier periods was characterized by the use of lines, nets, and harpoons. Women were also important contributors to the fishing economy at this time. Increasing reliance on marine resources may have been due to the change in amount of precipitation, which led to an abandonment of rice and bananas as locally produced subsistence crops. Between 1890 and 1940, then, the economy of Buen Hombre could be characterized as a subsistence economy based on a mixture of agriculture and fishing that supported an expanding population of approximately 120 persons.

The Problem of Water. The acquisition of water has historically been a central challenge for the inhabitants of Buen Hombre. Initially drinking water was obtained through a combination of household water catchment systems and earthen cisterns that captured runoff rainwater from hillside crevices and small gorges. During the dry season and times of drought, community members were forced to travel over the mountains by foot, mule and horse to collect water from the Rio Yaque del Norte. Thirsty individuals also traveled to the surrounding communities of Villa Vasquez, Las Aguitas, and Las Canas to obtain water. Domestic animals were able to take advantage of standing lagoons or water holes in the village which, during times of drought, were also used as sources of water for agricultural production.

Prolonged periods of drought, however, do not seem to have been a significant problem for the early inhabitants of Buen Hombre. Village elders recall this period as a time of abundance in terms of agriculture, animal production, and fishing. The productivity of this coastal ecosystem seems to have encouraged immigration into the region. The population of Buen Hombre steadily increased until 1957 (see Table 2). During the late 1930s, President Rafael Trujillo had initiated a large-scale road building program in order to increase mechanized transportation to the central-northern frontier (Georges 1990:61, 63-64). Thus immigration was further facilitated by the clearing of a small road from Villa Vasquez to Buen Hombre in 1952 as part of the national program. Although the road was rugged and became impassable after any substantial rainfall, it provided access for the first motorized vehicles to enter Buen Hombre and thus facilitated the importation of food and water into the community. The road probably also stimulated exportation of marine and terrestrial surpluses.

The road proved to be an invaluable asset when a three-year drought struck the region in 1957. The drought was catastrophic for the community. Village elders recalled that there was widespread crop failure, loss of animals, and hunger. What precipitation did occur could not be taken advantage of because the condition of the earthen catchment cisterns and canals on the mountain slopes had deteriorated due to deforestation and resulting erosion. Village elders mentioned that without the government's daily shipments of food and water, which were made possible by the road, everyone in the community would have died or been forced to migrate. Despite government assistance, village elders estimate that the village population declined to approximately 200 people.

During the early 1960s, the drought subsided. The road into the community was improved once again. As a result, the area experienced a resurgence in population growth. Whereas early muleteers served to establish connections between nodes of production on either side of the mountains, the improved road opened up the community to buyers, intermediaries and merchants to an unprecedented extent. The village economy expanded beyond subsistence production to include commercial production. Development of new infrastructure in terms of transportation networks and expansion of port towns seems to have been a significant development in the human ecology of the region. Growth led not only to a significant increase in the population on the north coast, but also to increased exploitation of marine and terrestrial resources. Key consultants who assisted in conducting a census of the community for the Dominican government estimated that the population of Buen Hombre had reached 721 in 1960.

While local population data are scant, ebbs and flows of population continued between 1960 and the present. Georges (1990:176) notes that the Central Valley and Sierra region of the Dominican Republic, just south over the mountains from the Buen Hombre coast, suffered severe droughts in 1966-67 and 1975-76, with dire consequences for small-scale farmers. Buen Hombre farmers must also have experienced the effects of these drought episodes.

Contemporary Buen Hombre

The village of Buen Hombre consists of a series of farmsteads organized in a line settlement pattern, extending inland from the small lagoon that serves as the boat launching location for community fishermen. As the village grew, new homes were built along the road and now stretch from the lagoon to the foot of the mountains. By 1985, the village population had grown to approximately 855 people (Stoffle 1986:81). The majority of homes contain nuclear families, although it is common for these homes to be arranged in extended family clusters. Social networks between relatives and neighbors are horizontal and multistranded (Wolf 1966).

Today Buen Hombre still lacks potable water. The community remains relatively isolated because its only transportation link with interior communities is the poorly maintained road over the mountain range. Although the road was improved in 1985, it often remains impassable to larger motorized vehicles, so water and other essential commodities are usually transported by horse, mule, motorbike, pickup trucks and small cars.

The people of Buen Hombre typically rely on more than one economic activity, an adaptive strategy termed "occupational multiplicity" (Comitas 1973), that is common throughout the Caribbean. Adult males engage in fishing and farming enterprises for household subsistence and cash income. Women play a significant role in agricultural production at certain critical times in the farming cycle. Occasionally, a few women accompany their spouses on fishing trips. When rainfall is adequate, women also cultivate mixed kitchen gardens, planting staple tuber and vegetable crops as well as medicinal plants and fruit trees. Women manage most aspects of domestic life. In many respects, the people of Buen Hombre use their natural resources much like the American Indian people who occupied this site before Columbus.

Terrestrial Ecozones and Resource Use

The people of Buen Hombre utilize two terrestial ecozones: (1) the hillslopes for agriculture, and (2) the upland mountain forests for collecting a variety of useful wild plant resources. The numerous resources found in the hillslope and upland mountain forest ecozones are used for subsistence, medicine, shelter, and cash income. Food crops are planted on the hillslopes and in the valleys. Plants and animals are harvested for food, medicine and construction. Timber harvested from the forested uplands is used for shelter, household fuel and charcoal for use and sale.

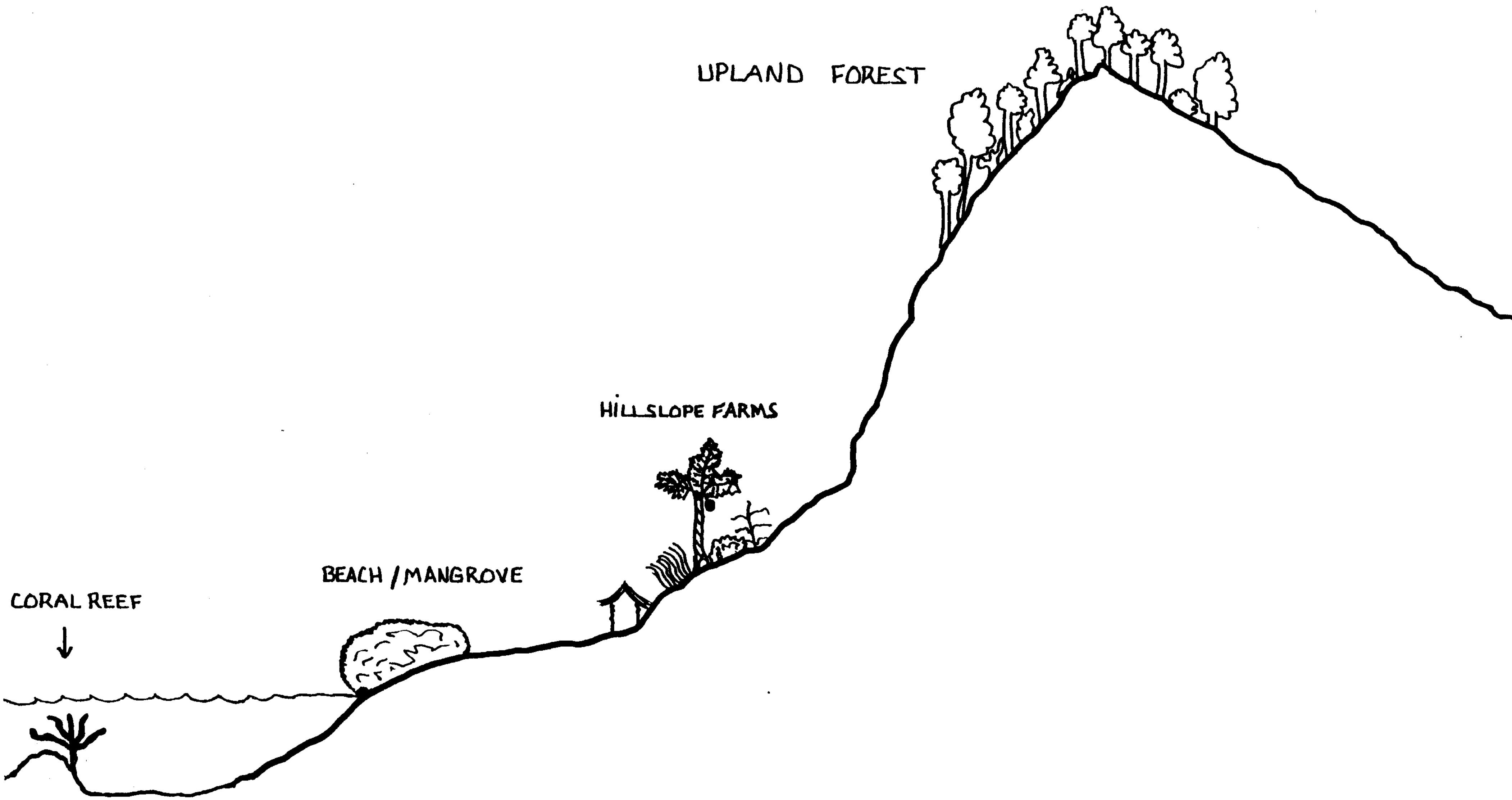
Soils

The topography of agricultural lands in the village ranges from 0 degree slopes at sea level to hills, valleys and mountainsides. Buen Hombre farmers describe three main soil types: (1) black, (2) yellow, and (3) mixed, a combination of black and yellow soil types. All soils are considered by farmers to be very productive in years when there is adequate rainfall. Black soil is described as the most productive.

Soil samples were taken from the top 30 centimeters for the three major soil types. In most locations the topsoil layer (A horizon) is unusually thick, commonly 100 centimeters deep. Soil physical properties were not specifically measured. Based on observations, however, Buen Hombre soils appear to have excellent physical properties. The topsoil depth of 100 centimeters allows ample room for root development and root exploration for nutrients. Soil structure in the topsoil appears excellent with good aggregation and a good mix of micropores and macropores that would allow for ample air exchange with the surface, good drainage, water retention, and infiltration.

The pH is high in all three soils, ranging from 7.6 to 8.1. The cation exchange capacity, or the soil's ability to retain critical nutrients against leaching by water for use by plants, is well above the critical minimum of 4 milliequivalents (meq) per 100 grams of soil.

Figure 4.1. Schematic map of Buen Hombre ecozones.



This cation exchange capacity of between 32 and 41 meq/100g is probably due to the presence of organic matter in the soil.

In the higher elevation black soils, phosphorous, potassium, and magnesium levels are adequate for producing medium crop yields. Nitrate-nitrogen levels are higher than usual for non-fertilized soils. Zinc levels appear low, but copper levels are high and may negatively affect crop growth. The dark color of the soil is probably due to the presence of substantial amounts of organic matter.

The fertility of the yellow soils is very similar to that of the black soil, with the exception of lower levels of copper and nitrate-nitrogen. This is probably due to the lower amounts of organic matter.

The fertility of the mixed soils is also similar to the black soil, except for lower levels of plant-available phosphorous. These levels are high enough, however, to permit adequate crop yields without the use of fertilizers.

It appears, then, that despite 100 years of cultivation, soil quality has been maintained at sufficient levels. Soil fertility may be related to cropping practices of Buen Hombre farmers.

Agriculture

Agriculture on the north coast of the Dominican Republic is rainfed. Because of Buen Hombre's location in the rainshadow on the leeward side of the Cordillera Septentrional mountain range, precipitation is seasonal and unpredictable. In stark contrast to the Samana peninsula in the eastern part of the country, which receives nearly 80 inches of rain annually, the northwest coast receives a mere 25 inches of annual precipitation (Lang 1988:11). Brief rainy seasons occur during the summer months of August and September, and between December and January in the winter.

Fields and Gardens. Fields are typically comprised of two plots--one adjacent to the homestead and another located on the forested flanks of the mountains. Dual location of fields may be related to local perceptions of crop growth and soil fertility. Root and tuber crops such as *yuca* are said to yield better in the black and mixed soils on the hillsides. Small game birds such as the guinea hen are hunted with rifles in fallow fields. Some farmers also retain access and use rights to plots that belong to relatives who live in interior villages. Kitchen gardens may be a separate small plot adjacent to the homestead or simply a small area in the dooryard around the house.

Agricultural Cycle. The local method of farming is most accurately described as slash and burn. Secondary vegetation is cleared any time from September through December. Crops are planted in November and December, and are timed accordingly prior to the advent of winter rains. Weeding occurs in intervals as necessary. Most crops are harvested in March and April. Cassava and tobacco are harvested over longer periods of time throughout the year.

Crops. Farming families in Buen Hombre cultivate *yuca* (cassava), maize, yams, sweet potato, several varieties of beans, squash, fruit trees such as *lechosa* (papaya) and lime. Tobacco is the major cash crop. Varieties of beans, pigeon pea and maize crops are planted in hillside plots. Fields adjacent to homesteads are largely reserved for the planting of tobacco crops. The yellow soils of these plots as well as of kitchen gardens are also planted with maize, beans, cassava, squashes, cotton, fruit trees, varieties of medicinal plants, herbs and spices, and other species of trees such as mesquite (locally known as *cambron*) which are used for shade and construction purposes. Wooden fences around field and garden boundaries support climbing vines which are used for fiber, medicinal plants, and spontaneously growing crop and non-crop plants. Living fencerows of cacti are also planted and serve as hedges around fields and gardens. Mesquite bean pods and crop residues are used as fodder for domestic chickens, pigs, goats, guinea hens, cattle, horses and mules.

Intercropping. The farmers of Buen Hombre practice mixed crop agriculture by intercropping. Beans and squash are interplanted with maize, tobacco and cassava. Beans and pigeon peas serve a nitrogen-fixing function for maize plants, thus replenishing soil nutrients. Fruit trees are grown in fields as well as in kitchen gardens. Edible greens, medicinal herbs and grasses which thrive in the disturbed soils between crop rows are spared and harvested from fields.

Buen Hombre farmers create, manage and maintain complex agroecosystems and field microclimates typical of rural small-scale, limited resource farmers (Altieri 1987; Gliessman 1984; Wilken 1972, 1987) by interplanting a variety of agricultural crops, selectively weeding and sparing useful plants that grow spontaneously between rows, and by incorporating tree crops into agricultural fields. Sufficient levels of soil fertility are maintained for longer periods of time by virtue of controlled burning of crop residues not used for animal fodder and by interplanting nitrogen-fixing bean plants with maize and tobacco. Differential heights of crop stories serve to preserve what little moisture is retained in crop plant material and soils. Multiple stories also modify shade patterns within fields. All other factors being equal, then, the farmers of Buen Hombre appear to be practitioners of sustainable agriculture.

Upland Forest Resource Collecting

The foothill woodlands are dominated by desert scrub vegetation, mainly varieties of cacti and Acacia. At higher mountain elevations, forests are comprised of pine, several types of hardwood tree species and numerous wild plants. Positive botanical identification of these species has not yet been completed. However, it is clear that these resources provide local people with many necessities of everyday life.

Wild Plant Harvesting. The people of Buen Hombre collect a wide variety of wild resources for fuel, medicine and construction. An inventory of over 90 distinct types of plants was obtained from respondents. These plants include herbs, fruits, grasses, cacti, flowers, and trees. Several of these plants are transplanted from the upland forests and slopes to kitchen gardens for easier access.

The majority of collected plants are used for medicinal purposes. Leaves, stems and roots are mixed with water and prepared as medicinal teas for treating a variety of ailments and illnesses. Trees and flowers are used primarily for shade and ornamentation. Several species of wood are used to make fish pots, traps, fences, palisades, and for the construction of houses and ramadas. Palm fronds are obtained from villages on the other side of the mountains and used as thatch for roofing. As with agricultural crops, seeds and cuttings of these useful plants are exchanged between relatives and neighbors.

Fuelwood Collection and Charcoal Production. The foothill woodlands and mountain forests are also utilized by the residents of Buen Hombre for collecting fuelwood. Based on observations, it appears that only deadfall timber and branches of several varieties of trees are collected as fuelwood.

Charcoal production is a supplemental economic activity in the community. Over half of the farmers interviewed (54%) are engaged in charcoal production, while thirty-seven percent of fishermen interviewed make charcoal. Most charcoal is produced for cash income.

Local Factors Affecting Agriculture and Forest Resources

The most significant limiting factor in agriculture for Buen Hombre is water, in the form of both precipitation and stream flow for irrigation. Like the northwestern region in general, the bimodal annual rainfall schedule is subject to considerable fluctuation within and between specific years (Georges 1990:15, 176). Needed rainfall may not occur during crucial months of the agricultural year, a condition that has been defined as *agricultural drought* (Glantz 1987:45). Between 1989 and 1990, the people of Buen Hombre had experienced extended drought conditions.

Subsistence goods and cash derived from agricultural produce declined according to those interviewed. Respondents commented that 1989 had been the driest year of the previous four, which were also very dry. The drought situation was confirmed dramatically during the 1990 study. Comments made by community members and government officials, as well as national newspapers, emphasized the impacts of the severe drought that affected the entire nation. Millions of dollars in crop and livestock losses stimulated government relief programs, including crop seedling distribution, to the hardest hit areas. By January 1991, the drought seemed to have subsided somewhat.

Lack of adequate rainfall led women temporarily to abandon full-scale kitchen gardening. Small amounts of purchased water are used to pot irrigate medicinal and other plants in dooryards. The crisis in village agriculture is related not to exhausted soil fertility, but to the prolonged lack of adequate rainfall--in short, drought conditions.

It is not clear whether the drought can be characterized as *meteorological* (defined as a 25% decrease in long-term average rainfall) or as agricultural drought (Glantz 1987:45-46). Whatever the case, drastic conditions stimulated emigration from Buen Hombre. Compounding the effects of vagaries in climate are a number of social processes and policies that have adverse consequences for terrestrial ecozones, resources, and village economy.

External Factors Affecting Agriculture and Forest Resources

Social and economic processes have also played important roles in the agricultural and forest sectors of the Dominican economy. In the mid-1980s, the Dominican government initiated a subsidized tobacco-growing program. Loans were provided to farmers to begin cultivation of tobacco as an export crop. Many if not most Buen Hombre farmers participated in the program. By 1987, however, the tobacco market had crashed. Since the collapse of the market, large portions of the Buen Hombre tobacco harvest remains stacked inside houses and outbuildings because there is no longer a decent price received for it, according to agricultural association members.

Historically, government programs have affected population-environment dynamics on the north coast in general. At the turn of the century, the development and expansion of the lumbering and cattle industries resulted in deforestation and land concentration dominated by large holders. Opening up of the northwestern frontier region stimulated both spontaneous and directed colonization, thus increasing population and exacerbating destructive land use practices (Georges 1990). Colonists, seeking new lands to cultivate because of land concentration and population pressure in the interior, have begun to slash and burn their way up the southern slopes of the Cordillera Septentrional range to the crest of the mountains. Deforestation has adversely affected the already arid environment's capacity to maintain and generate moisture, thus leading to desertification.

Marine Ecozones and Resource Use

Buen Hombre fishermen-farmers utilize two marine ecozones and the resources found within them. These are (1) the tidal shore ecozone, and (2) the coral reef ecozone. Each of these ecozones is described below, followed by a discussion of the environmental and human factors and their impacts on each ecozone. These sections are meant to characterize the marine ecozones in a broad way. The marine ecology and resources of the coastal zone is described more fully in Chapter Five.

Tidal Shore Ecozone

The tidal shore or littoral ecozone used by the people of Buen Hombre is composed of three microzones. These are (1) the beach, (2) the mangrove swamp, and (3) the lagoon.

The beach area is used as the cleaning and weighing station for fishermen returning with their catches. It is here that the various fish captured are weighed for sale and cleaned for home consumption. Intermediaries from interior towns as far away as Santiago and the capital city of Santo Domingo, as well as buyers from nearby villages, congregate at the beach on a daily basis and wait for Buen Hombre fishermen to return with their catch. While they wait, spouses of

Buen Hombre fishermen prepare dishes of fish, rice and plaintains from a stand adjacent to the weigh station for sale to waiting buyers. Intermediaries buy portions of the first class species for sale to retail dealers in urban centers. Buyers from neighboring villages purchase seafood to take back to their homes for food.

The Buen Hombre shoreline consists of white sandy beaches interspersed with extensive mangrove swamps. This microzone constitutes the junction of sea and land. Water and heavy vegetation result in an environment rich in plant and animal life. In contrast to the arid conditions further inshore, the mangrove is characterized by high humidity. Currently, the mangroves continue to expand seaward. The mangrove provides a natural nursery for numerous species of aquatic life that are harvested by Buen Hombre fishermen. Crabs, turtles, and shellfish are found in the mangroves and the shallows just offshore. These warm waters support healthy beds of seagrasses and algae which are consumed by a range of marine species.

The Buen Hombre lagoon serves primarily as the boat launch for village fishing crews. The majority of these are typical wooden *yolas*, the local term for small fishing vessels. Other, more modern boats of aluminum and fiberglass, powered by 15 horsepower Johnson, Yamaha and Evinrude outboard motors, also comprise part of the local fishing fleet. The lagoon shallows also support thick beds of seagrass which are used by marine species such as crabs, lobsters and other shellfish as nesting and feeding grounds. During low tide, these seagrass beds are exposed just offshore in shallow waters. Frequently, fishing families walk along the shoreline in shallow waters to collect clams and other shellfish. Crabs are a highly valued resource harvested from nearshore waters.

Local Factors Affecting Beach, Mangrove, and Lagoon Microzones

Field observations and interview responses indicate that the residents of Buen Hombre recognize the value of the beach, lagoon and mangrove microzones, and so are conservative in their use of these microzones and resources. Mangroves are only occasionally used to collect wood poles from the dominant tree species for use as roof beams.

Over and above the wise and careful utilization of the mangrove by local people is the presence of the coral reef, which serves the function of preventing beach erosion and mangrove destruction by buffering the Buen Hombre shoreline (cf. DuBois and Towle 1985:233). Both environmental features and sustainable human practices on the local village level combine to protect the beach and mangrove microzones from large-scale degradation.

External Factors Affecting Beach, Mangrove, and Lagoon Microzones

The Buen Hombre tidal shore ecozone is beginning to undergo changes as a result of exogenous developments. In the beach and mangrove microzones, the number of national and foreign tourists has increased. A small 28-room hotel has recently been constructed in the neighboring village of Punta Rucia. As a result of road improvement, the number of tourists visiting and residing in Buen Hombre has also increased. Beach front property and plots along the new road have been sold and six new single and multi-family vacation homes have been constructed. There is a direct connection between the new road and these homes because the tourists who drive for hours to spend a few days at these homes need to leave the village regardless of weather. Day tourists come more often because of the new road, but their numbers and impacts are unknown. Despite its small scale, the effects of tourism in terms of increased motorized boating for snorkeling excursions and water skiing may have detrimental effects. Nearshore waters may potentially become convenient disposal areas for non-biodegradable trash such as glass, plastic and metal. Pollutants such as battery acid, spilled or leaking gasoline and oil from boats, could adversely affect marine species, seagrass beds, and water conditions.

In the mangrove microzone, government interventions in the form of legislation have been initiated to protect mangroves. This legislation prohibits the use of mangroves for any unlawful purpose, including tree cutting. Prohibition of mangrove use and tree cutting has resulted in a significant decline in wood harvesting by Buen Hombre residents. Recreational tours for tourists, however, have increasingly subjected the mangrove microzone to disturbance and pollution. As the population of small-scale fishermen increases in the surrounding area, exploitation of mangroves would likely increase, leading to degradation.

The Coral Reef Ecozone

The coral reef ecozone located off the north coast of the Dominican Republic consists of an inner reef about a quarter-mile off shore, and an outer reef which is located a quarter mile beyond the inner reef. For most of its length, the coral reef serves as a barrier between the deep ocean and the shore. The only major break in the reef is at the entrance to the Buen Hombre lagoon. Because it is a double reef ecozone, changes in weather, water temperature, and wave action affecting the outer reef potentially affect the inner reef. Smithsonian marine scientists have described the Buen Hombre reef as one of the best in the Caribbean in terms of both size and condition.

Fishing

Fishing is one of the two major economic activities in Buen Hombre. As is the case among most small-scale coastal fishermen, the task of fishing is constrained by fluctuations in weather conditions and a general lack of mechanized technology. Buen Hombre fishermen adapt to these constraints by forming social and economic relationships that help ensure access to resources for fishing as well as subsistence.

The next chapter provides a detailed description of the marine biology and ecology of the coastal marine ecozone of Buen Hombre. These data were collected during February, 1991. Aquatic plant communities and fish species are described for each of the ecozones and microzones discussed above. Chapter Six then describes in detail the human ecology of fishing and marine resource use in Buen Hombre. These data were collected by ethnographers in January and February of 1991. Sociocultural and economic aspects of fishing, and the influences of environmental factors such as weather, are discussed.

CHAPTER FIVE

MARINE ECOLOGY OF THE BUEN HOMBRE COAST

Joseph Luczkovich

The marine coastal region along the North Coast of the Dominican Republic near Buen Hombre is a very diverse, ecologically complex ecosystem that is relatively pristine. The coastal region can be subdivided into general zones along a depth and distance-from-shore gradient: (1) intertidal mangrove swamp; (2) the first lagoon with extensive seagrass meadows and macroalgae; (3) patch reefs in the first lagoon; (4) the first barrier coral reef; (5) the second lagoon; and (6) the second barrier coral reef. A third reef system can be seen in the satellite images in deeper water, but we were unable to visit this reef (Figure 5.1). In this chapter, I will briefly characterize the biodiversity each of these six major *ecozones*, describing their physical appearance, the species observed in each zone, and some of the ecological relationships observed within and between zones. In addition, a statistical classification of the *sea-truth* sites visited will be made in order to further subdivide the region by species composition of the plant, invertebrate, and fish communities. These descriptions and lists should be regarded as preliminary, because we visited the region during a two-week period in February and March 1991 and may have missed species that grow in or use these habitats at other times. This general description will be further enhanced in a later chapter (Chapter 7) detailing the site-by-site patterns of distribution of the species listed in this chapter. Finally, I will make some observations on the fishery for snappers and groupers in this reef ecosystem.

Methods

In order to characterize the extensive region defined by the LANDSAT Thematic Mapper satellite image brought by Environmental Research Institute of Michigan (ERIM) personnel to the field, we visited as many single-pixel sites as possible during the field visit (13 Feb 1991 through 5 March 1991), often relying on the guidance of the local fishermen of Buen Hombre and Punta Rusia for locating areas of ecological and ethnographic interest. At each of 52 selected sites (ecological sampling units, or ESU's; Table 5.1 and Figure 5.2), a SCUBA or snorkeling dive of approximately 20 minutes was conducted, and an ecological inventory was compiled (species list) within a 28.5 m X 28.5 m area near the boat. Frequently, multiple sites that were more than 28.5 m apart (and hence in a separate pixel) were

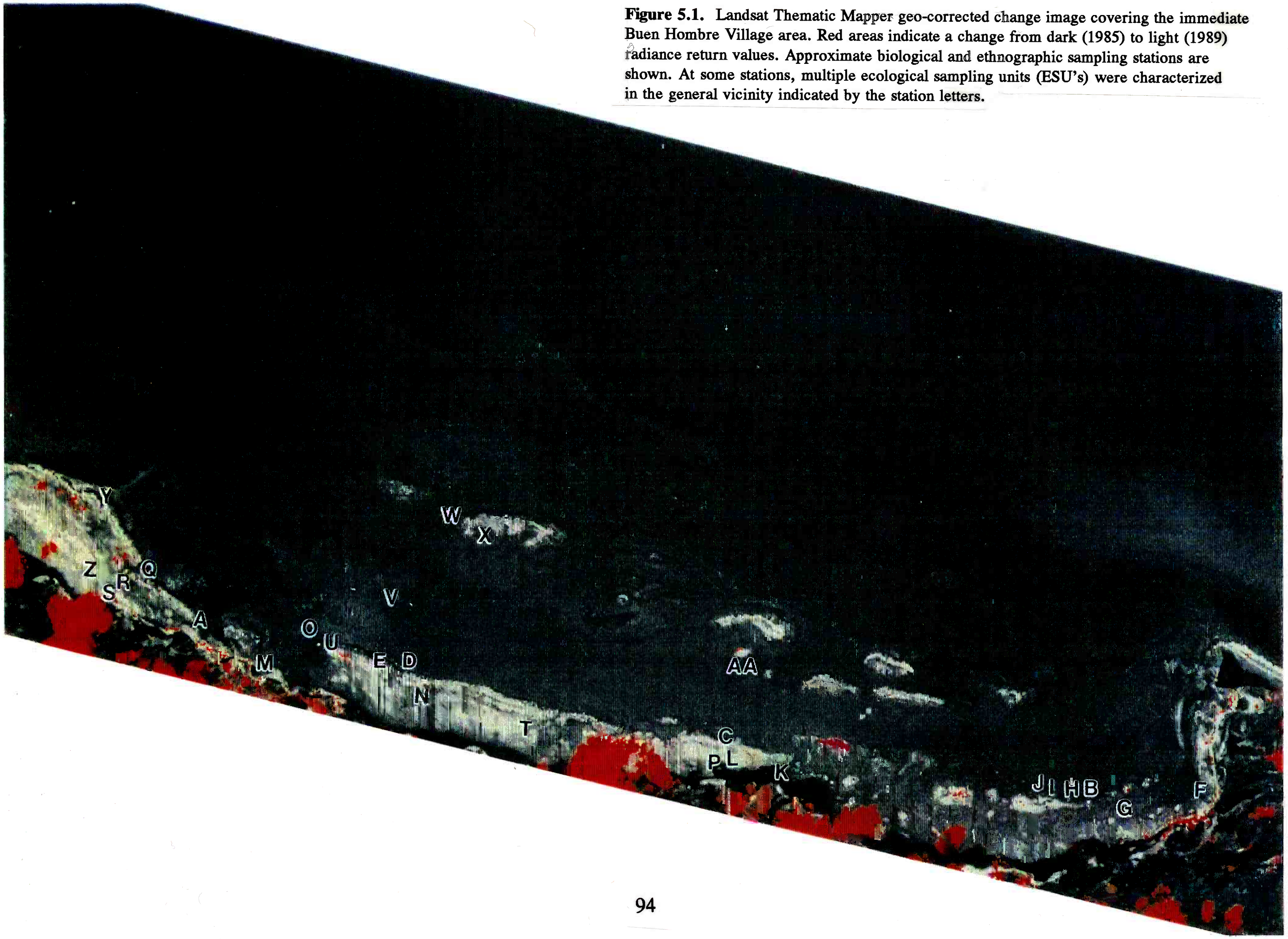
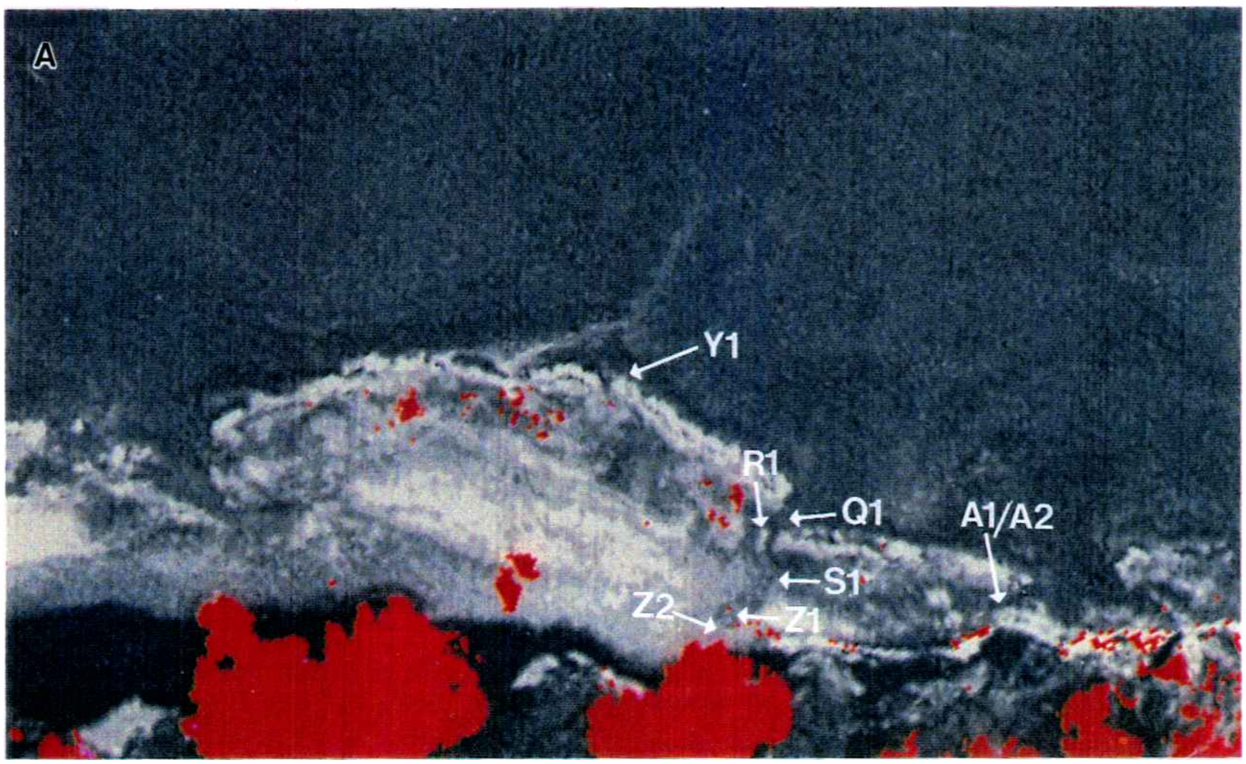
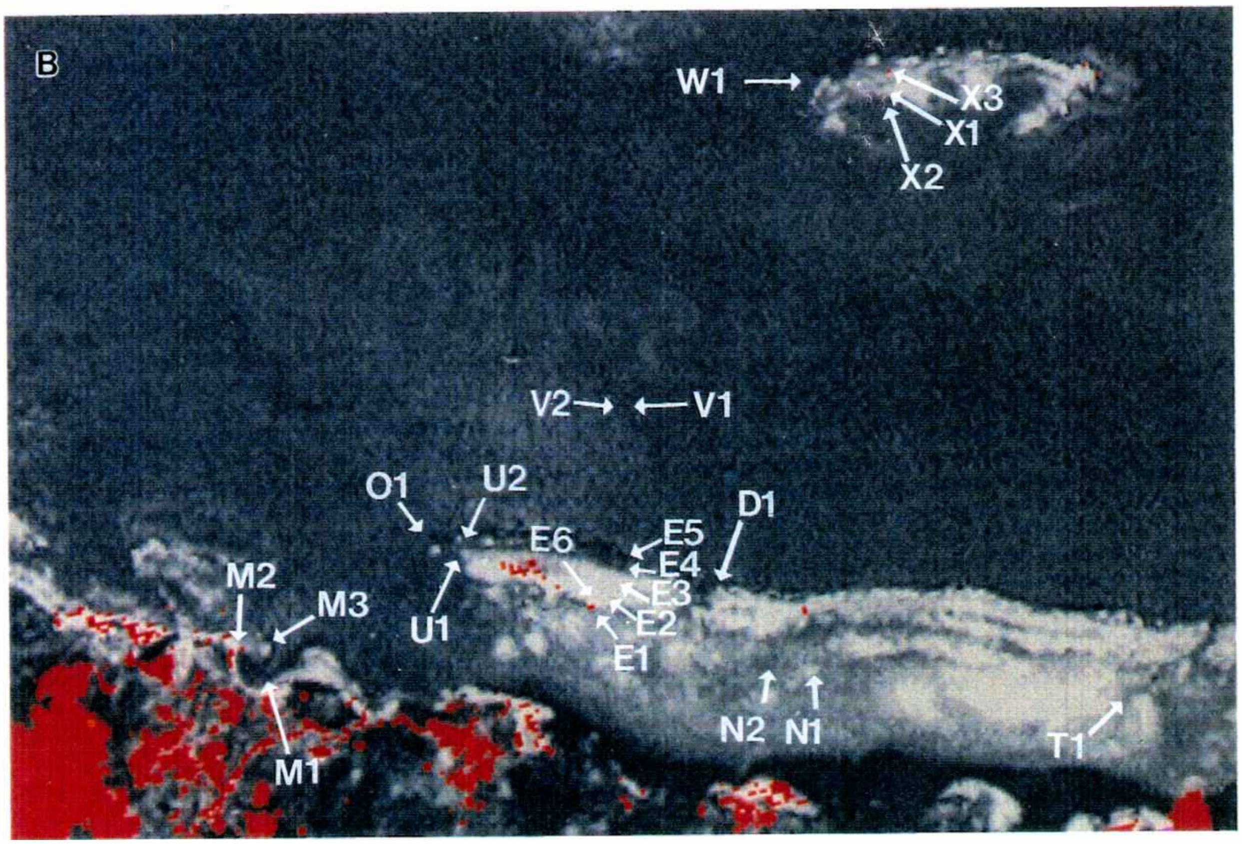


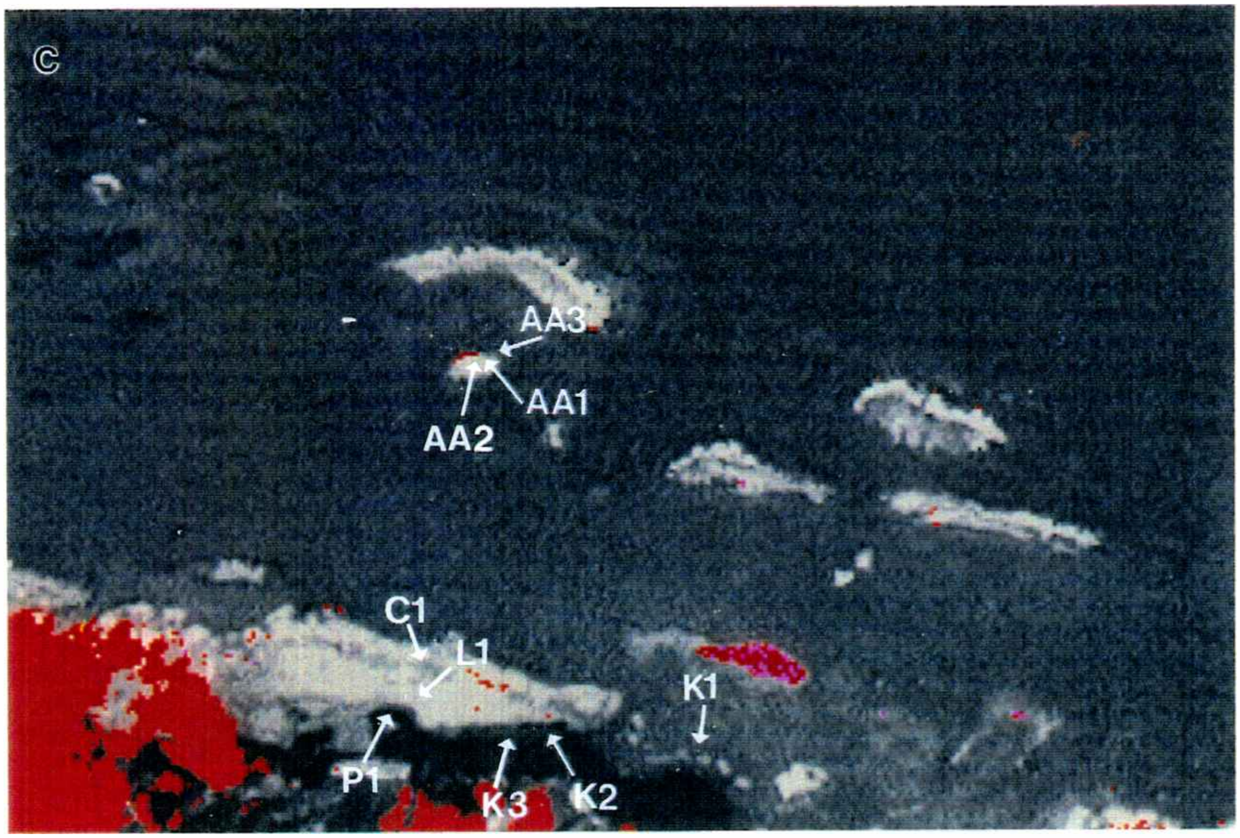
Figure 5.1. Landsat Thematic Mapper geo-corrected change image covering the immediate Buen Hombre Village area. Red areas indicate a change from dark (1985) to light (1989) radiance return values. Approximate biological and ethnographic sampling stations are shown. At some stations, multiple ecological sampling units (ESU's) were characterized in the general vicinity indicated by the station letters.

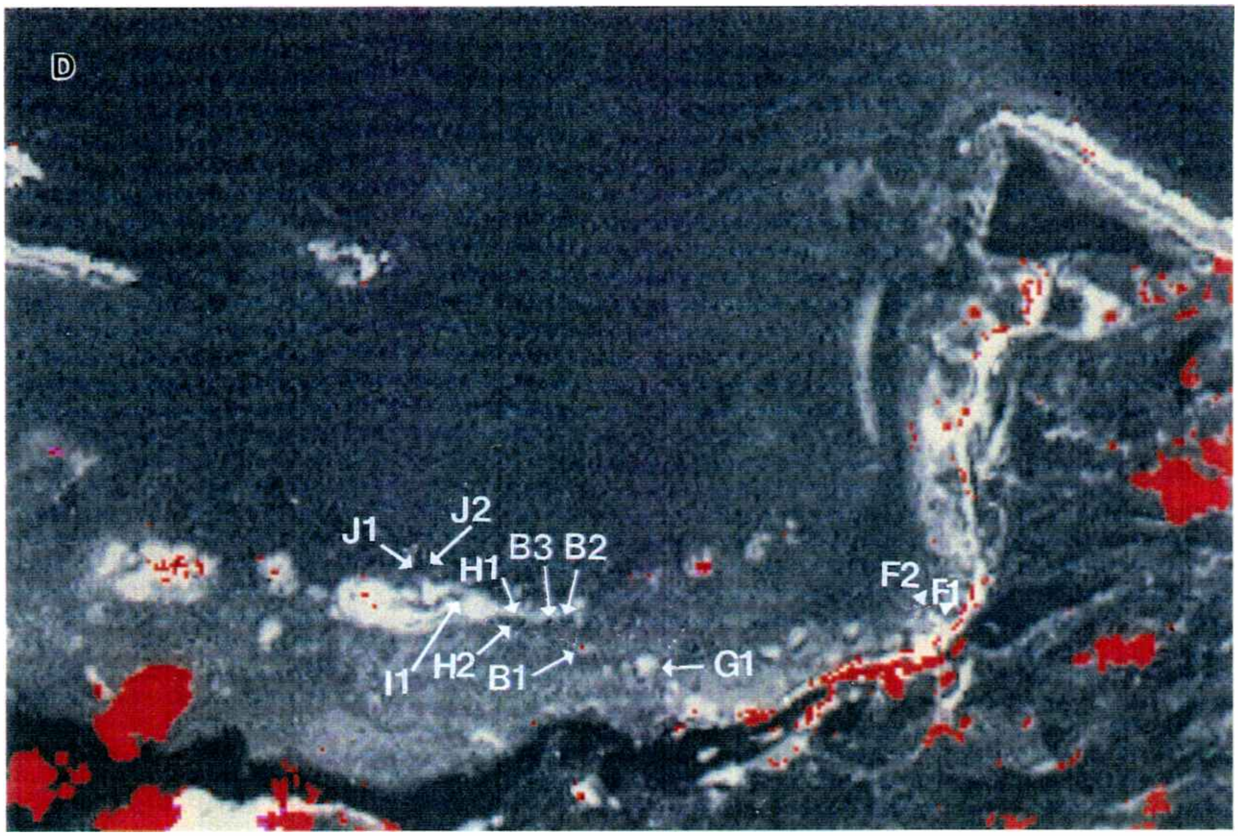
Figure 5.2. Landsat Thematic Mapper (TM) geo-corrected change image covering four subsections of the scene shown in Figure 5.1. The sections are: (A) westernmost section sea-truthed, showing the Buen Hombre Rocks area (Station A); (B) east of the section shown in (A), showing the Buen Hombre Harbor area (Station M); (C) east of the section shown in (B), showing Sand Key area (Station AA); (D) eastern-most section sea-truthed, near Punta Rusia (Station F). Station locations are approximate and red-highlighted areas indicate a change from dark (1985) to light (1989) radiance return values.





B
W1
X3
X1
X2
V2
V1
O1
U2
D1
E6
E5
E4
E3
E2
E1
M2
M3
U1
M1
N2
N1
T1


C
AA3
AA1
AA2
C1
L1
K1
P1
K3
K2


D
J1
J2
H1
B3
B2
F2
F1
I1
H2
B1
G1

visited in a general location where the boat was anchored, and each new site was designated as an ESU and given a distinct identifier (for example Station K1, K2, K3 are all mangrove stations that were visited during a single boat visit, but were more than 28.5 meters away from one another). In this way, each ESU was associated with a single 28.5 X 28.5 m LANDSAT Thematic Mapper pixel on the image.

At each ESU, a precise position (measured to the nearest 0.0001 minute longitude and latitude) was obtained using a Magellan NAV 1000 Pro GPS (Global Positioning System) receiver. Water depth was measured to the nearest 0.1 feet at each ESU with a ScubaPro PDS, a battery-powered sonar device. Due to limited availability of satellites at certain times of the day, 5 sites (M4, V2, Y1, AA4, and AA5) were not precisely positioned by GPS; these stations had geomorphological features that could be visually located on the image during the field visit. At an additional 7 sites (E6, N1, P1, X2, AA1, AB1, and AB2), no ecological data were collected because these sites were on land, were too deep to sample and remain within SCUBA saftey limitations, or were skipped because of limited time. However, satellite data or ethnographic data were collected at these sites (see Chapters 2, 6, and 7). Due to limitations of time available to sample each station, qualitative rather than quantitative data were gathered on relative abundances of species at each site. Species were divided into 3 categories during collection of field notes on underwater slates: plants, invertebrates, and fishes. Approximately 5-10 minutes underwater was spent listing species within each category, depending upon the diversity of the plant, invertebrate, and fish community at a site. While diving, one team member noted species present and collected unidentified specimens for later laboratory identification, while the other took underwater photographs. Identification of seagrasses, corals, and many invertebrates were made in the field in order to leave each site as undisturbed as possible using current field guides (Kaplan, 1982; Goodson, 1985; Littler et al. 1989; Morris, 1975; Robbins and Ray, 1986; Stokes, 1984). Algae and sponges were removed and preserved for later identification. Fishes were observed for 5 minutes at a point in the middle of the pixel and recorded *in situ*. Visibility was always better than 10 m the exception of several ESU's (K1, K2, Q1, S1, Z2) that had a silty bottom and a great deal of turbidty.

Statistical Analysis of Data

A species-by-sampling unit (ESU) matrix of presence-and-absence data was constructed for all stations with ecological data; this type of matrix is recommended for studies in which broad-scale patterns are required and the time and effort outlay is limited, as in the present case, without the loss of useful information (Pielou, 1984). Station-by-species matrices were created for plants, invertebrates, fishes, and all species observed and similarity matrices calculated with Jaccard's index, an index specifically for presence-and-absence data (Pielou, 1984). In addition, a station-by-species matrix based on the Spanish names for fishes and invertebrates listed by Buen Hombre fishermen (Chapter 7) was created. These raw data matricies are printed in Appendix A. Natural groupings of sites were made using the centroid-linkage method hierarchical clustering strategy (Wilkinson, 1988). Stations were classified based on these statistical methods into groupings with similar suites of species.

Table 5.1. The Ecological Sampling Units (ESU's) visited during sea-truthing, February and March 1991.

ESU No.	SITE No.	DATE of visit	LAT. 19°	LONG. 71°	DEPTH (FEET)	ECOZONE DESCRIPTION	BOTTOM TYPE
1	A1	15-Feb-91	52.6033	24.9774	5.0	LAGOON 1	SEAGRASS AND CORAL REEF
2	A2	20-Feb-91	52.6033	24.9774	5.0	LAGOON 1	SEAGRASS AND CORAL REEF
3	B1	17-Feb-91	50.2986	14.2956	13.5	LAGOON 1	SEAGRASS
4	B2	17-Feb-91	50.3856	14.3201	11.0	LAGOON 1	SEAGRASS
5	B3	17-Feb-91	50.3768	14.3259	35.2	LAGOON 1	SEAGRASS
6	C1	17-Feb-91	51.0923	18.5654	3.5	LAGOON 1	SAND AND SEAGRASS
7	D1	17-Feb-91	52.0843	22.3867	27.6	REEF 1	CORAL REEF
8	E1	18-Feb-91	52.0848	22.8572	1.5	LAGOON 1	SAND AND SEAGRASS
9	E2	22-Feb-91	52.1059	22.8453	2.0	REEF 1	SEAGRASS
10	E3	22-Feb-91	52.1366	22.8273	2.5	REEF 1	CORALLINE ALGAE
11	E4	22-Feb-91	52.1692	22.8208	1.0	REEF 1	CORALLINE ALGAE/CORAL REEF
12	E5	22-Feb-91	52.2168	22.7940	2.0	REEF 1	CORAL REEF
13	E6	22-Feb-91	52.1110	22.8779	5.0	REEF 1	SAND
14	F1	19-Feb-91	50.3524	12.9402	4.5	LAGOON 1	SAND AND SEAGRASS
15	F2	19-Feb-91	50.3871	12.9776	8.2	LAGOON 1	SEAGRASS
16	G1	19-Feb-91	50.2055	13.9953	13.7	LAGOON 1	SEAGRASS
17	H1	19-Feb-91	50.3638	14.5548	17.2	LAGOON 1	SEAGRASS
18	H2	19-Feb-91	50.3524	14.5615	5.5	LAGOON 1	CORAL REEF
19	I1	19-Feb-91	50.4045	14.7607	6.0	LAGOON 1	SEAGRASS
20	J1	19-Feb-91	50.5445	14.9369	22.7	LAGOON 1	GREEN ALGAE
21	J2	19-Feb-91	50.5685	14.9138	7.0	REEF 1	CORAL REEF
22	K1	20-Feb-91	50.7926	17.5376	2.5	MANGROVE	SEAGRASS
23	K2	20-Feb-91	50.8806	18.1117	9.8	MANGROVE	SILT/PROP ROOTS
24	K3	20-Feb-91	50.9036	18.2337	6.1	MANGROVE	SEAGRASS
25	L1	20-Feb-91	51.0120	18.6393	3.3	LAGOON 1	SEAGRASS
26	M1	20-Feb-91	52.0130	24.1127	4.0	LAGOON 1	SEAGRASS
27	M2	28-Feb-91	52.1559	24.2170	1.0	LAGOON 1	SEAGRASS
28	M3	28-Feb-91	52.1244	24.0924	1.5	LAGOON 1	CORALLINE ALGAE
29	M4	28-Feb-91	NO SATS AVAIL.		7.0	LAGOON 1	CORAL REEF
30	N1	21-Feb-91	51.6751	22.1171	4.0	REEF 1	CORALLINE ALGAE/SEAGRASS
31	N2	21-Feb-91	51.6900	22.2518	11.1	REEF 1	SEAGRASS
32	O1	21-Feb-91	52.4948	23.5239	33.8	LAGOON 2	CORAL REEF

Table 5.1.(continued) The Ecological Sampling Units (ESU's) visited during sea-truthing, February and March 1991.

ESU No.	SITE No.	DATE of visit	LAT. 19°	LONG. 71°	DEPTH (FEET)	ECOZONE DESCRIPTION	BOTTOM TYPE
33	P1	21-Feb-91	50.9434	18.8561	12.2	MANGROVE	SILT/MUD
34	Q1	21-Feb-91	53.2400	25.6017	45.0	REEF 1	SPONGE REEF
35	R1	21-Feb-91	53.2312	25.6981	3.6	REEF 1	CORAL REEF
36	S1	21-Feb-91	53.0595	25.7861	23.8	LAGOON 1	SILT
37	T1	24-Feb-91	51.3422	20.9842	6.1	LAGOON 1	SEAGRASS
38	U1	24-Feb-91	52.3149	23.3507	12.8	REEF 1	SEAGRASS
39	U2	24-Feb-91	52.3394	23.3127	2.0	REEF 1	CORAL REEF
40	V1	25-Feb-91	52.7884	22.8628	44.8	LAGOON 2	SEAGRASS
41	V2	25-Feb-91	NO SATS AVAIL.		---	LAGOON 2	CORAL PATCH REEF
42	W1	25-Feb-91	53.7680	21.7255	19.7	REEF 2	CORAL REEF
43	X1	25-Feb-91	53.6801	21.4943	20.1	REEF 2	GREEN ALGAE
44	X2	25-Feb-91	53.6576	21.5089	52.7	REEF 2	SAND
45	X3	25-Feb-91	53.7263	21.4848	3.0	REEF 2	CORAL REEF
46	Y1	27-Feb-91	NO SATS AVAIL.		16.2	REEF 1	CORAL REEF
47	Z1	27-Feb-91	53.1107	25.9789	1.5	LAGOON 1	CORALLINE ALGAE
48	Z2	27-Feb-91	53.1409	26.1378	12.8	LAGOON 1	GREEN ALGAE
49	AA1	01-Mar-91	52.2221	18.3523	0.0	REEF 2	BEACH (ON LAND)
50	AA2	01-Mar-91	52.2363	18.4145	4.3	REEF 2	SAND
51	AA3	01-Mar-91	52.2528	18.3165	4.5	REEF 2	CORAL REEF
52	AA4	01-Mar-91	SAND KEY		60.0	REEF 2	CORAL REEF (DEEP)
53	AA5	04-Mar-91	SAND KEY		70.0	REEF 2	CORAL REEF (DEEP)
54	AB1	-----	-----	-----	---	REEF 3	CORAL REEF ? - SITE NOT VISITED
55	AB2	-----	-----	-----	---	LAGOON 3	CORAL/SPONGE REEF? - SITE NOT VISITED

NO SATS AVAILABLE indicates that the Magellan GPS receiver was not able to obtain a position for that site due to insufficient satellite coverage for the region. Sites AB1 and AB2 were not visited, but species brought to us by fishermen were catalogued from those sites.

These groupings were then compared to our field observations on zonation patterns and bottom-type descriptions recorded during our field visit.

Results

One of the most striking features of the Buen Hombre coastal region is the amount of the sea-bottom area that is covered with seagrass, mangrove, macroalgae, or corals, all of which provide physical structure to the ecosystem. For example, 46 of the 52 sea-bottom sites that were sampled during the February 1991 *sea-truthing* field trip were classified as one of four bottom types (seagrass, coral reef, mangrove, or macroalgae)(Table 5.1). At the other 6 sea-bottom sites there is little structure present (i.e., sand, silt, or sediment lacking in vegetation). Consequently, the marine environment near the coast is high in structural complexity and shelters many organisms including many juvenile invertebrates and fishes. The presence of abundant small fishes indicates that these coastal ecozones, especially the mangrove and seagrass zones, function as nursery areas (areas that provide abundant food and shelter for the youngest stages of fishes) of the larger species harvested in the fisheries of the area.

Biodiversity

Overall, we collected or observed 59 species of plants, 78 species of fishes, and 103 species of invertebrates, giving a total species richness for the region of 240 species. Coral reef stations (AA5, A1, M4, D1, X3, AA4, Y1, U2, AA3, R1, W1, E5, J2, H2, O1, and V2) exhibited the greatest total species richness (average = 37.4 species per station, including plants, macroinvertebrates, and fishes) (Table 5.2). Stations around Sand Key (AA5, AA4, AA3) were especially diverse, averaging 49 species per station. Seagrass-dominated stations (E2, M1, N2, L1, V1, B1, T1, F2, C1, M2, I1, B2, F1, G1, B3, U1, and H1) were much less diverse, averaging 11.4 species per station. Coralline red algae dominated stations (E3, Z1, M3, and E4) were similar in diversity to seagrass meadows, averaging 11.5 species per station. Green-macroalgae-dominated stations (J1, X1, Z2) averaged 7.7 species per station. Mangrove-dominated stations (K1, K2, and K3) were not very diverse, averaging 5.3 species per station. Stations with little or no bottom cover, i.e. open sand and silt stations (AA2 and S1) were the least diverse in the region, averaging only 3.5 species per station.

These estimates of biodiversity are certainly underestimates for at least some groups of organisms. We were limited by the time and money available for detailed sampling, so many organisms went undescribed due to sampling methodology. For example, the fishes and mobile invertebrates may have been more readily sampled using nets and traps, and none were used. Additionally, invertebrates that associated with epifaunal or infaunal habitats were incompletely sampled. We are certain that this species inventory will increase over repeated samples on subsequent visits. However, the data support theoretical predictions that the greatest species diversity is associated with structurally complex habitats like coral reefs

Table 5.2. The biodiversity of the Buen Hombre coast as indicated by species richness (no. of species) estimates for each station. The table lists the number of species of plants (macroalgae and vascular plants), invertebrates (macroinvertebrates) and fishes for each station, as well as the total species richness. Stations N1, P1, AB1, X2, E6, K1, H1, and A1 were not sampled adequately and thus have been excluded.

STATION	BOTTOM TYPE	SPECIES RICHNESS			
		PLANTS	INVERTS	FISHES	TOTAL
AA5	CORAL REEF	16	29	28	73
M4	CORAL REEF	15	16	16	47
A1	SEAGRASS/CORAL REEF	18	19	9	46
D1	CORAL REEF	10	12	19	41
X3	CORAL REEF	8	17	15	40
AA4	CORAL REEF	10	18	12	40
Y1	CORAL REEF	9	14	16	39
U2	CORAL REEF	9	15	11	35
AA3	CORAL REEF	10	11	13	34
R1	CORAL REEF	5	20	8	33
W1	CORAL REEF	4	20	9	33
E5	CORAL REEF	8	9	14	31
J2	CORAL REEF	5	8	17	30
H2	CORAL REEF	2	14	13	29
O1	CORAL REEF	4	13	11	28
E2	SEAGRASS	10	7	3	20
M1	SEAGRASS	11	3	6	20
V2	CORAL REEF	1	18	0	19
E1	SAND AND SEAGRASS	8	7	4	19
N2	SEAGRASS	9	5	3	17
L1	SEAGRASS	10	3	4	17
V1	SEAGRASS	8	0	8	16
AB2	OFFSHORE REEF	0	8	7	15
Z2	GREEN ALGAE	13	1	1	15
B1	SEAGRASS	5	5	4	14
E3	CORALLINE ALGAE	7	7	0	14
T1	SEAGRASS	9	2	3	14
F2	SEAGRASS	14	0	0	14
Z1	CORALLINE ALGAE	4	9	0	13
Q1	SPONGE REEF	0	9	3	12
M3	CORALLINE ALGAE	12	0	0	12
C1	SAND AND SEAGRASS	4	3	4	11
A2	SEAGRASS/CORAL REEF	7	1	3	11
M2	SEAGRASS	9	0	0	9
I1	SEAGRASS	5	3	0	8
K2	MANGROVE CHANNEL	3	0	5	8
B2	SEAGRASS	7	0	1	8
F1	SAND AND SEAGRASS	4	1	2	7
E4	CORALLINE ALGAE	7	0	0	7
K3	MANGROVE	2	5	0	7
G1	SEAGRASS	6	0	0	6
AA2	SAND	3	0	3	6
X1	GREEN ALGAE	6	0	0	6

Table 5.2. (continued)

B3	SEAGRASS	3	0	0	3
J1	GREEN ALGAE	2	0	0	2
U1	SEAGRASS	1	0	0	1
S1	SILT	0	1	0	1

and seagrass meadows. Mangroves studied here were not particularly diverse, but they are nontheless, highly productive areas.

Sample Adequacy

The adequacy of the sampling was assessed by examining species accumulation plots (Figures 5.3, 5.4). A plot of the cumulative number of species versus the ESU number was created for plants, invertebrates, and fishes. The type of curve resulting can give insight into the degree of sampling adequacy we achieved: curves that approach an asymptote are thought to be indicators of good sampling, for few or no species are added at each successive station. If the plot continues to rise as successive samples are taken, then many more species remain to be surveyed. In our data, we have sampled the plants and fishes fairly well, for they appear to rise to a level of 59 and 78 species asymptotically (Figure 5.3). The number of fish species showed a large jump at the end of the sampling, because we sampled the offshore reef system last and discovered many new species; plants were less affected because they were light-limited at the offshore stations, and few species were tolerant of the conditions on the deep reefs. The invertebrates were less well sampled as a group, however. We broke the invertebrates group into subgroups (hard corals, soft corals, sponges, and other invertebrates) and noted that the hard coral, soft coral, and sponge subgroups approached assymptotes at 22, 15, 19 species, respectively (Figure 5.4). These three subgroups, representing 54 % of the invertebrate sample, appeared to be well sampled. The remaining invertebrate groups (anenomes, crustaceans, echinoderms, molluscs, tunicates, and polychaetes) must be regarded as under-sampled and require a return visit to adequately determine their patterns of association. Additionally, offshore stations appear to need further sampling.

Figure 5.3. A species accumulation curve for all stations showing separate plots of plant species, invertebrate species, and fish species. The stations at which many new species were observed (producing an upward jump in each curve) are printed over the curves. Stations are presented in the order in which they were sampled in the field.

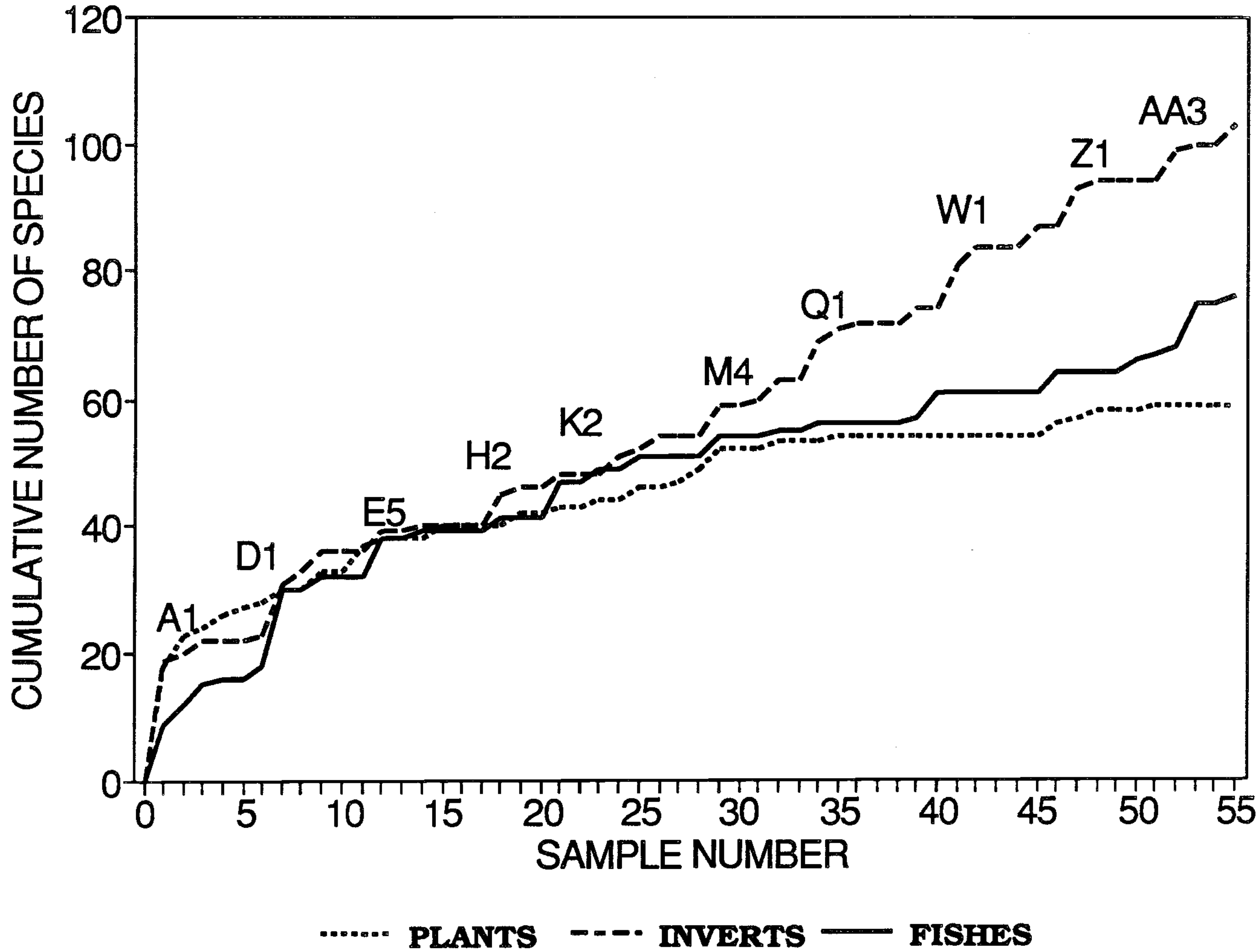
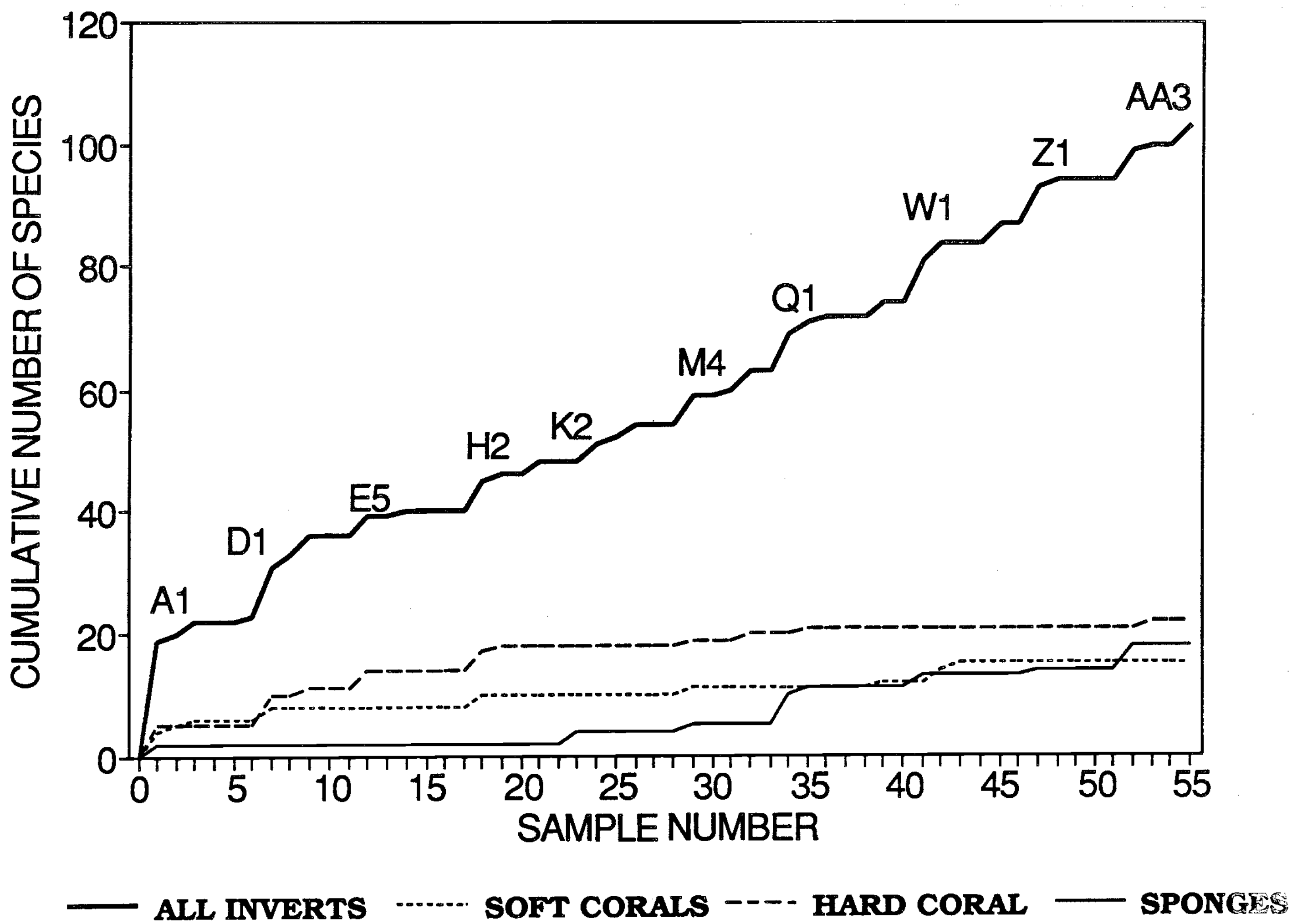


Figure 5.4. A species accumulation curve for all stations showing separate plots of all invertebrate species, sponges, soft corals, and hard coral species. The stations at which many new species were observed (producing an upward jump in each curve) are printed over the curves. Stations are presented in the order in which they were sampled in the field.



Ecozone Characterizations

Mangrove Forests

This coastal ecosystem is dominated by large mangrove trees that grow in the intertidal region and along the beach. They extend from just west of Punta Rucia to Buen Hombre and westward. They are bounded by upland forests to the south and seagrass meadows to the north. Small natural channels of open water wind among the mangrove islands near the seagrass meadows, but the density of the vegetation increases towards shore as the water gets shallower. The mangroves at the seaward edge of the forest, adjacent to the seagrass meadows, are the red mangrove (*Rhizophora mangle*), whereas along the upland forests, black mangroves (*Avicennia germinans*) are dominant.

Red mangroves grow in a monoculture to a height of 50 feet (15 m) along the coast. The prop roots of these trees provide abundant habitat for fishes, invertebrates, and birds (Table 5.3). Although no manatees (*Trichechus manatus*) were observed, these endangered marine mammals are known to frequent mangrove habitats, especially if there is freshwater input into the swamp. Mangroves in the area we visited apparently had little or no freshwater input, and manatees were absent. Fishermen told us of other mangrove areas that have manatees present; perhaps they have a greater input of freshwater. Many species of invertebrates were observed attached to these roots underwater, notably sponges, tunicates, and hydroids, shrimps, and amphipods, polychaetes, and macroalgae (Table 5.3). Fishes (mojarras, damselfishes, mullets, snappers) were observed feeding on this microbiota and hiding among the roots, in water depths of less than 3 feet (1 m). The Yellowfin Mojarra was observed both in the mangrove and on the coral reef; this species was harvested by local fishermen during our trips. Above the water, birds (Ospreys, Great Blue Herons, Great Egrets, Snowy Egrets, Green Herons, Kingfishers, Brown Pelicans) were observed perching on the prop roots and branches of red mangrove trees, and wading or diving into the water for fishes. The Magnificent Frigatebirds were observed soaring high overhead as we traveled through the mangroves each day, but were also observed over the seagrass meadows of the lagoons, and the reefs.

Table 5.3. Species list for the mangrove ecozone (ESU nos. K1, K2, K3) in the vicinity of Punta Rucia and Buen Hombre, Dominican Republic.

Taxon Name	Common Name
Vascular Plants	
Rhizophora mangle	Red Mangrove
Avicennia germinans	Black Mangrove
Thalassia testudinum	Turtle Grass
Algae	

Table 5.3. (continued) Species list for the mangrove ecozone (ESU nos. K1, K2, K3) in the vicinity of Punta Rucia and Buen Hombre, Dominican Republic.

Taxon Name	Common Name
Sargassum fluitans	Sargassum weed
Halimeda monile	Halimeda
Ceramium sp.	Red Filamentous Algae
Dictyota sp.	Dictyota
Unidentified Green Algae	
Sponges	
Tedania ignis	Fire Sponge
Unidentified sponge	
Echinoderms	
Holothuria mexicana	Donkey Dung Sea Cucumber
Holothuria arenicola	Burrowing Sea Cucumber
Tunicates	
Tunicate species1	sea squirt or tunicate
Fishes	
Gerres cinereus	Yellowfin Mojarra
Eucinostomus sp.	Mojarra (unidentified)
Lutjanus griseus	Gray Snapper
Microspathodon chrysurus	Yellowtail Damselfish
Abudefduf saxatilis	Sergeant Major
Mugil sp.	Mullet (unidentified)
Aetobatus narinari	Spotted Eagle Ray
Birds	
Pandion haliaetus	Osprey
Ardea herodias	Great Blue Heron
Casmerodius albus	Great Egret
Egretta thula	Snowy Egret
Butorides striatus	Green Heron
Megaceryle alcyon	Belted Kingfisher
Eudocimus albus	White Ibis
Pelecanus occidentalis	Brown Pelican
Fregata magnificens	Magnificent Frigatebird

First Lagoon

The first lagoon is a relatively shallow [mean depth = 9.28 ft (2.78 m); range 1 - 35.2 feet (0.3 - 10.6 m)] basin in which extensive seagrass meadows and sessile macroalgae are present (Table 5.4). The dominant seagrass is turtle grass (*Thalassia testudinum*), which covers the bottom in dense (> 1000 shoots/m^2) meadows. The turtle grass grows to a canopy height of 0.3 m, and is the single most common plant observable in the first lagoon. It grows both in shallow areas (adjacent to red mangrove islands and inside the mangrove channels) and deeper water. In shallow water, two other seagrasses, manatee grass (*Syringodium filiforme*) and shoal grass (*Halodule wrightii*) also occur among the turtle grass shoots, but are relatively rare compared with other seagrass meadows. For example, turtle grass occurred in 32 of the 49 sites (ESUs) visited along the Dominican Republic North coast during February 1991, whereas manatee grass occurred in 12 ESUs and shoal grass in 3 ESUs. In ESUs where they co-occurred, turtle grass was always the dominant species of seagrass (greatest percentage cover), with manatee grass second and shoal grass third. At stations A1 and B2, large *blowouts* or storm-induced depressions in the sea-bottom were observed. In these features, which dropped from 3 to 6 m (10 to 20 feet) down and were 40 - 50 m across, the seagrass had recolonized the floor of the depression, indicating that the storm damage occurred some time ago.

The seagrass meadows were not exclusively comprised of seagrass, however. Interspersed among the *Thalassia* shoots at every seagrass station was a diverse assemblage of macroalgae (Table 5.4). These were mostly green algae that grew in densities of 10 - 50 plants per m^2, some reaching heights of 0.3 m, but most were small (<0.1 m) and cryptic. The dominant species were *Penicillus capitatus* (16 ESUs), *Halimeda monile* (15 ESUs), *H. incrassata* (15 ESUs), *H. opuntia* (15 ESUs), *Rhipocephalus phoenix* (13 ESUs), *Penicillus dumetosus* (11 ESUs), and *Avrainvillea longicaulis* (10 ESUs). Many other species occurred in fewer than 10 ESUs, and these species are listed in Table 5.4. In general, no one species of macroalgae was dominant in the lagoon, unlike the seagrasses.

Some interesting features visible in the satellite image are the shallow areas comprised of calcareous red algae, *Amphiroa fragilissima* and *Neogoniolithon strictum*. These tended to be the dominant algal species at stations E2, M3, and Z1 forming large patches that excluded the otherwise dominant *Thalassia*. Such areas show up as lighter areas on the image and are more like small coral patch reefs due to the large amount of calcareous structures secreted by these algae. Indeed, these patches of calcareous red algae co-occurred with small finger corals, *Porites furcata*, and fire corals *Millepora* sp. The calcareous algae and corals gradually decline in abundance as the water deepens onto the *Thalassia* meadows that surround them.

The dominant fishes in the seagrass meadows of the first lagoon are the striped parrotfish (*Scarus croiensis*) juveniles. They dart into the seagrass for cover when approached. Other species observed were gobies (*Gobiosoma* sp.), blue tang (*Acanthurus coeruleus*), slippery dicks (*Halichoeres bivittatus*), and anchovies (*Anchoa* sp.).

Table 5.4. Species list for non-coral reef sites in the first lagoon (ESU nos. A2, B1, B2, B3, C1, E1, F1, F2, G1, H1, I1, J1, L1, M1, M2, M3, Z1, and Z2). Sites A1, H2, J2, and M4 are coral patch reefs that occur in the first lagoon and are described in Table 5.4.

Taxon Name	Common Name
Algae	
Acetabularia calyculus	
Amphiroa brasiliana	
Amphiroa fragilissma	
Asparagopsis taxifolia	
Avrainvillea longicaulis	
Taxon Name	**Common Name**
Avrainvillea nigricans	
Avrainvillea rawsonii	
Avrainvillea sp.	
Caulerpa lanuginosa	
Caulerpa paspaloides	
Caulerpa sertularioides	
Ceramium sp.	
Cladocephalus luteofuscus	
Cymopolia barbata	
Derbesia sp.	
Dictyosphaeria cavernosa	
Dictyota mertensii	
Dictyota sp.	
Enteromorpha flexuosa	
Halimeda incrassata	
Halimeda monile	
Halimeda opuntia	
Laurencia intricata	
Laurencia poitei	
Lobophora variegata	
Neogoniolithon strictum	
Padina gymnospora	
Penicillus capitatus	
Penicillus dumetosus	
Penicillus pyriformis	
Penicillus sp.	
Rhipocephalus phoenix	
Sargassum fluitans	
Sargassum polyceratium	
Stypopodium zonale	
Trichogloea requienii	
Turbinaria tricostata	
Turbinaria turbinata	
Udotea cyathiformis	
Udotea flabellum	
Udotea occidentalis	
Ventricaria ventricosa	
Vascular plants (Seagrasses)	
Halodule wrightii	shoal grass
Syringodium filiforme	manatee grass
Thalassia testudinum	turtle grass

Table 5.4. (continued) Species list for non-coral reef sites in the first lagoon (ESU nos. A2, B1, B2, B3, C1, E1, F1, F2, G1, H1, I1, J1, L1, M1, M2, M3, Z1, and Z2). Sites A1, H2, J2, and M4 are coral patch reefs that occur in the first lagoon and are described in Table 5.4.

Anenomes	
Aracnanthus nocturnus	banded tube-dwelling anenome
Calliactis tricolor	tricolor anenome
Crustaceans	
Pachycheles ackleianus	rough-clawed porcelain crab
Petrochirus diogenes	red hermit crab
Portunus sp.	portunus crab
Portunus sebae	swimming portunus crab
Echinoderms	
Actinopyga agassizii	five-toothed sea cucumber
Echinometra lucunter	red rock urchin
Holothuria mexicana	donkey dung sea cucumber
Holothuria arenicola	burrowing sea cucumber
Lytechinus variegatus	variable sea urchin
Oreaster reticulatus	reticulated sea star
Tripneustes ventricosus	sea egg
Hard corals	
Manicina areolata	common rose coral
Mussa angulosa	large flower coral
Porites furcata	thin finger coral
Molluscs	
Cittarium pica	magpie snail
Octopus sp.	octopus
Siphonaria pectinata	striped false limpet
Strombus gigas	queen conch
Polychaetes	
Serpulidae unid.	sepulid polychaetes
Soft Corals	
Eunicea mammosa	knobby candelabra
Gorgonia sp.	sea fan
Plexaurella grisea	sea rod
Pseudoplexaura porosa	false plexaura
Pseudopterogorgia bipinnata	forked sea feather
Pseudopterogorgia acerosa	smooth sea feather
Sponges	
Anthosigmella varians	variable sponge
Chondrilla nucula	chicken liver sponge
Cliona delitrix	red boring sponge
Spheciospongia vesparium	common loggerhead sponge

Table 5.4 (continued). Species list for non-coral reef sites in the first lagoon (ESU nos. A2, B1, B2, B3, C1, E1, F1, F2, G1, H1, I1, J1, L1, M1, M2, M3, Z1, and Z2). Sites A1, H2, J2, and M4 are coral patch reefs that occur in the first lagoon and are described in table 5.4.

Taxon Name	**Common Name**
Fishes	
Acanthurus bahianus	ocean surgeon
Acanthurus coeruleus	blue tang
Anchoa sp.	anchovy
Astrapogon stellatus	conchfish
Caranx bartholomaei	yellow jack
Caranx ruber	bar jack
Diodon hystrix	porcupinefish
Gobiosoma sp.	goby, unidentified
Halichoeres bivittatus	slippery dick
Halichoeres poyei	blackear wrasse
Halichoeres radiatus	puddingwife
Ocyurus chrysurus	yellowtail snapper
Polydactylus virginicus	barbu
Pomacentrus dorsopunicans	dusky damselfish
Pomacentrus leucosticus	beaugregory
Pomacentrus variabilis	cocoa damselfish
Psuedupeneus maculatus	spotted goatfish
Scarus croicensis	striped parrotfish
Scarus sp.	parrotfish, unidentified
Sparisoma rubripinne	redfin parrotfish

First Lagoon Patch Reefs

Coral patch reefs occurred inside the first lagoon at stations A1, H2, J2, and M4. These reefs were similar in species composition to the first barrier reef system. They were small in size, usually occupying less than one pixel area (28.5 X 28.5 m), sometimes 2 pixels. Thus they may not be visible in the satellite image. Toppled over staghorn coral, *Acropora cerviconis*, on to which brown macroalage had attached, occurred at station J2, suggesting that at some of these stations, storm-induced damage was responsible for this natural disturbance. These patch reefs are very important to the fishermen, because they occur near the shore and are thus protected from high wave surge. These sites have few large fishes, however, most likely due to the intensity of fishing pressure on them. They support a diversity of brown and green macroalgae, hard and soft coral, and small fishes (Table 5.5).

Table 5.5. Species list for patch reef sites in the first lagoon (ESU nos. A1, H2, J2, and M4).

Taxon Name	**Common Name**
Algae	
Amphiroa fragilissma	
Asparagopsis taxifolia	
Avrainvillea rawsonii	
Caulerpa cupressoides	
Caulerpa lanuginosa	
Caulerpa mexicana	
Caulerpa paspaloides	
Derbesia sp.	

Table 5.5 (continued). Species list for patch reef sites in the first lagoon (ESU nos. A1, H2, M2 and M4).

Dictyopteris delicatula	
Dictyota mertensii	
Enteromorpha flexuosa	
Halimeda monile	
Halimeda opuntia	
Lobophora variegata	
Padina gymnospora	
Penicillus capitatus	
Penicillus pyriformis	
Rhipocephalus phoenix	
Sargassum fluitans	
Sargassum polyceratium	
Siphonocladus tropicus	
Stypopodium zonale	
Turbinaria turbinata	
Ventricaria ventricosa	
Vascular Plants (Seagrasses)	
Halodule wrightii	shoal grass
Syringodium filiforme	manatee grass
Thalassia testudinum	turtle grass
Anenomes	
Stoichactis helianthus	sun anenome
Zooanthus sociatus	green colonial anenome
Crustaceans	
Stenopus hispidus	banded coral shrimp
Echinoderms	
Echinometra lucunter	red rock urchin
Holothuria mexicana	donkey dung sea cucumber
Lytechinus variegatus	variable sea urchin
Oreaster reticulatus	reticulated sea star
Hard Corals	
Acropora palmata	elkhorn coral
Acropora cervicornis	staghorn coral
Agaricia agaricites	tan lettuce-leaf coral
Colpophyllia natans	large-grooved brain coral
Diploria strigosa	common brain coral
Diploria labyrinthiformis	depressed brain coral
Diploria clivosa	sharp-hilled brain coral
Isophyllia sinuosa	stalked cactus coral
Manicina areolata	common rose coral
Millepora alcicornis	crenelated fire coral
Millepora complanata	flat-topped fire coral
Montastrea cavernosa	large-cupped boulder coral
Montastrea annularis	boulder coral
Porites astreoides	yellow porous coral
Porites furcata	thin finger coral

Table 5.5 (continued). Species list for patch reef sites in the first lagoon (ESU nos. A1, H2, M2 and M4).

Molluscs	
Cassis flammea	flamingo tongue
Codakia orbicularis	great white lucine
Pinna carnea	flesh pen shell
Strombus gigas	Queen stromb
Polychaetes	
Sabellastarte magnifica	magnificent banded fanworm
Soft Corals	
Briareum asbestinum	deadman's fingers
Eunicea mammosa	knobby candelabra
Gorgonia sp.	sea fan
Plexaura homomalla	common bushy soft coral
Plexaura flexuosa	tan bushy soft coral
Pseudoplexaura porosa	false plexaura
Pseudopterogorgia bipinnata	forked sea feather
Pseudopterogorgia acerosa	smooth sea feather
Pseudopterogorgia americana	slimy sea feather
Sponges	
Aplysina fistularis	yellow tube sponge
Chondrilla nucula	chicken liver sponge
Siphonodictyon coralliphagum	yellow boring sponge
Fishes	
Abudefduf saxatilis	sergeant major
Acanthurus bahianus	ocean surgeon
Acanthurus coeruleus	blue tang
Acanthurus randalli	gulf surgeonfish
Aulostomus maculatus	trumpetfish
Bodianus rufus	Spanish hogfish
Canthigaster rostrata	sharpnose puffer
Caranx bartholomaei	yellow jack
Caranxruber	bar jack
Chromis multilineatus	brown chromis
Diodon hystrix	porcupinefish
Epinephelus guttatus	red hind
Epinephelus striatus	Nassau grouper
Gobiosoma evelynae	sharknose goby
Gobiosoma genie	cleaner goby
Gobulus myersi	paleback goby
Gobiosoma oceanops	neon goby
Gramma loreto	royal gramma (fairy basslet)
Haemulon flavolineatum	french grunt
Haemulon melanurum	cottonwick
Haemulon sciurus	bluestriped grunt
Halichoeres bivittatus	slippery dick
Halichoeres garnoti	yellowhead wrasse
Holocentrus adscensionis	squirrelfish
Holocentrus sp.	squirrelfish

Table 5.5 (continued). Species list for patch reef sites in the first lagoon (ESU nos. A1, H2, M2 and M4).

Lactophrys bicaudalis	spotted trunkfish
Lachnolaimus maximus	hogfish
Microspathodon chrysurus	yellowtail damselfish
Ocyurus chrysurus	yellowtail snapper
Pomacentrus dorsopunicans	dusky damselfish
Pomacentrus leucosticus	beaugregory
Pomacentrus planifrons	threespot damselfish
Pomacentrus variabilis	cocoa damselfish
Psuedupeneus maculatus	spotted goatfish
Scarus croicensis	striped parrotfish
Scarus sp.	parrotfish
Sparisoma rubripinne	redfin parrotfish
Sparisoma viride	stoplight parrotfish
Thalassoma bifasciatum	bluehead

First Barrier Reef

The first lagoon gradually became shallower away from the coast and became the first barrier reef. Stations on the first barrier reef (D1, E2, E3, E4, E5, N1, Q1, R1, U1, U2, and Y1) were high-energy habitats with a good deal of wave surge. They were characterized by high-diversity coral communities with encrusting algae, sponges, anenomes and tunicates. The inshore side of the barrier reefs had a very expansive reef flat that was less than 1 foot deep and typically comprised of seagrass and coralline red algae. The reef crest often appeared to be exposed at low tide and showed a good deal of storm induced wave damage (i. e., toppled *Acropora cervicornis* and *A. palmata* colonies at U2 and Y1). The fore reef of the first barrier reef was relatively steep, sloping to deeper than 30 feet over a relatively short horizontal distance. A *halo* effect, which is region of vegetation-free sand near the base of the reef and is most likley caused by reef-associated herbivores, was visible at Y1 in 30 feet of water.

The dominant species of plants on the first barrier reef stations are brown macroalgae (*Dictyota, Turbinaria, Sargassum, Stypopodium*, and *Lobophora*). These genera of brown macroalgae grow profusely on the surfaces of toppled coral heads. They are well adapted to the high energy environments at these stations, for they are strongly attached to dead corals with holdfasts. Green macroalgae (*Halimeda opuntia, Caulerpa racemosa*) attach to rocks and dead coral here as well. Open spaces are often colonized by encrusting coralline red algae.

The dominant invertebrates at these sites are the hard coral species. Boulder coral, *Montastrea annularis*, staghorn coral, *Acropora cervicornis*, elkhorn coral, *A. palmata*, leaf lettuce corals, *Agaricia* sp., brain corals, *Diploria strigosa, D. labyrinthiformis, D. clivosa*, fire corals, *Millepora* sp., finger coral, *Porites porites*, and yellow porous coral, *Porites asteroides*, are all dominant at various sites. It was in this region that much of the bleached coral (*Acropora palmata*) were observed, exposed to the air at low tide.

The dominant fishes at these sites are members of the family Labridae, the wrasses. Various parrotfishes (*Scarus*, *Sparisoma viridens*) are large adults, unlike the seagrass parrotfish. In addition, bluehead wrasse (*Thalassoma bifasciatum*), and blue tang (*Acanthurus coeruleus*) are very abundant in places. Very few larger groupers (*Epinephelus striatus, E.*

guttatus, and E. fulvus) and snappers (*Lutjanus griseus, Lutjanus apodus, Lutjanus synagris*) were observed. The groupers and snappers may have hiding in the presence of a diver.

Table 5.6. Species list for the first barrier reef (ESU nos. D1, E2, E3, E4, E5, N1, N2, Q1, R1, U1, U2).

Taxon Name	Common Name
Algae	
Amphiroa fragilissma	
Avrainvillea longicaulis	
Avrainvillea nigricans	
Caulerpa lanuginosa	
Ceramium sp.	
Dictyopsphaeria cavernosa	
Dictyota divaricata	
Dictyota mertensii	
Filamentous red alage	
Halimeda monile	
Halimeda opuntia	
Halimeda incrassata	
Halimeda tuna	
Laurencia papillosa	
Lobophora variegata	
Neogoniolithon strictum	
Penicillus dumestosus	
Penicillus capitatus	
Penicillus pyriformis	
Rhipocephalus phoenix	
Sargassum fluitans	
Sargassum platycarpum	
Sargassum polyceratium	
Siphonocladus tropicus	
Stypopodium zonale	
Turbinaria tricostata	
Turbinaria turbinata	
Udotea cyathiformis	
Udotea occidentalis	
Ventricaria ventricosa	
Vascular Plants (Seagrasses)	
Syringodium filiforme	manatee grass
Thalassia testudinum	turtle grass
Anenomes	
Aracnanthus nocturnus	banded tube dwelling anenome
Condylactis gigantea	giant Caribbean anenome
Palythoa caribaeorum	encrusting colonial anenome
Crustaceans	
Panulirus argus	spiny lobster
Echinoderms	

Table 5.6.(continued) Species list for the first barrier reef (ESU nos. D1, E2, E3, E4, E5, N1, N2, Q1, R1, U1, U2).

Echinometra lucunter	red rock urchin
Holothuria mexicana	donkey dung sea cucumber
Holothuria arenicola	burrowing sea cucumber
Oreaster reticulatus	reticulated sea star
Tripneustes ventricosus	sea egg
Hard Corals	
Acropora palmata	elkhorn coral
Acropora cervicornis	staghorn coral
Agaricia undata	lettuce-leaf coral
Agaricia sp.	lettuce-leaf coral
Agaricia agaricites	tan lettuce-leaf coral
Colpophyllia natans	large-grooved brain coral
Diploria strigosa	common brain coral
Diploria labyrinthiformis	depressed brain coral
Diploria clivosa	sharp-hilled brain coral
Manicina areolata	common rose coral
Millepora sp.	fire coral
Millepora alcicornis	crenelated fire coral
Millepora complanata	flat-topped fire coral
Montastrea annularis	boulder coral
Porites porites	finger coral
Porites astreoides	yellow porous coral
Porites furcata	thin finger coral
Molluscs	
Lima scabra	rough file shell
Sepioteuthis sepioidea	reef squid
Strombus alatus	Florida stromb
Polychaetes	
Hermodice carunculata	fireworm
Soft Corals	
Briareum asbestinum	deadman's fingers
Euniceamammosa	knobby candelabra
Eunicea sp.	knobby candelabra
Gorgonia sp.	sea fan
Plexaura sp.	bushy soft coral
Plexaurella grisea	sea rod
Pseudopterogorgia bipinnata	forked sea feather
Pseudopterogorgia acerosa	smooth sea feather
Sponges	
Aplysina fistularis	yellow tube sponge
Erylus sp.	formosan sponge
Haliclona rubens	red finger sponge
Haliclona viridis	blue-green finger sponge

Table 5.6.(continued) Species list for the first barrier reef (ESU nos. D1, E2, E3, E4, E5, N1, N2, Q1, R1, U1, U2).

Niphates digitalis	gray cornucopia sponge
Ptilocaulis spiculifer	
Siphonodictyon coralliphagum	yellow boring sponge
Xestospongia muta	basket sponge
Fishes	
Acanthurus coeruleus	blue tang
Acanthurus randalli	gulf surgeonfish
Aulostomus maculatus	trumpetfish
Canthigaster rostrata	sharpnose puffer
Chaetodon capistratus	foureye butterflyfish
Chromis multilineatus	brown chromis
Clinidae (unidentified)	clinid
Diodon hystrix	porcupinefish
Epinephelus striatus	Nassau grouper
Fistularia sp.	coronetfish
Gerres cinereus	yellowfin mojarra
Gobiosoma genie	cleaner goby
Gramma loreto	royal gramma (fairy basslet)
Haemulon flavolineatum	french grunt
Haemulon sciurus	bluestriped grunt
Halichoeres bivittatus	slippery dick
Halichoeres garnoti	yellowhead wrasse
Halichoeres maculipinna	clown wrasse
Halichoeres pictus	rainbow wrasse
Halichoeres radiatus	puddingwife
Holocentrus adscensionis	squirrelfish
Hyporhamphus unifasciatus	halfbeak
Hypoplectrus unicolor	blue hamlet
Lactophrys trigonus	trunkfish
Lutjanus griseus	gray snapper
Ocyurus chrysurus	yellowtail snapper
Pomacentrus dorsopunicans	dusky damselfish
Pomacentrus partitus	bicolor damselfish
Pomacentrus planifrons	threespot damselfish
Psuedupeneus maculatus	spotted goatfish
Scarus croicensis	striped parrotfish
Scarus taeniopterus	princess parrotfish
Sparisoma viride	stoplight parrotfish
Sphyraena barracuda	great barracuda
Thalassoma bifasciatum	bluehead

Second Lagoon

The second lagoon was a deeper lagoon than the first lagoon, with depths exceeding 50 feet. We visited three stations (O1, V1, and V2) that were in between the first and second reefs and truly in the second lagoon. Generally, these stations were patch reefs in the second lagoon and we were taken to them by the fishermen who fished them regularly. We did not sample any sites fay away from patch reefs in the second lagoon. The patch reefs were surrounded by sparse cover of seagrass and algae with an obvious *halo* (open sand and sediment; no vegetation present) effect around the patch reef. The species observed at these station are listed in Table 5.7.

The bottom cover at Station O1 was a patch reef surrounded by flat sandy sediment bottom with a sparse cover of macroalgae (*Penicillus* sp., *Halimeda opuntia*). Although seagrasses might be expected to occur in this area around the reef at a depth of 33 feet in very clear water, none were observed. Other algae growing on the reef itself (*Dictyota* sp. and corraline red alage) were present in great abundance. The reef was comprised of coral species listed, of which *Montastrea annularis* was the dominant species. The fishes present at the site were fairly abundant but no large predator fishes were observed. One Nassau grouper, *Epinephelus guttatus*, was speared by the fishermen visiting the site with us, however. The dominant fish at this site was the bluehead wrasse, *Thalassoma bifasciatum*.

The bottom types present at Station V1 was sparse seagrass (*Thalassia*) and macro-algae (*Udotea, Avrainvillea, Rhipocephalus*, and *Penicillus*). There was a very obvious *halo* effect around the patch reef at station V2. Station V1 was located in the vegetated area outside the *halo*. The fishermen described this *halo* to us prior to our diving. Among the invertebrates noted at this site were sea lillies, cactus coral, and tube sponges. The most abundant fish at this site was the blue chromis, of which there were thousands. The coney, *Epinephelus fulvus*, was also observed here for the first time, and was fairly abundant. The fishermen shot a schoolmaster, *Lutjanus apodus*, and a hogfish, *Lachnolaimus maximus*, at this site.

Table 5.7. The species list at sites O1, V1, V2 in the second lagoon ecozone.

Taxon	Common Name
Algae	
Avrainvillea nigricans	
Dictyota mertensii	
Halimeda monile	
Halimeda opuntia	
Penicillus dumetosus	
Rhipocephalus phoenix	
Udotea cyathiformis	
Udotea occidentalis	
Vascular Plants (Seagrasses)	
Thalassia testudinum	turtle grass
Anenomes	
Palythoa caribaeorum	encrusting colonial anenome
Zooanthus sociatus	green colonial anenome
Crustaceans	
Domecia acanthophora	elkhorn coral crab
Porcellana sp.	porcelain crab

Table 5.7. (continued) The species list at sites O1, V1, V2 in the second lagoon ecozone.

Echinoderms

Ophiactis quinqueradia	five-armed ophiactis
Ophiothrix angulata	angular brittle star
Tropiometra carinata	banded sea lily

Hard Corals

Agaricia agaricites	tan lettuce-leaf coral
Colpophyllia natans	large-grooved brain coral
Diploria strigosa	common brain coral
Diploria labyrinthiformis	depressed brain coral
Isophyllia sinuosa	stalked cactus coral
Millepora squarrosa	encrusting fire coral
Millepora alcicornis	crenelated fire coral
Montastrea annularis	boulder coral
Porites porites	finger coral

Soft Corals

Eunicea mammosa	knobby candelabra
Gorgonia sp.	sea fan
Plexaura flexuosa	tan bushy soft coral
Pseudopterogorgia bipinnata	forked sea feather
Pseudopterogorgia acerosa	smooth sea feather
Pseudopterogorgia americana	slimy sea feather

Sponges

Aplysina fistularis	yellow tube sponge
Cliona delitrix	red boring sponge
Haliclona viridis	blue-green finger sponge
Oligoceras hemmorrhages	bleeding sponge

Tunicates

Tunicate sp. (2) unidentified	sea squirt

Fishes

Acanthurus coeruleus	blue tang
Acanthurus randalli	gulf surgeonfish
Canthigaster rostrata	sharpnose puffer
Chromis cyaneus	blue chromis
Epinephelus fulvus	coney
Epinephelus guttatus	red hind
Gobiosoma genie	cleaner goby
Halichoeres garnoti	yellowhead wrasse
Lachnolaimus maximus	hogfish
Lutjanus apodus	schoolmaster
Pomacentrus partitus	bicolor damselfish
Pomacentrus planifrons	threespot damselfish
Scarus croicensis	striped parrotfish
Scarus taeniopterus	princess parrotfish
Sparisoma viride	stoplight parrotfish
Thalassoma bifasciatum	bluehead

Second Barrier Reef

The second lagoon is relatively deep (> 50 feet) and the second barrier reef rises from the second lagoon. The stations on the second barrier reef (Stations X1, X2, X3, W1, AA2, AA3, AA4, and AA5) were fairly deep (mean depth = 31.8 feet) and were surrounded by deeper water than similar stations on the first barrier reef. Depth dropped off sharply from very shallow areas in the center of the reef (Stations AA2, AA3, X3, mean depth = 3.9 feet) to very deep sites inside and outside the reef (Stations X1, X2, W1, AA4, AA5, mean depth = 44.5 feet). There was a good deal of wave surge in the shallow reef locations, but areas in deeper water were well protected from this surge. For example, station X3, which was shallow (2 feet depth), had a great deal of toppled *Acropora cervicornis* and *A. palmata*, suggesting that storm surge contributed to the death of these coral colonies. Station X1 (depth 20 feet) had none of these toppled colonies and it was located just inshore of X3.

The dominant species of plants on the second reef were coralline red algae (*Amphiroa, Neogoniolithon*), green macroalgae (*Avrainvillea, Caulerpa, Halimeda, Penicillus, Rhipocephalus*), brown algae (*Dictyota, Sargassum, Lobophora, Padina, Stypopodium, Turbinaria*) and seagrasses (*Thalassia, Syringodium, Halodule*). The invertebrates were dominated by hard corals (*Acropora palmata, Acropora cervicornis, Diploria* sp., *Montastrea* sp., and *Porites* sp.) and soft corals. Sponges, especially tube sponges (*Aplysina* sp.), were abundant at the deeper sites. Fishes were observed in great abundance, especially the groupers (*Epinephelus* sp.) and snappers (*Lutjanus* sp.). The complete species list is presented in Table 5.8.

In general these stations appeared to be the most diverse stations, with the greatest abundance of fishes. These sites appeared to be the least disturbed by humans. Sand Key, (Stations AA1, AA2, AA3, AA4, and AA5) is a popular location for visits by ecotourists from a hotel at Punta Rusia. Effects on the coral can be seen at this site (toppled coral heads and anchor damage) including a good deal of bleaching of *Acropora palmata* in shallow water. This site is also a very beautiful site, and is very diverse in spite of the effects ecotourism. Many irridescent tube sponges occur here at Stations AA4 and AA5, just byond the shallow reef zone, in 40 - 50 feet of water. Many new species of fish were observed at this site, suggesting it is unique in its biodiversity: harlequin bass, trumpetfish, yellow stingray, southern flounder, banded butterfly fish, palometa, lane snappers, and blue parrotfish were observed here and nowhere else.

Stations X1, X2, and X3 were all close to one another behind a cresent-shaped reef island to the west of Sand Key. The sites were very different in spite of there proximity. Station X1 was typical of the surrounding seagrass and green macroalgae bottom near the reef, whereas X3 was on the reef proper in 3.0 feet of water. Station X2 was further inshore, really into the second lagoon; it was 53 feet deep, just 10-20 m inshore of the reef. The bottom at X2 was not investigated by SCUBA diving, because of depth and time limitations, but appeared to be mostly sediment, with sparse but uniform distribution of macroalgae.

Table 5.8. The species list for the second barrier reef (Stations X1, X2, X3, W1, AA2, AA3, AA4, and AA5).

Taxon Name	Common Name
Algae	
Amphiroa fragilissma	
Avrainvillea longicaulis	
Avrainvillea nigricans	
Avrainvillea sp.	
Caulerpa cupressoides	
Caulerpa lanuginosa	
Caulerpa racemosa	
Coralline red algae	
Dictyota jamaicensis	
Dictyota mertensii	
Dictyota sp.	
Halimeda incrassata	
Halimeda monile	
Halimeda opuntia	
Lobophora variegata	
Neogoniolithon strictum	
Padina gymnospora	
Penicillus capitatus	
Penicillus dumetosus	
Penicillus pyriformis	
Rhipocephalus phoenix	
Sargassum fluitans	
Sargassum hystrix	
Stypopodium zonale	
Turbinaria tricostata	
Turbinaria turbinata	
Udotea cyathiformis	
Udotea flabellum	
Udotea occidentalis	
Vascular Plants (Seagrasses)	
Halodule wrightii	shoal grass
Syringodium filiforme	manatee grass
Thalassia testudinum	turtle grass
Anenomes	
Condylactis gigantea	giant Caribbean anenome
Zooanthus sociatus	green colonial anenome
Crustaceans	
Domecia acanthophora	elkhorn coral crab
Porcellana sp.	porcelain crab
Echinoderms	
Astrophyton muricatum	basket star
Diadema antillarum	long-spined black urchin
Echinometra lucunter	red rock urchin
Ophiactis quinqueradia	five-armed ophiactis
Ophiothrix angulata	angular brittle star

Table 5.8. (continued) The species list for the second barrier reef (Stations X1, X2, X3, W1, AA2, AA3, AA4, and AA5).

Tropiometra carinata	banded sea lily
Hard Corals	
Acropora palmata	elkhorn coral
Acropora cervicornis	staghorn coral
Agaricia agaricites	tan lettuce-leaf coral
Colpophyllia natans	large-grooved brain coral
Diploria strigosa	common brain coral
Isophyllia sinuosa	stalked cactus coral
Manicina areolata	common rose coral
Millepora sp.	fire coral
Millepora alcicornis	crenelated fire coral
Millepora complanata	flat-topped fire coral
Montastrea cavernosa	large-cupped boulder coral
Montastrea annularis	boulder coral
Mussa angulosa	large flower coral
Mycetophyllia lamarckiana	large cactus coral
Porites porites	finger coral
Porites astreoides	yellow porous coral
Porites furcata	thin finger coral
Hydrozoa (jellyfish)	
Cassiopeia xamachana	upside-down jellyfish
Molluscs	
Cassis flammea	flamingo tongue
Polychaetes	
Spirobranchus giganteus	feathered christmas tree worm
Soft Corals	
Briareum asbestinum	deadman's fingers
Eunicea mammosa	knobby candelabra
Gorgonia sp.	sea fan
Muriceopsis flavida	sea plume
Plexaura homomalla	common bushy soft coral
Plexaura flexuosa	tan bushy soft coral
Plexaura sp.	bushy soft coral
Plexaurella dichotoma	sea rod
Plexaurella grisea	sea rod
Pseudoplexaura porosa	false plexaura
Pseudopterogorgia bipinnata	forked sea feather
Pseudopterogorgia acerosa	smooth sea feather
Pseudopterogorgia americana	slimy sea feather
Pterogorgia sp.	sea blade
Sponges	
Aplysina fistularis	yellow tube sponge
Aplysina lacunosa	giant tube sponge
Cliona delitrix	red boring sponge

Table 5.8 (continued). The species list for the second barrier reef (Stations X1, X2, X3, W1, AA2, AA3, AA4, and AA5).

Haliclona rubens	red finger sponge
Haliclona viridis	blue-green finger sponge
Niphates digitalis	gray cornucopia sponge
Pandaros acanthifolium	purple bush sponge
Ptilocaulis spiculifer	
Spinosella vaginalis	lavender tube sponge
Spinosella plicifera	iridescent tube sponge
Sponge (unidentified)	sponge
Xestospongia muta	basket sponge
Tunicates	
Tunicate sp. (2) unidentified	sea squirt
Fishes	
Abudefduf saxatilis	sergeant major
Acanthurus bahianus	ocean surgeon
Acanthurus chirurgus	doctorfish
Acanthurus coeruleus	blue tang
Aulostomus maculatus	trumpetfish
Balistes capriscus	gray triggerfish
Bodianus rufus	Spanish hogfish
Calamus sp.	porgy
Canthigaster rostrata	sharpnose puffer
Caranx ruber	bar jack
Chaetodon capistratus	foureye butterflyfish
Chaetodon striatus	banded butterflyfish
Chromis cyaneus	blue chromis
Chromis multilineatus	brown chromis
Diodon hystrix	porcupinefish
Epinephelus fulvus	coney
Epinephelus striatus	Nassau grouper
Gerres cinereus	yellowfin mojarra
Gobiosoma genie	cleaner goby
Gobiosoma sp.	goby
Gramma loreto	royal gramma (fairy basslet)
Haemulon sciurus	bluestriped grunt
Halichoeres bivittatus	slippery dick
Halichoeres garnoti	yellowhead wrasse
Halichoeres pictus	rainbow wrasse
Holocentrus adscensionis	squirrelfish
Holocentrus sp.	squirrelfish
Holacanthus tricolor	rock beauty
Hypoplectrus unicolor	blue hamlet
Lachnolaimus maximus	hogfish
Lactophrys triqueter	smooth trunkfish
Lactophrys trigonus	trunkfish
Lutjanus apodus	schoolmaster
Lutjanus synagris	lane snapper
Microspathodon chrysurus	yellowtail damselfish
Mulloidiclithys martinicus	yellow goatfish
Ocyurus chrysurus	yellowtail snapper
Paralichthys albigutta	southern flounder
Pomacanthus arcuatus	gray angelfish
Pomacanthus paru	french angelfish

Table 5.8 (continued). The species list for the second barrier reef (Stations X1, X2, X3, W1, AA2, AA3, AA4, and AA5).

Pomacentrus dorsopunicans	**dusky damselfish**
Pomacentrus partitus	**bicolor damselfish**
Pomacentrus planifrons	**threespot damselfish**
Psuedupeneus maculatus	**spotted goatfish**
Scarus coeruleus	**blue parrotfish**
Scarus croicensis	**striped parrotfish**
*Scarus*sp.	**parrotfish**
Serranus tigrinus	**harlequin bass**
Sparisoma viride	**stoplight parrotfish**
Sphyraena barracuda	**great barracuda**
Thalassoma bifasciatum	**bluehead**
Trachinotus goodei	**palometa**
Uroplophus jamaicensis	**yellow stingray**

Classification of the ESUs

There are ten natural groups of the stations based on the cluster analysis of all species of plants, invertebrates, and fishes using an arbitrary cut-off point of 0.0 dissimilarity (stations that have similar suites of species have negative dissimilarity values in Jaccard's index). Natural groups of stations are linked at joining distances of < 0.0 dissimilarity and are more similar than stations joined at > 0.0 dissimilarity)(Figure 5.5).

The most dissimilar group of stations (Group 1) show a low species richness, which is due to the inadequate sampling done at stations U1, H1, and K1, where little time was allotted for ecological surveying. It is interesting that seagrass (*Thalassia testudinum)* was the dominant bottom cover at all three stations.

The second large cluster of coral reef stations is composed of 3 natural groups of stations (Groups 2, 3, and 4; Figure 5.5). Group 2 is comprised of stations that are deep (mean depth = 55.0 feet), with sponges and corals as bottom cover (Q1, V2, AA4, AA5). AA4 and AA5 were both located on the fore-reef of Sand Key, a deep and diverse coral and sponge reef. Group 3 is comprised of shallow (mean depth = 9.5 feet) coral reef stations (U2, D1, X3, AA3, E5, R1, W1, Y1, M4) located in the high-surge zones along the first and second barrier reefs. The stations in Group 4 (O1, H2, and J2) were all patch reefs isolated from other reefs and surrounded by seagrass meadows in intermediate depths (mean depth = 15.4 feet).

The remaining stations are subdivided into the six natural groups (Groups 5 - 10; Figure 5.5). Five of these groups have seagrasses and macrolagae as the dominant bottom cover types (Groups 5 - 9). The last group (Group 10) has silt as bottom type, or share species in common with silty areas.

Stations E2 and E3 comprise a single group (Group 5) that are similar to one another, but very different from all other seagrass/macroalage stations. They were very shallow stations (mean depth = 2.25 feet) with sand, seagrass, and coralline red algae as bottom cover, but with generally low diversity. These two shallow stations are typical of the reef flat as it intergrades into the seagrass meadows of the first lagoon. Additional shallow seagrass and coralline red algae stations with slightly greater species diversity are included in Group 8 below.

Group 6 stations (AA2, C1, E1, M1, and A1) have shallow (mean depth = 3.66 feet) algae or seagrass as a defining characteristic. With the exception of AA2, they all are dominated by the seagrasses *Thalassia testudinum* and *Syringodium filiforme*. In addition, green and brown macroalgae were part of the bottom cover for this group. Station AA2 was most dissimilar member of this group, and was characterized by open sand with small patches of brown algae *Dictyota* and *Turbinaria* attached to rocks. There was no seagrass of any kind at this station. These areas should appear as brightish areas due to their shallow depth. AA2 should appear very bright with its lack of seagrass vegetation.

Group 7 stations (F1, B3, J1, K3, I1, and M2), are slightly deeper (mean depth = 12.58 feet) low diversity seagrass stations. These stations had sparse seagrass cover of *Thalassia*, *Halodule*, or *Syringodium*, but also had a diversity of green macroalage. They were not very diverse stations, and frequently were mixed in with a great deal of open sand patches. These stations should show as areas of intermediate brightness in the satellite image.

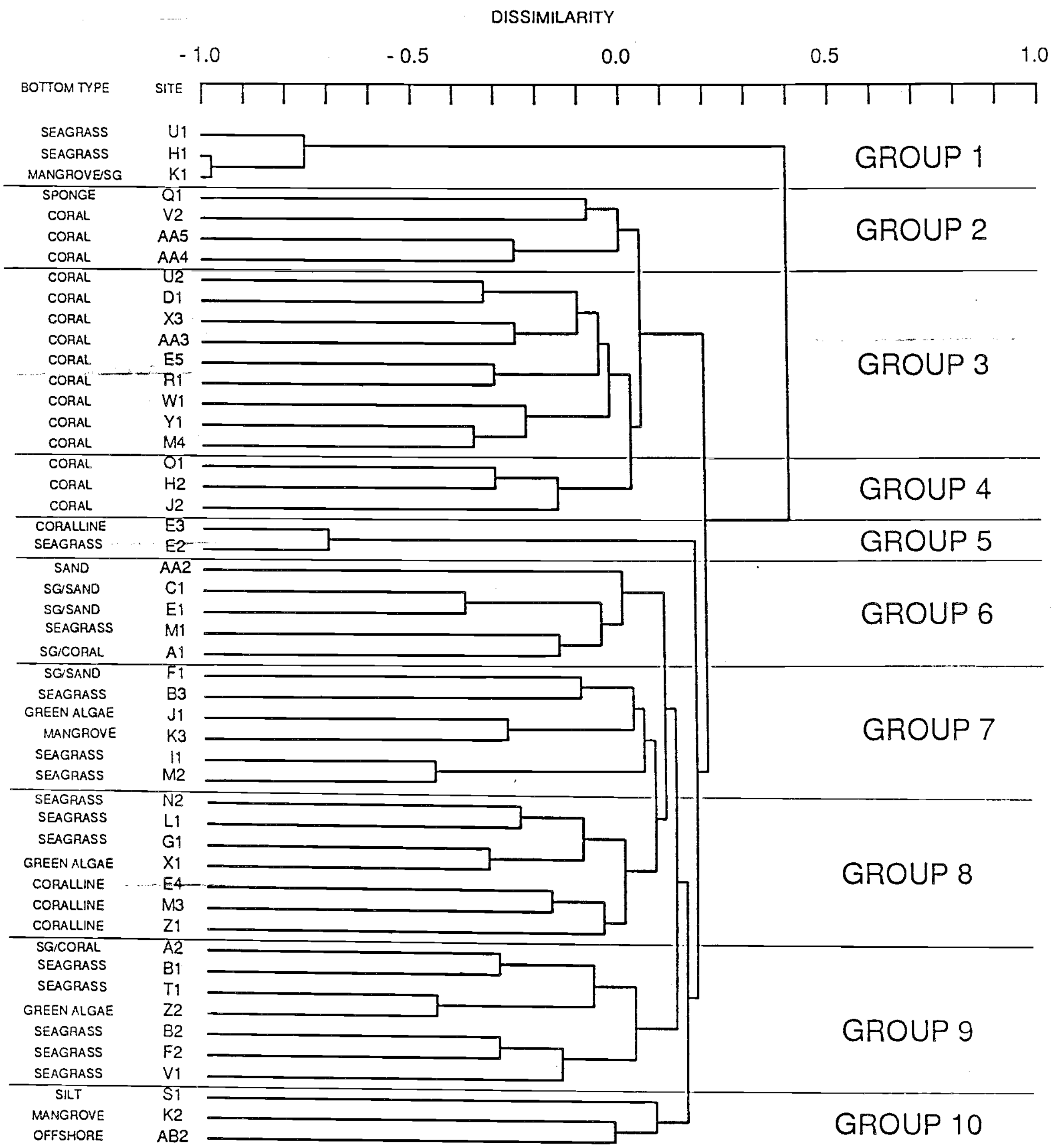


Figure 5.5. The dendrogram for the cluster analysis of all species (plants, invertebrates, and fishes) observed at all the sites visited. Bottom type is listed for each site (determined during the sea-truthing visit). Group membership was determined arbitrarily at a cutpoint of 0.0 dissimilarity.

Group 8 stations (N2, L1, G1, X1, E4, M3, and Z1) are of intermediate depth (mean depth = 7.46 feet) and contain a good deal of macroalgae in addition to seagrass. In particular, coralline algae (*Neogoniolithon*, *Amphiroa*) was very abundant at E4, M3, and Z1, which were small patches of coralline red algae, green macroalgae, small corals, and encrusting sponges mixed with the short plants of the seagrass *Thalassia*. The calcareous nature of the coralline red algae will make these stations very good reflectors of light, and these stations should show up in satellite imagery as brightish areas.

Group 9 stations (A2, B1, B2, T1, Z2, F2, and V1) are all dominated by seagrass *Thalassia testudinum* and *Syringodium filiforme*, and green rhizoidal macroalgae (*Halimeda, Penicillus, Avrainvillea, Udotea, Rhipocephalis*) and occurred at the greatest depth (mean depth = 14.49 feet). These stations were similar because they had extensive vegetation of some kind in deep water of the first lagoon. The seagrass or algae covered most of the bottom at these sites, with little or no sand exposed. These stations should not have a bright reflectivity if viewed from space.

Group 10 (Stations S1, K2, and AB2) was judged to be very different in that it contained stations that lacked species diversity. Two of these stations had a very silty bottom cover type. Station S1, for example, was covered entirely with a fine silt sediment and was totally depauperate in terms of plants and fishes. The only life at S1 was evident from the many infaunal polychaete tubes observed. The bottom type at station AB2 is unknown (we did not visit this site), but samples of the species present at that site between the second and third reef brought to us by fishermen suggest it has a species composition most similar to the mangrove silt bottom station (K2). This is interesting, because it suggests that there is some degree of similarity between the fish communities closest to shore and offshore communities. Indeed, mojarras and gray snappers caused this linking of inshore and offshore stations, because these fishes occur in both areas, the juveniles in the mangroves and the adults on the reefs, where they are harvested by the fishermen of Buen Hombre.

Comparison of Fish Communities at Ethnographic Sites

The fish assemblages present at a subset of 17 stations during our visit were compared with those known to be present historically (from oral reports of local expert fishermen in Chapters 6 and 7). A reduced matrix of fish species observed at those stations where we also had ethnographic data were grouped using the same type of cluster analysis as above. Fishes observed during snorkling and diving observations were grouped into six natural groups at an arbitrary cutoff of 0.0 dissimilarity (Figure 5.6). Fish species harvested by Buen Hombre fishermen (listed in Chapter 7) at each of the sites were clustered into six natural groups (Figure 5.7).

It is very interesting to note that the same three stations (V2, W1, and Y1) form natural groups in both these cluster dendrograms. These stations are all located far from the village of Buen Hombre, either between the first and second barrier reef (V2) or on the second reef (W1 and Y1). Station W1 was an area where aggregations of groupers and snappers were found. These large carnivorous fishes are much less abundant or absent at most of the inshore reef stations we visted. The grouping of these three offshore stations in both cluster analyses suggests that the fish communities observed during our visit were very similar to the mixed species catch Buen Hombre fishermen harvest at these stations. Inshore stations clustered differently in the two data sets, probably due to the fact that the fish assemblage observed during our visit was very different than the assemblage the fishermen have harvested over a long period of time. In essence, the inshore reef, seagrass, and mangrove stations had different fish species present during our visit than have been historically harvested.

The difference in clustering of the two data sets suggests that overfishing has probably occurred at these nearshore stations, causing a radical shift in fish community structure. Other explanations are possible for this difference, however. Fishes at the inshore station could have been more easily frightened by divers making fish obervations, but fish probably react similarly to divers everywhere. It is quite possible that the fishes that are harvested by the fishermen only can be found inshore during certain seasons, or migrate frequently between the inshore and distant stations. Tagging studies with frequent monitoring of fish abundance at the inshore and offshore sites are needed to determine if this is may explain the differences. Because all species appeared more abundant at the offshore stations (based on rough counts during our visit), overfishing at the inshore stations is more likely an explanation. The offshore sites (V2, W1, Y1) are much more difficult to reach in the small boats fishermen use, hence fishing effort is much lower there than at the inshore stations (see Chapter 6). This is an important result, because it suggests that scientific observers and Buen Hombre fishermen can detect similarity in fish community structure in the absence of excessive harvests. The sites V2, W1, and Y1 are obvious candidates sites for comparative studies between heavily exploited and underexploited fish communities and their supporting food webs. Specifically, it would be enlightening to compare the population size-structure and the abundance of large carnivorous fishes (groupers, snappers, and jacks) at three offshore stations with three inshore sites.

It is also interesting to note that the satellite change image shows more brightening (red squares) on the inshore reefs than on the offshore reefs (Figure 5.1). This suggests that the inshore stations are changing more rapidly and over a wider area than offshore stations due to damage associated with fishing practices. For instance, fishermen from Buen Hombre and elsewhere may cause anchor and net damage to the seagrasses and corals while fishing. This damage could could cause the change form dark to light visible in the change images, as seagrasses and corals die and become open sand bottom. More information is needed from the red areas on the change image about the fishing activities carried out there and the fish, invertebrate, and plant communities present at those sites.

Figure 5.6. A cluster dendrogram of the fish species recorded during diver observations at the stations where ethnographic data was independently recorded during the dive.

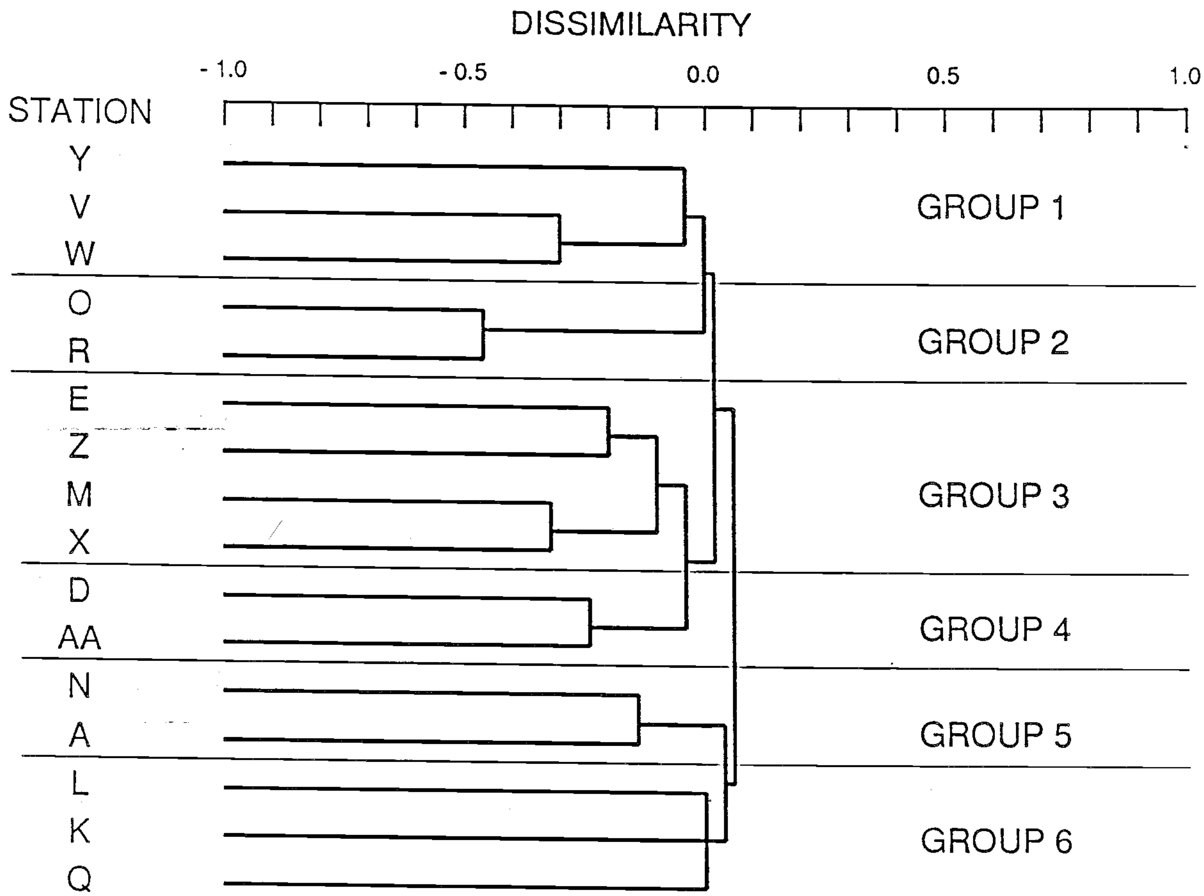
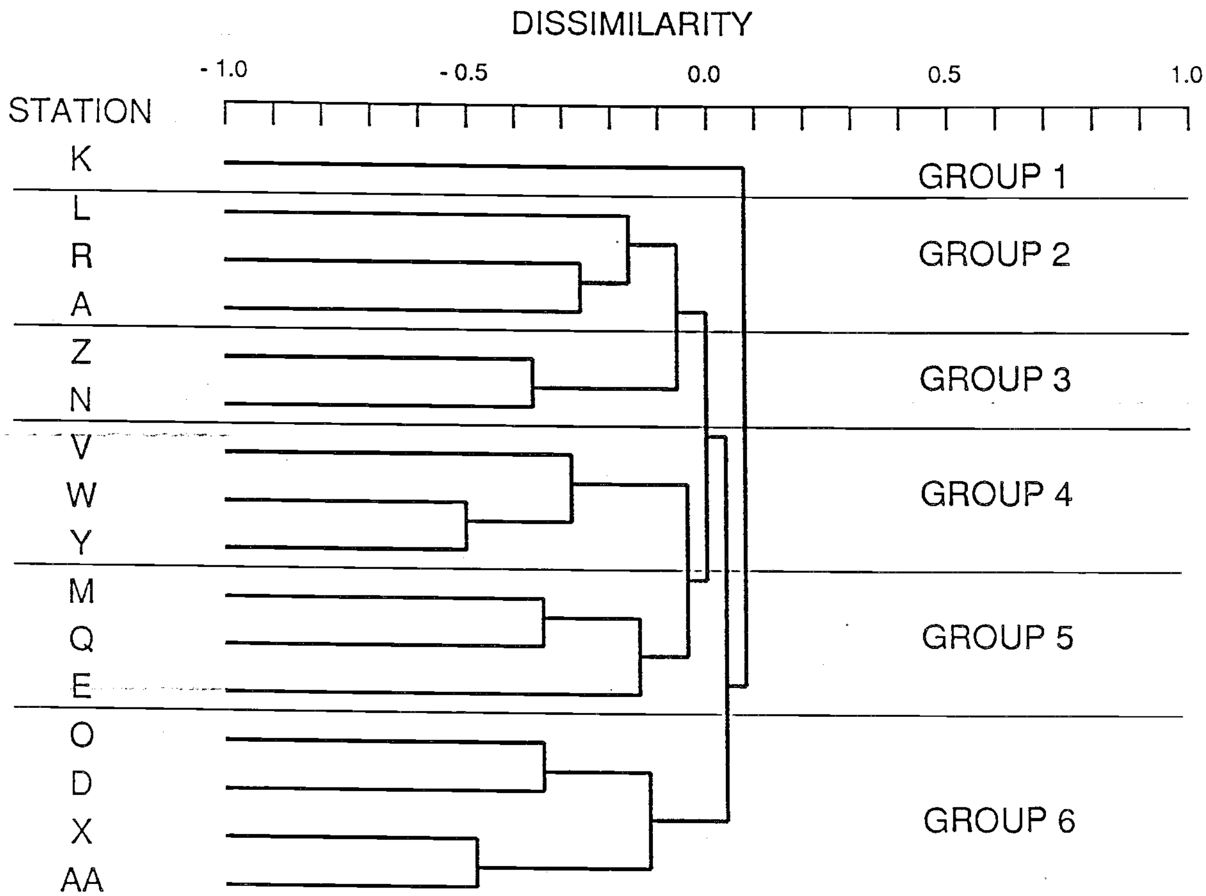


Figure 5.7. A cluster dendrogram of the fish and invertebrate species mentioned by Buen Hombre fishermen during ethnographic interviews at selected stations. Fish visual observations were recorded simulataneously (but independantly) at the same places.

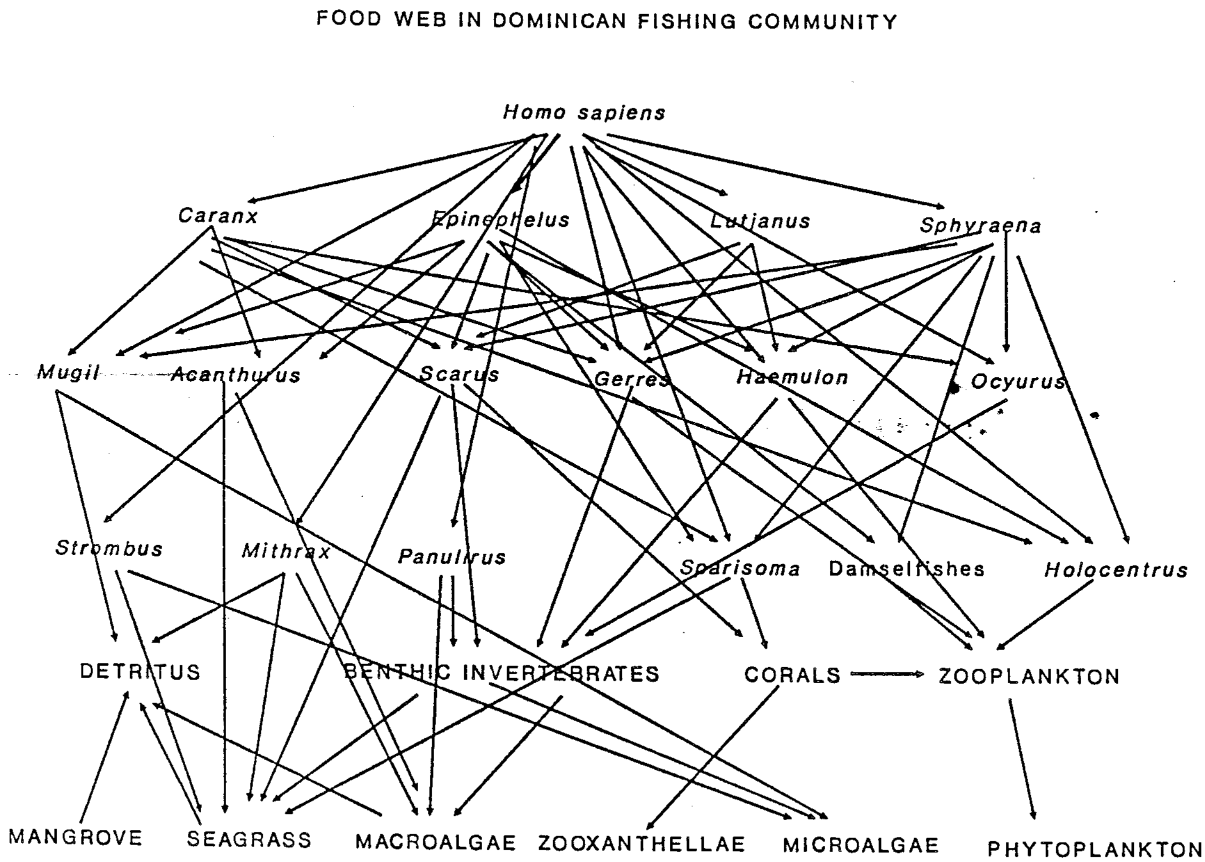


Observations on Fisheries

The coral reef, seagrass, and mangrove zones are connected via a complex food web upon which the population of Buen Hombre depends for seafood (see Figure 5.8 for generalized food web diagram obtained from the literature and knowledge of local fishing catches detailed in Chapters 6 and 7). The coral reef zone serves a nursery function for some fishes and is where most of the adult fishes are harvested by local fishermen. Seagrass and mangrove zones are also important as nursery areas for fishes and invertebrates due to their high primary productivity and structural complexity, but are used less frequently by the Buen Hombre fishermen as zones for harvesting fishes. For example, of 106 species of fishes in a field guide (Goodson, 1976), 66 were caught or observed by fishermen in coral reefs, 46 in seagrasses and algae, 13 in mangroves, 1 in the beach zone, and 3 *way offshore*. These fishermen recognized that some species occurred in more than one zone, but did not distinguish between seagrasses and macroalgae (both are considered *yerba del mar* or *grass of the sea*). Thus, the fishermen realize that all of these ecozones are interdependent.

The ultimate goal of this research is to model the various interactions in this food web with Buen Hombre residents at the top of the web. It is apparent that the food resources for Buen Hombre residents (carnivorous fishes and some herbivorous fish and invertebrates) are ultimately dependent upon primary producers (seagrasses, macroalgae, phytoplankton, mangrove detritus, and corals) at the base of the web. Detailed studies of each of these linakges will be needed to understand the effects of harvests by humans on this food web (top-down effects) and changes in the primary production induced by siltation and nutrient loading from terrestrial sources (bottom-up effects) on the structure and functioning of this food web. For example, increases in fishing pressure by humans may lead to declines in the carnivorous (groupers, *Epinepheleus*, snappers, *Lutjanus*, and jacks, *Caranx*) fishes upon which the heaviest fishing pressure is directed. These carnivores are the least numerous and have the smallest biomass due to their position near the top of the food web. Declines in the carnivore population may increase the population of smaller, herbivorous and omnivorous fishes and invertebrates and thus lead to declines in the producer biomass (due to increased herbivore pressure). In this case, Buen Hombre fishermen may increase their fishing pressure on food items that are lower in the web (parrotfishes, *Scarus* and *Sparisoma*, spider crabs, *Mithrax*, spiny lobsters, *Panulirus argus*, and queen conch, *Strombus*), which should be more numerous or have a greater biomass, theoretically. The large-scale destruction of upland forested areas for agriculture and development of human settlements may have a bottom-up effect on this food web, creating nutrient and sediment inputs that could alter the growth and survival of plants and corals. Such inputs may impact the primary producer base so that they could not support a large food web and consumer biomass above them. Currently, neither of these situations prevails, although increased fishing pressure has led to declines in some species (e.g. lobster and conch) according to local fishermen (see Chapter 6).

Figure 5.8. A simplified food web diagram derived from the ethnographic interviews (for linkages to *Homo sapiens*) and from known feeding relationships in the literature. Many more linkages likley to be present in the actual web.



Snappers (Family Lutjanidae) or the "Pargo" Species

Snappers are extremely diverse and abundant fishes on coral reef ecosystems throughout the world. They are important game and food fishes worldwide, and they are highly prized by Buen Hombre fishermen (See Chapter 7 for a listing of the many species of *pargo* taken by them). In the Caribbean, there are fifteen species of lutjanids (Robins et al. 1986). Adult stages are typically associated with the reefs proper, both in shallow and deeper water. The young stages are often found in mangrove and seagrass habitats. The maximum size of snappers often reaches 60-70 cm (24-28 inches), with fish weighing between 2.3 and 4.5 kg (5-10 pounds). They are primarily carnivores that take shrimp, crabs, and small fishes, mostly at night (Parrish, 1987). They do not exhibit sex changes like the groupers (see below), but typically females are among the largest members of the population. Sex-ratios in the population tend to be skewed towards females, especially at the largest sizes (Grimes, 1987). Because larvae of snappers, like most marine fishes, are carried great distances by currents, the populations near Buen Hombre may be derrived from spawning that happens elsewhere along the coast. No information is available on spawning locations for local populations of snappers. Elsewhere, snappers group-spawn during full or new moons at specific sites during the entire year, with reproductive peaks during the spring or fall (Grimes, 1987).

We observed four species of lutjanids in ESU's near Buen Hombre: schoolmaster (or pargo amarillo), *Lutjanus apodus*; mangrove or gray snapper (or pargo prieto), *L. griseus*; lane snapper (or pargo manchego), *L. synagris*; and yellowtail snapper (unknown Spanish name), *Ocyurus chrysurus*. The most common was the yellowtail snapper, which occurred at 7 ESU's (B1, D1, F1, H2, W1, AA5, and AB2). Two species occurred at 3 ESU's, the schoolmaster (V1, AA2, and AA5) and the gray snapper (D1, K2, and AB2). Only one lane snapper was observed, at station AA5. In general, the abundance of snappers in the study area was relatively low, as compared with other reefs elsewhere. The size of individuals and their abundance increased with distance from shore and water depth. The yellowtail snapper was fairly abundant where it was observed, but all individuals were small (approximately 10-15 cm in length). Gray snapper were not very abundant where they occurred and few large (20 cm and up) individuals were present. However, these fish are very good at hiding from divers so may be under-represented in the visual survey. On one occasion, one of the Buen Hombre fishermen reported to me that there was a very large school of gray snappers at station R1. Lane snapper and schoolmaster were rare where they occurred. In summary, there appears to be depressed population sizes of snappers, with small-to-medium size fish being harvested, and abundant populations occurring only at the deeper and farther offshore reefs.

The small size of individuals in the lutjanid populations near Buen Hombre is probably due to overfishing the adults, although such a conclusion rests entirely on a non-quantitative assessment of population size, size-structure and demographic trends. For example, the fishermen of Buen Hombre state that they prefer to spear the largest sizes of fishes while hunting them on the reefs (see Chapter 6, pages 65, 71). Such size-selective fishing pressure may have important consequences for the continued harvesting of snappers, because the largest sizes are often females and they may be harvested before they reach sexual maturity (Grimes, 1987). For example, the gray snapper reaches maturity at 24.5 cm (10 inches) for males and 32.5 cm (13 inches) for females (Grimes, 1987) and many of the individuals that were observed by us or taken by the fishermen were smaller than this. The maximum size for this species is 52.5 cm (21 inches), so that most of the fish are being taken before maximum size is reached as well. I photographed a typical-sized snapper being harvested by the Buen Hombre fishermen (Figure 5.9). This schoolmaster, *Lutjanus apodus*, was 21.5 cm (9 inches) Fork Length (FL); the size at sexual maturity for schoolmasters is 25.0 cm (10 inches) for both males and females and maximum size is 57.0 cm (23 inches) (Grimes 1987). In future studies, an effort should be made to document the sizes of fish taken by Buen Hombre fishermen with spears, as well as the sizes taken by the compressor fishermen and the chinchorros fishermen, to arrive at a size-specific fishing mortality estimates for the populations of snappers.

It is quite possible that intensive spearfishing has removed the reproductive portion of the population and continued fishing pressure has led to harvests of fishes below the size of sexual maturity. Such selectivity for the largest sizes of snappers can significantly impact the fishery and future year's catches may drop. In other studies, exploited areas have shown significant decreases in fish size compared to unexploited preserve populations; one species, *Petrus rupestris* (Family Sparidae), was 87% larger in the unexploited area (Buxton 1989). The ultimate result of the *taking-the-largest-fish-first* strategy is a collapse of the fishery or the ability of the fishermen to harvest only small individuals that never reproduce, as may have happened in reef systems near Haiti (Brass, Unpublished). The new recruits to the local fish populations must then come from ajacent coastal regions (i.e. the local population is no longer self-recruiting). Currently, it is not known if reproduction from local stocks around Buen Hombre are self-recruiting. Snapper populations elsewhere may be producing young that are carried by currents or migrate into the Buen Hombre area. Possibly, the population of snappers in Buen Hombre maybe reproducing at a smaller size of maturity (size at maturity varies somewhat according to geographic area; the data above was reported for Jamaica). A further possiblity is that an adult spawning population exists in the Buen Hombre area that is active nocturnally and thus was not observed during our visual survey, which was conducted during daylight hours only. A much more thorough study of snapper populations in the area is required before conclusions regarding the future of the fishery can be made.

Figure 5.9. A typical sized snapper, in this case a schoolmaster, *Lutjanus apodus*, taken by a Buen Hombre fisherman with a speargun at station V2. This fish is 21.5 cm Fork Length (FL); the dive slate is 29.5 cm. Schoolmaster reach sexual maturity at 25.0 cm and maximum size of 57.0 cm.

Groupers (Family Serranidae)

The groupers (or sea basses) are a very diverse and abundant group of fishes that occur around reefs worldwide; there are 22 species of groupers in the Caribbean. They are heavily harvested for food and recreation where they occur. An interesting phenomenon that has implications for management of grouper fisheries is the dominance of sex-reversal in most populations studied: groupers are typically protogynous hermaphrodites, meaning that an individual begins life as a female and then switches to become an male at a larger size (Shapiro, 1987). Such sex-reversals make populations of groupers different with regard to their management under harvest, because size-selective harvests may severely alter the sex ratio of the population. In the only study of selectivity of fishing techniques, Shapiro et al. found that there was no selectivity for particular sizes or sexes of red hind (or cabrilla), *Epinephelus guttatus*, taken by handline fishermen in spawning aggregations near Puerto Rico (cited in Shapiro, 1987). Like snappers (Lutjanidae) adult serranids are associated with reefs proper, and the juvenile stages can be found in seagrass beds or on reefs as well. Normally, they are solitary ambush predators found near reefs, wrecks, and any type of bottom relief. They prey predominantly on fishes smaller than themselves, but are also known to take shrimp, lobsters, and crabs (Parrish, 1987). Small-group (2-3 fish) and large group (thousands of fish) spawning aggregations at certain locations with spawning peaks occurring during full moons from January-March, depending on location and species involved (Munro et al, 1973; Shapiro, 1987; Colin et al. 1987). Certain species of groupers may reach a maximum size of 163 cm (5.4 feet) in length, weigh 263 kg (580 pounds), and live as long as 20 years or more (Robins et al., 1986; Manooch, 1987).

We observed three species of epinepheline groupers in the study area: the coney (Spanish name unknown) *Epinephelus fulvus*; the red hind (cabrilla), *Epinephelus guttatus*; and the Nassau grouper (mero), *Epinephelus striatus*. The Nassau grouper occurred most frequently in our samples at 5 ESU's (D1, J2, M4, Q1, and X3). It was fairly abundant at some stations, but rare at ESU's M4 and J2. The coney occurred at 4 ESU's (V1, W1, X3, and AA5). These groupers were common at the offshore (second reef) stations and were particularly abundant at station W1. I did not see any fishermen take this species, however. Red hind occurred only at ESU's M4 and O1 and were not abundant at either station.

Although most of the grouper observed in our survey were small (< 25 - 30 cm, 10 - 12 inches) individuals, the effects of harvest selectivity by the Buen Hombre fishermen cannot be adequately assessed without size-specific data from catch records, which are not currently available. The sizes of groupers in our visual surveys were much smaller than the size at maturity and maximum size for the species. For example, red hind reach sexual maturity as females at around 25 cm (10 inches), then change into males, reaching a maximum size of 48 cm (19 inches) (Shapiro, 1987). Nassau grouper reach sexual maturity as females at around 48 cm (19 inches) and change into males before reaching a maximum size of 64 cm (26 inches) (Shapiro, 1987). Little is known about the coney's reproductive biology (Shapiro, 1987). Spawning locations for local grouper populations are not currently known. If the populatuions are similar to Puerto Rican populations, then they spawn just prior to sunset during full moons in January and February on coral reefs in 20-30 m deep water (Colin et al., 1987). Colin et al. (1987) speculated that the larvae of red hind spawning in southwestern Puerto Rico may travel as far as Hispaniola, as well as Cuba, Jamaica, the Turks and Caicos, and the southeastern Bahamas. Thus, populations of red hind may be dependant for brood stock from as far away as Puerto Rico, and effects of harvesting on the population off Buen Hombre may reach far downstream to Haiti, Cuba, and the Bahamas, if spawning is occurring around Buen Hombre. No data suggests that there are active spawning stocks in the Dominican region, but perhaps this is because no one has looked for it. Clearly, more work is needed on the populations of groupers in the study area with respect to reproductive biology and size-selective harvests by fishermen.

Management of the Grouper and Snapper Fisheries

The future of the fishery for groupers and snappers is uncertain unless steps are taken to reduce fishing effort and overharvesting. For example, in Puerto Rico, a multispecies grouper trap fishery has showed declining total catch and catch-per-unit-effort with increases in effort (number of trap-days/year) (Bannerot et al., 1987). Such a situation is likely to occur along the Dominican coast near Buen Hombre if fishing effort is not restricted. Intervention may be required in the form of a limited-entry or privatization of the grouper and snapper fishery and other marine resources. Buen Hombre fishermen may be required to limit their fishing effort on certain species of groupers, particularly the Nassau grouper (mero) and red hind (cabrilla). This limit to effort must be applied to all fishermen equally, including outsiders (Monti Cristi chinchorros fishermen, compressor fishermen). Enforcement is likely to be a problem with outsiders in particular. However, Buen Hombre fishermen perceive *boundaries* to their fishing territory, so there appears to be a tendancy to privatize the fishery already from within the local culture.

Fishing areas should be established to allow harvests of fishes under a system of limited-entry. By limited entry, I mean that fishing permits would be required and only persons with an historical presence in the fishery would get permits. The permits could regulate the type of gear that would be allowed in the fishery. The permits could be bought and sold on a open market, or passed down from father to son (parent to child?). A lottery system could be used to allocate permits if data fishing effort suggests that there are already too many fishermen. Limits might be established on the size of fishes that can be harvested. For example, a *slot* limit might be established, so that small fishes and large fishes (i.e. fish larger than the size at maturity that are potential spawners) are protected. Further study would be required to determine if such a system of limited-entry would be enforceable and acceptable to local fishermen. It should be noted that no fishermen would be prevented from fishing, except in protected zones and in the case of a lottery, which would only apply under unusually high fishing effort.

Conclusions

Although the reef and its lagoon complex near Buen Hombre appears to be in good overall condition and relatively undisturbed by human influences, there are some indications of ecosystem change that may suggest a general decline in environmental conditions. There appears to be low abundances of some fishes (i.e., snappers and groupers), few remaining lobsters and conch, and anchor and net damage to the reefs from fishing practices. There also is some evidence of coral bleaching. Extensive natural storm disturbance (toppled coral colonies and seagrass *blowout* areas) has occurred in many areas. Such natural disturbances may occur with great regularity on relatively pristine reefs (Grigg and Dollar, 1990), and will be difficult to distinguish from anthropogenic impacts on the reefs. Satellite change images between 1985 and 1989 (Figure 5.1) indicate specific areas on the reef and in the seagrass meadows have increased their reflectivity. We did not possess the change imagery when we sea-truthed the original natural color image. Thus, we would like to return and examine the areas that increased their bottom reflectivity. The causes of these changes in reflectivity are not currently understood, but appear to be related to human disturbance from fishing practices and ecotourism. Further intensive study of the areas highlighted in the change image is strongly suggested, as these areas show the potential for increasing in size.

Satellite imagery (Figure 5.1) will be useful for monitoring long-term (10-20 year periods) changes in the distribution and areal coverage of the corals, seagrasses, macroalgae, and mangroves. One type of change that can be monitored by satellite is coral bleaching, which occurs when symbiotic zooxanthellae, (a type of algae that produces energy via photosynthesis for the coral) are expelled from the coral polyps (Roberts, 1990; Goenaga and Canals, 1990; Glynn, 1991). When this occurs, the coral colony loses its natural color due to photosynthetic pigments of the zooxanthellae (yellow, red, orange, etc.) and becomes pale or white in appearance. If the coral bleaching occurs over a widespread area, such changes may be visible in satellite images. Although little coral bleaching was observed in this survey, the incidence of bleaching could increase if environmental stress increases in the Buen Hombre coastal region. Similarly, seagrasses, mangroves and macroalgae, which are visible in the Landsat scene of Buen Hombre and vicinity, may be removed or killed by human activities. Changes in the areal coverage of seagrasses, macroalgae, and mangroves may be indicative of large-scale changes in the marine food web on which local populations depend. One of the major benefits of monitoring the coastal ecosystem with satellite imagery will be the ability to detect changes in the physical structure of the ecosystem that occurred over the past two decades and may be continuing.

The marine ecosystem of the North Coast of the Dominican Republic is very complex. Stations that are in close proximity spatially may have very different bottom types and thus different producer bases. However, clear patterns of association of bottom communities (coral reef, seagrass meadows, mangrove, macroalgae, etc.) are apparent among stations that are spatially separate, and these can be described and grouped (Figure 5.5). Thus, remote sensing of the changes in the producer base areal coverage is possible, though will be difficult. Bottom types may be difficult to distinguish at the currently available

LANDSAT satellite wavelength and pixel resolution constraints. Future research may be directed at locating the edges of major bottom types (seagrass, mangrove, coral reef, algae complex, sediment) with a pixel resolution of 5 X 5 m, as is available on other platforms (e.g., SPOT), because changes in bottom type seem to occur at that level of resolution.

Recommendations

In the future, the effects of various fishery management plans mentioned above need to be considered in light of food web linkages (Figure 5.8) and changes to the producer base that are observable from space. Areas of sea-bottom with increasing reflectivity should be closely monitored, annually or more frequently, if possible, to detect increases in the size of regions of significant change. It is recommended that the Sand Key area be made into a protected marine park for all to enjoy and boat visitation be limited and monitored. We recommend that additional large *marine reserves* along the North Coast of the Dominican Republic be placed completely off-limits to fishing to protect spawning stocks of important fishery species (i.e., areas surrounding known grouper and snapper spawning habitats). Marine reserves have been increasingly used to protect marine resources worldwide and the Great Barrier Reef Marine National Park in Australia should be used as an example of a multiple-use reserve (Craik, et al., 1990). This approach has been successful in other areas (off South Africa, Buxton 1989; off Belize, J. Carter, Personal Communication). We recommend that biological studies be conducted on grouper and snapper population abundance, size-structure, migrations (using modern tagging methods), and reproduction. Such studies should be done in nearby exploited areas as well as in reserves to see if differences in these parameters become apparent under such a management scheme. The entire coastal zone region out to at least the third reef needs to be considered as a single ecosystem for management purposes.

CHAPTER SIX

ETHNOGRAPHY OF FISHING IN BUEN HOMBRE

Richard W. Stoffle, Andrew Williams, Brent Stoffle, and David Halmo

This chapter presents ethnographic data on the human ecology of fishing in Buen Hombre. General ethnographic interviews were conducted to better understand relationships between marine ecology, community economy, and patterns of fishing. Data discussed in the chapter are drawn in part from research initiated in 1985 (Stoffle 1986; Stoffle et al. 1990; Stoffle, Halmo and Stoffle 1991). Data generated from these previous studies contribute baseline information from which new iterations of questions were tailored for the CIESIN/NASA pilot project. The general ethnographic interviews, conducted in January and February 1991 enhanced the quality of earlier data, thereby extending the long-term ethnographic research program in the community of Buen Hombre. These longitudinal data provide a comprehensive view of fishing as an economic activity.

Ethnographic research was combined with the analysis and interpretation of TM satellite imagery (see Chapter Two). While satellite imagery can provide timely and accurate information on spatial and environmental parameters of a study area, ethnography serves to add the rich detail concerning local perceptions, practices, and values concerning these parameters. That is, ethnography verifies and validates the spatial and environmental information contained in the satellite image. The TM imagery also allows local people, who have limited if any access to photographs and maps of their communities, to see first hand their lands and resources in enlarged photo form. Using the TM image as a reference, local people are able to point out sites of significant social and economic activities. Ethnographic interviews with local people generate data about the cultural meanings and patterns of use associated with these sites. Through this interactive procedure, satellite imagery and ethnography are combined to produce a unique study of the human ecology of fishing.

This chapter has five sections. The first is about the methods used to collect the data and the national and local consultation that made the research possible and hopefully will make the findings useful to people in the Dominican Republic. The second section is a description of what fishing is like in Buen Hombre. The third section is about local factors that influence patterns of fishing in Buen Hombre. The fourth section is about the external factors that influence how Buen Hombre fishermen fish. The fifth section discusses the uses of satellite imagery for studying the impact of fishing and other changes in the coral reef and marine coastal ecosystems.

Methods

As used in this study, the term ethnography refers to the standard fieldwork methods of anthropologists. One aspect of our ethnographic research involved participant observation--that is, immersing oneself into the daily activities of the local people and recording both what the ethnographer observes and the interpretations of local people about what they are doing. Data were also collected through formal interviews. These occurred as part of surveys administered to a stratified random sample of the local population and to key experts who know about some aspect of local culture. Focus group discussions were conducted with members of community organizations to collect new information and to check past interpretations. Interviews were conducted with government officials having national responsibilities for studying and administering the Dominican Republic fishery and associated natural resources. Documents were available for describing community and national patterns of fishing.

Permission To Conduct Research

The research was conducted with the permission of government officials of the Dominican Republic. They reviewed the initial proposal which was submitted to CIESIN/NASA and were consulted in person in February of 1991. During this consultation the project was described in detail and copies of past materials were left with Lic. Ivonne Garcia, Sub-Secretaria de Recursos Naturales, Secretaria de Estado de Agricultura; Narciso Almonte C., Director de Recursos Pesqueros; and Jose Martinez, Director of DIRENA, Departamento Inventario De Recursos Naturales. These consultations recognize the national sovereignty of the Dominican Republic and responsibilities of individual officials to be aware of and responsive to research on topics within their authority. The consultations were to draw upon the expertise of knowledgable local officals and to focus the research so it produces knowledge that has practical application in resource policy decisions.

Consultation with other persons from national groups occurred during the fieldwork. The study team was visited by Rafael Castillo who is a technician in Estadistica y Limite Geografico in the Instituto Cartografico Militar; Lic. Venecia Alvarez, who is Director of Centro de Investigacion de Biologia Marina (CIBIMA); Dr. Carlos Cano Corcuera, a biology specialist in the Agencia de Cooperacion Espanola; and Dr. Jose Serulle Ramia who is the president of Fundacion Ciencia y Arte, Inc. Accompanying these people during the field visit was Ivonne Garcia and Jose Martinez. This in-field consultation involved a trip to the mangrove and coral reef system, a presentation of satellite images and demonstration of the Global Positioning Device, and a review of ethnographic findings. Satellite images were provided to the Department of Agriculture, Department of Fisheries, and the Department of Natural Resources. These officials also met formally with members of the Buen Hombre fishermen's association.

Senor Tomas Montilla is a staff person from the Department of Natural Resources who worked with the CIESIN/NASA study team. The Department of Natural Resources provided black and white aerial photographs of the study area and maps for geocorrecting the TM satellite images. He participated in the agricultural interviews and provided insights through participant observation. At the end of the field session he wrote a summary of his research and observations which was submitted with the Department of Natural Resources and the study team (Montilla 1991).

The people of Buen Hombre were given the right to learn about the study and accept or reject it. Group meetings, locally called *reunions*, were held in Februrary 1991 with members of the Buen Hombre agricultural association, fishermen's association, and women's association. Each group was shown satellite images, told about the proposed research procedures, and made aware of possible study outcomes. All groups took a voice vote which affirmed their interest in and support for the study. When local community members were selected for formal survey interviews, they were orally informed of the study's purpose, assured informant confidentiality, and asked if they wanted to proceed. The interview only proceeded after oral permission was received from the respondent.

The CIESIN/NASA study team agreed to provide copies of the report to the Dominican Republics' Departments of Agriculture, Fisheries, and Natural Resources. Copies of the report are to be provided to the Buen Hombre associations for fishermen, farmers, and women. The study team also agreed to provide geocorrected satellite images to each of the government departments and to the fishermen's association.

The General Fishing Study

Much of this chapter is based upon interviews with expert senior fishermen. The purpose of these interviews was to address general questions about patterns of fishing, the forces that cause changes in these patterns, and the impacts of these patterns on the marine ecosystem. The instrument was developed in the fall of 1990, based on previous studies. The instrument was pretested in February of 1991 during the consultation visit with the Dominican government officials.

General fishing interviews were conducted with six fishermen. Past research indicated that these fishermen were recognized experts who could speak with authority about many aspects of fishing. The fishermen were interviewed separately with the formal general fishing instrument that was pretested in February. They also were interviewed as a group using a 1:50,000 satellite image of the coastal area.

The key expert senior fishermen were chosen as respondents based on standard criteria for selecting key informants most recently described by van Willigen and DeWalt (1985). That is, each of the expert senior fishermen was (1) thoroughly enculturated in terms of having long experience in a culture, (2) each was currently involved with the aspect of culture being studied, and (3) due to the long-term cooperative research relationship with ethnographers, it was assumed that they would be capable of conveying an understanding of the culture without bias or selectivity (van Willigen and DeWalt 1985:69).

The number of fishermen interviewed and the procedure by which they were selected were interpreted as more than sufficient based upon the work of Romney et al. (1986), who suggest a model for predicting the minimal number of informants needed to describe a relatively homogeneous cultural domain. They found three critical factors: (1) the cultural competence of the informants, (2) the required confidence level of the study, and (3) the proportion of questions to be classified correctly. Based on these criteria, a sample of four highly competent (at the 90% level) informants could provide correct answers 85% of the time at a 99% confidence level. The Romney et al. model was grounded using a dimensional sample of Lake Michigan sport fishermen and found to be accurate (Stoffle, Jensen, Rasch 1987). These studies argue for the validity of our study sample because it contains six highly competent individuals, two more than would have been required. The homogeneity of the cultural domain under analysis is attested to by the commonality of fishermen responses to our questions.

Formal reunions were held with the membership of the fisherman's association and officials from the Dominican government's Department of Natural Resources on February 21 and 24, 1991. Less formal group discussions, termed here focus group interviews (Morgan 1988), were also conducted. The focus group discussions with senior fishermen occurred on February 28, 1991 and March 3, 1991.

Ethnographic interviews and focus group discussions included questions on the values associated with being a fishermen, the productive careers and developmental cycle of fishermen, the role of the fisherman's association in establishing market prices, providing fishing equipment and other services, the types of fishing equipment used by local and other fishermen, and the economic and ecological constraints and incentives on fishing as an economic activity.

The ethnographic interviews elicited data regarding local knowledge of the marine environment and its resources by the people of Buen Hombre. In addition, the interviews and focus group discussions generated data on the impacts of ecological factors such as climatic seasonality, and human factors, including the use of various fishing technologies, on the biological condition of the marine system, patterns of fishing, and the health and well-being of the local fishermen and their families.

The verbatim responses of the fishermen are presented in the following text. This style of data presentation was chosen because these fishermen represent all fishermen. So the responses represent the extent to which issues being discussed are homogeneous.

Fishing in Buen Hombre

This section of the chapter discusses general patterns of fishing in Buen Hombre. The section provides a general overview of what it means to be fishermen in Buen Hombre. The discussion begins with a series of questions on the culture and social organization of fishing, with special emphasis on the rights and obligations associated with belonging the the fishermen's association and the developmental cycle of fisherman careers. Methods and technology used in fishing are then discussed. Patterns of fishing are discussed, with special emphasis on the amount of time invested in fishing and the targeting of marine species.

A wide variety of typical reef fish species are harvested by Buen Hombre fishermen. Large groupers and red snappers are first class fish high in market demand. Coral-eating parrotfish of several sizes and varieties are either sold or consumed in the household. The size and variety of parrotfish determines whether it is classified as first or second class. Delicacies such as octopus are also captured. Larger shellfish such as *lambi* (conch), lobster, and *bulgao* are captured by spearfishermen diving inside the inner reef. Third class fish species are kept primarily as subsistence fish. They bring the lowest price in the market, if and when they are sold. Occasionally, barracudas and sharks are taken. Shark is captured for sale and barracuda is generally kept for home consumption. A more detailed discussion of the marine system was presented in Chapter 5.

Culture and Social Organization of Fishing

Fishermen in Buen Hombre rarely fish alone, preferring instead to go to the sea each day with a team of fellow fishermen, called a fishing crew. Together there is strength and security, a sharing of personal equipment and the costs of renting equipment like boats and motors that are not owned by most fishermen. Fishing in groups also reduces the risk of returning with a catch too small for family subsistence because the crew can be relied upon to share when needed. Fishing in groups results in social leveling, because it assures that no fisherman will become wealthier than another.

The fishing crew is the primary unit of production, but the fishermens' association is the primary marketing unit. Fishermen have organized themselves into a voluntary fishermen's association to increase the market price of their catch and reduce spoilage. The fisherman's association is composed of men who have risen through the ranks of the developmental cycle of fishing, which involves four distinct stages: (1) apprentice, (2) journeyman, (3) craftsman, and (4) beached (Stoffle 1986:95-100). The questions in this section focus on moving through this developmental cycle and belonging to the association.

The expert fishermen were asked, "Why did you choose to become a fisherman?" Their individual responses are listed below:

Simon: Father liked fishing, went out with him and liked it.

Dionicio: I chose to become a fisherman because fishing is a good way to earn money and maintain family.

Narciso: From the time I was little I wanted to be one. I was born with a feel. Moreover, after awhile I developed a good knowledge. It is like a thing of work in another country to manage the fishery well.

Bacilio: One of the best ways to make money in the community is by fishing. It is a better way than being only an agriculturalist.

Eugenio: I always wanted to be a fisherman. My father taught me how to fish.

Tuba: My father taught me to be a fisherman as a way of life.

It is clear from the responses that the occupation of fishing is valued positively as a way of making a living. The response of Bacilio illustrates also the advantage of being involved in more than one occupation to spread risk. This is the system known as "occupational multiplicity" (Comitas 1973). The local adaptive strategy of engaging in multiple occupations (fishing and farming), based on mixed production of diverse commodities (varieties of seafood and crops), serves to reduce the risk of economic failure. Perhaps an under-recognized adaptive function of occupational multiplicity is that such a system potentially serves to reduce the risk of environmental degradation in terms of overuse of terrestrial and marine ecozone components of coastal ecosystems.

As the responses above indicate, males are oriented and trained to be fishermen early on, in a context of parent to offspring transmission of knowledge and skill. Prior to becoming formally integrated into the structure of fishing life--that is, moving up in the hierarchy of fisherman classifications, the novice is expected to demonstrate certain levels of knowledge and skill (Stoffle 1986:95-96). Fishermen were asked, "How many years should a man have in order to begin fishing with a crew?"

Simon: 11 years of age.

Dionicio: They usually begin at 14 years.

Narciso: Actually, boys that are 11 or 12 years old.

Bacilio: 14 or15 years.

Eugenio: 11 to 12 years.

Tuba: 10 or 11 years.

Responses to this question indicate that there is a good deal of experential learning required before one is formally identified as a *fisherman*. Apprentice fishermen typically are fairly young boys and generally are not members of the fisherman's association. Entrance into the association normally occurs when novice fishermen have achieved the status of journeyman.

Once a member of the association, fishermen become members of a corporate group that provides services and access to resources. In turn, fishermen take on social obligations and responsibilities for educating new members, maintaining the fishing equipment (boats, motors), looking out for the safety and welfare of others while fishing, and promoting the unity and law-abiding informal rules of proper fisherman behavior. Senior fishermen were asked a series of questions about the role of the fisherman's association in fishermens' lives.

Each of the expert fishermen were asked, "For you, what is the importance of the Fisherman's association?"

Simon: The association is good, we can work together if we are organized.

Dionicio: First, in unity there is strength. Second, alone a human cannot do much. Together we are looking for a project that will help us find fishing equipment--boats, motors, and cages.

Narciso: The importance of the association is that here it is like a school. We teach fishermen to protect environment, and teach the laws of fishing and natural resources, also agriculture. It is easier to obtain help.

Bacilio: The association provides access to resources and equipment for all different types of fishing.

Eugenio: The association promotes unity. We have more strength when unified.

Tuba: The importance of the association is that we always work together, we are a group of fishermen who are united, and promote the protection of the fauna marina (marine animals). We don't cut coral, and we protect the turtle.

Fishermen were next asked, "What are the obligations of membership in the association?"

Simon: To follow rules of association.

Dionicio: To carry out and fulfill the duties of the association that are required by the laws of the association. These include maintaining the equipment and obtaining fair credit.

Narciso: To maintain the order of law, keep up equipment. To report exploitation of the mangrove and the activities of other fishermen that are prohibited here. Also we have an obligation to teach other fishermen members of the association and share resources with *socios* (partners).

Bacilio: To sign things out and take care of equipment, and when get back from fishing we have to sell fish to the association. We do this to pay for the usage of the boats and motors.

Eugenio: We have the responsibility to take care of equipment and look out for one another.

Tuba: The obligations are to try to attend meetings.

Fishermen were then asked, "What types of services does the fisherman's association provide?"

Simon: The association buys fish.

Dionicio: The association provides education primarily, information, and a source of work.

Narciso: Often we do not have the money to do this. When we do not have money to buy sufficient equipment, we sell our fish to the association and association buys equipment.

Bacilio: The president of the association has the obligation to go and look at the price of fish. Also we can sell fish, and get ice from Juanito who works at the place where the fish is weighed.

Eugenio: Helps the progress in future equipment. Get loans if have no money.

Tuba: Provide meetings, reports to government.

Knowing the market prices for certain types and classes of fish is important to association members. Senior fishermen were asked, "Does the fisherman's association announce the price of fish each day?"

Simon: More or less.

Dionicio: Yes, I look at the price before leaving to fish.

Bacilio: Yes.

Narciso: Yes. There is a price announced for food. We announce this lower price that doesn't occur on the coast for fish. There is a higher price for food. With the buyers, *patrones*, they maintain a price. Now we seek to fish more to get a part of the seafood market.

Eugenio: (Did not use question)

Tuba: Yes, every day they announce the price, but it does not matter for us because we do not have any control over the price. No one really cares about the price because this is the only way to make money so we just go out and fish.

Membership in the association has both social and economic advantages. Expert fishermen were asked, "If you were not a member of the association, would the manner in which you fish change?"

Simon: Yes, I would have to sell to intermediaries.

Dionicio: Yes, I would then have to sell fish to intermediaries.

Narciso: I have always been a member of the association, through which I have access to equipment. It is beneficial.

Bacilio: Yes, the association here gives us access to equipment. We also earn more money because we work in the association.

Eugenio: Yes, I would have more responsibility, sell at higher price.

Tuba: No, but being a member of the association is much better.

As fishermen move through the hierarchical stages of their fishing careers, they tend to become more influential in the association. Individuals can aspire to the presidency (Narciso is current president) or secretary (Dionicio is current secretary) of the association. Eventually, fishermen pass into the stage of their careers known as *beached association member*. While occasionally able to fish, they do not venture out as often, but instead impart their wisdom, gained from many years of experience, to younger fishermen. In order to understand the productive life cycle of fishermen, senior experts were asked, "For how many years can a man fish?"

Simon: Approximately 50 years.

Dionicio: With a speargun, up to 45 years of age.

Narciso: A man can fish more than 40 years. I have 42 and still I feel good. I can still go 60 to 70 feet down.

Bacilio: Almost 50 years.

Eugenio: About 45 years.

Tuba: 50 years.

All of the senior fishermen were in agreement that the productive life of a fisherman lasts until the individual is between 40 and 50 years of age. Fishing over this time is a physically taxing and potentially harmful occupation. Ear problems are common among fishermen who spend many years and long hours making repeated deep dives in order to catch fish. As lung capacity decreases (many fishermen also smoke), the amount of time they can remain submerged also decreases. These conditions are indicated in the fishermens' responses to the question, "Does the method of fishing change for fishermen as they grow older?

Simon: A little--they cannot go as deep.

Dionicio: As fishermen get older, they lose physical equilibrium, get colder, and have problems with their ears. They cannot go as deep, and cannot hold their breath as long.

Narciso: When one starts, he can fish more but has to build a capacity and gain experience. One can go down as far as 105 feet, but I can no longer do it. After 45, he starts to lose strength in his lungs.

Bacilio: They do not catch as much, often older folks will row boats while others fish for them. They cannot dive as much or as deep. I can go down 60-70 feet at 40 years of age, Eugenio can go 30-40 feet.

Eugenio: Yes, one loses his capacity to dive very deep.

Tuba: Yes, we have less strength as we get older.

Methods of Fishing

Buen Hombre fishermen use a variety of methods for catching fish. The most common method is the use of snorkel and speargun for diving in the coral reef ecozone. This method involves the ability to remain submerged for substantial periods of time in order to locate, stalk, wait for and shoot one's target. Accuracy is crucial because spears must be retrieved and refastened to the gun should a fisherman miss his target.

A 1989 inventory of fishing equipment illustrates that the 34 fisherman's association members employ multiple methods in fishing. Forty-one percent of association members use handlines (*cordeles*), which are used mainly during night fishing. Fifty percent use snorkeling gear and spearguns. Thirty-five percent of association members own and deploy *nasas*, or fish traps in deeper waters. Access to and use of traditional yolas and motors is controlled by 26% of association members, but it must be remembered that fishing crew members cooperate in boat travel to fishing locations. Twelve percent of association members use *atarrayas* or beach cast nets. Only two association fishermen use boat nets (*trasmallos*); no fishermen use beach set nets (*chinchorros*) as a fishing strategy. Night fishermen also use flashlights and makeshift lamps. These are submerged into the sea in order to attract fish. Social relationships, both kin and non-kin based, facilitate sharing or loaning of equipment among and between fishermen.

The CIESIN project team asked senior fishermen a series of questions regarding the cost of using association equipment and how personal fishing gear is obtained. Fishermen were asked, "How much does it cost to rent a boat for a day?

Simon: 20-25% of fish.

Dionicio: It costs 25-30% of catch.

Narciso: It costs 25% of catch for equipment.

Bacilio: 25%.

Eugenio: 25--30%.

Tuba: (Did not use question)

Fishermen were then asked, "How much does it cost to rent a motor for a boat?"

Simon: 20%.

Dionicio: 25-30% of catch.

Narciso: 25% of fish.

Bacilio: 25%.

Eugenio: 25--30%.

Tuba: (Did not use question)

From the foregoing responses, it can be surmised that boat and motor rental can cost a fisherman and his crew over one-half (between 50-60%) of his catch. If rental fees for snorkeling gear and spearguns are added, the total cost of equipment rental could total as high as three-quarters of an individual's catch.

Most association fishermen have their own diving and fishing equipment. Senior fishermen were asked how they obtained that equipment. "How did you obtain your fishing equipment?"

Simon: I worked for and bought it.

Dionicio: I have no equipment. I rent boat and motor only. I use the equipment that belongs to the owner of the boat.

Narciso: My speargun was a gift from a man from Santiago. A *rifle* (local term for a speargun) cost about $1,000 pesos. *Chapaletas* (swimfins) cost $600 pesos.

Bacilio: I bought it.

Eugenio: I got it in Santo Domingo.

Tuba: (Did not use question)

Fishermen were asked, "Are you able to fish without a spear gun?"

Simon: Yes, with a *gancho* (hook), *cordel* (line), and net.

Dionicio: Yes, you can fish for octopus, lobster, conch, and *bulgao* with a hook (*gancho*) and spear (harpoon).

Narciso: Yes, I can fish without a speargun by fishing another way. I mostly fish at night with line. If I don't have the equipment to snorkel fish, I fish at night with a line.

Bacilio: No.

Eugenio: I likes to use the *rifle*, but I can fish with hand line.

Tuba: I can fish with *cordel*, *nasa*, and a *gancho* (line, trap and hook) but very seldom.

The responses indicate that, while the speargun is the most preferred method of fishing, there are other methods and technology available to and used by fishermen.

Fishermen were asked, "What is the worst problem with fishing equipment?"

Simon:	The lack of motors and boats.
Dionicio:	Lack of motors and boats.
Narciso:	The biggest problem is that we don't have the money to buy or rent equipment.
Bacilio:	The lack of good equipment, and the need to constantly repair and fix it.
Eugenio:	Lack of motors and equipment.
Tuba:	We don't have motors or sufficient boats.

Schedule of Fishing

Fishing occurs three times a day, in what researchers term *shifts*. Fishing crews usually operate in three shifts because of frequent equipment failure, access to boats, or other economic commitments in the system of occupational multiplicity. The first shift is usually worked by the majority of fishermen, who begin about 8:00 AM and return around noon, depending on weather conditions. In the early morning hours, the sea is at its calmest, allowing easier boat travel to the reefs and beyond. Returning is also easy because fishermen have the prevailing northeast wind at their backs.

The second shift begins after 12 noon. Rowing or motoring out to the reefs can be difficult against the strong afternoon winds and rough waters. After four or five hours of fishing, the return trip home is facilitated by the same winds.

Several individuals and some crews fish at night. Their shift begins around 8:00 PM and lasts throughout the night. Equipped with containers of coffee and rum, a flashlight hooked up to an automobile battery, hand lines and hooks, night fishermen have the advantage of calm waters. Fish are attracted to the light and thus some of the largest catches occur at night. Night fishing is, however, the most dangerous because of the risks of running into coral heads, damaging boats and motors, and the possibility of being attacked by barracudas or sharks, should the fisherman decide to snorkel dive. The night shift is the longest because fishermen must wait until morning to bring their catch to the market, when someone is there to weigh the fish and put them on ice.

Each of the shifts, then, has advantages and disadvantages. Some fishermen will occasionally fish more than one shift, going out in the morning and then making another all-night trip (Stoffle 1986:101-102). Ethnographers hypothesized that the greater distance to the site, the more potential risk in fishing at the site. Consequently, fishermen were asked, "Do you do anything for good luck before leaving with the crew?"

Simon: No.

Dionicio: No.

Narciso: Yes, I say a prayer to God before leaving.

Bacilio: I ask for God's help and the help of the virgin of Carmen.

Eugenio: I ask God to help.

Tuba: Not really.

Three of the six fishermen indicated that they pray prior to leaving on a fishing trip, indicating the potentially precarious nature of fishing in the sea. Fishermen were then asked, "Where are the most dangerous spots for fishing?"

Simon: Outside the third reef. El Veril.

Dionicio: El Veril, because there are a lot of shark, barracuda and congle.

Narciso: El Veril. It is far away and if you have a problem with your motor then you would not be able to get back to Buen Hombre.

Bacilio: On top of the reefs, there is a lot of movement. El Veril is dangerous because there are many sharks.

Eugenio: El Veril, because it is very deep and many sharks are found there.

Tuba: Banco de Lulu. There is also a place in close where the wind is very strong and that makes it very dangerous. In El Veril you will find a large number of sharks. There are also sharks in other distinctive sites. And in a part of a bank called Banquera de la Mata.

It is clear that the El Veril site, outside the third reef, is perceived by the majority of fishermen as the most dangerous site to fish at. A couple of other sites in addition are seen as dangerous because of the number of sharks. Interestingly, one fishermen stated that tops of reef were dangerous and related the danger to the movement of aquatic animals over the reefs. This is probably due to the wave action near the surface of the reefs.

Ethnographers sought to understand a typical fishing trip in terms of hours fished and the number of sites visited. Fishermen were asked, "In general, how many hours do you fish in one day?"

Simon: 6:00am to 12:00pm. Six hours.

Dionicio: 5 to 7 hours.

Narciso: If the day is good and there is no breeze, one can fish for 6 hours.

Bacilio: 4 to 5 hours.

Eugenio: 6 hours.

Tuba: 8 hours.

The range of responses indicates that typical fishing trips last between four and six hours. These responses most likely refer to first shift outings, as night trips usually last 10 to 12 hours.

In response to the question, "How many sites do you visit in one day of fishing?" the fishermen said:

Simon: 3 sites.

Dionicio: 2 to 3 sites.

Narciso: You can visit 4 to 5 sites. At times, depending on distance, you visit 3 or 4. The number of sites and time spent fishing depends if the fishing is good or not at a certain site.

Bacilio: 3 or 4 sites.

Eugenio: 2 or 3 sites.

Tuba: 3 to 4 sites.

In order to understand more fully longer term patterns, fishermen were then asked, "How many locations did you fish last week?" They responded:

Simon: 18 sites.

Dionicio: Between 15 and 18 sites, more or less.

Narciso: (Did not use question)

Bacilio: 4 to 5 or 6 sites.

Eugenio: 4 sites.

Tuba: NR

Fishermen were then asked, "How many different locations did you fish in the last 30 days?"

Simon: 18 sites.

Dionicio: Between 12 and 18 sites.

Narciso: N/A

Bacilio: 4 to 5 sites per day for a total of about 30.

Eugenio: NR

Tuba: NR

Ethnographers were also interested in the frequency of fishing site visits on a daily basis. Fishermen were asked, "Are there places that you fish everyday?" Their answers were:

Simon: Yes, I go to lobster spots on the way out.

Dionicio: No. Some sites I visit two or three times a week.

Narciso: No.

Bacilio: Yes, the Cordillera de Cayito (near the Tuba's Rock site).

Eugenio: Yes, the Playa de los Cocos, Cordillera de Afuera, and Silla de Caballo.

Tuba: If one does not have a motor, it is more possible to visit the same sites.

Three of the fishermen visit certain sites on a daily basis. Two fishermen do not repeat visits to the same sites each day. One fishermen stated that sites visited are based on the contingency of access to technology (i.e., a motor).

Fishermen were asked, "Do you look at the prices of fish before going out?" They responded:

Simon: Yes.

Dionicio: Yes.

Narciso: Yes, because the price that is maintained is usually established.

Bacilio: Yes.

Eugenio: Yes.

Tuba: Yes.

The next step for ethnographers was to gain an understanding of the species composition as related to certain sites. Senior fishermen were asked, "When you go to a particular spot to fish, are you looking for a specific type of fish?"

Simon: Yes.

Dionicio: Yes. I look for fish that will bring a good price.

Narciso: Yes. There are some places which we know will have a lot of certain types of fish. Some sites they are always moving. At other sites they live.Sometimes we will go to a place where we think there is mero (grouper) or lobster. There are classes of fish that migrate, like the cohinua, jurel, picua, cariti, and guatapanar. They are moving always. There are other fish that live, have and live in their house, like mero--all migrate, too--but they look for a site where they spend the most time, like pargo, arrigua, bocallate, candil, barraco.

Bacilio: No.

Eugenio: No.

Tuba: Yes, there are places where there are more of one specific type of fish or lobster which we like to catch.

Four of the six fishermen stated that certain sites are known to contain a certain type or types of fish, particularly lobster. Grouper, a first class fish, is also found in higher densities in certain locations.

Fishermen were asked, "How do you decide the members of the crew?"

Simon: Three at a time, does not seem to change much. I will find people on the beach and say, "I am leaving now, do you want to go?" But for the most part I fish with the same three people.

Dionicio: I go out with friends. I fish with two other people all the time. We are associates, partners. For example, Tuba and I are very good friends.

Narciso: It depends on who can get the equipment. I ask friends and members of the association if they can get a boat and want to go out. We go to find a motor. Now there is not equipment of the association.

Bacilio: We decide the day before who we are going to fish with.

Eugenio: I go with experienced fishermen, and whoever is around when I want to go.

Tuba: We have meetings to see who are the people that they want but there is no preference because everybody is equal. I fish with different people.

Ethnographers asked about the degree to which fishermen act communally in terms of fishing information: "Do you share information on sites where the fishing is good?"

Simon: Yes.

Dionicio: Yes.

Narciso: Yes.

Bacilio: Yes.

Eugenio: Yes.

Tuba: Yes.

All fishermen share information and knowledge about locations where the fishing is good. Ethnographers then asked whether certain locations existed where fishing is preferred and the catch is typically plentiful. In other words, ethnographers wanted to understand something of the productivity of certain sites. Fishermen were asked, "Where are the best places to fish?"

Simon: Piedra de Buen Hombre, Pasita de lo Coco.

Dionicio: Los Lomo, El Veril, a number of different sites.

Narciso: (Did not use question)

Bacilio: (Did not use question)

Eugenio: (Did not use question)

Tuba: (Did not use question)

Ethnographers then asked fishermen about the seasonality of fishing. "Are there certain times of the year when you fish more than others?" "Why?"

Simon: Yes, during the summer, because the water is warmer.

Dionicio: Yes, during the summer, because the water is much warmer.

Narciso: (Did not use question)

Bacilio: (Did not use question)

Eugenio: (Did not use question)

Tuba: (Did not use question)

The least understood fishing shift is the night shift. Fishermen were asked, "Why do you fish at night sometimes?"

Simon: Because we can catch a lot of lobster.

Dionicio: When fishing is bad during day, we fish at night.

Narciso: If day fishing is not so good, if the water is cloudy or if there is no equipment or if the water is cold, then I will fish at night with lines. We call them *cordel* because you can fish deeper--bottom fish.

Bacilio: I don't like to fish at night.

Eugenio: Yes, when the water is cold during the day, you can go out at night and fish. It is a good way to fish.

Tuba: If the ocean is bad during the day, I will go out and fish during the night.

Fishermen were then asked, "How many sites do you visit when fishing at night?"

Simon: Two--La Piedra de Buen Hombre, and the Cordillera de la Posa.

Dionicio: 1 to 2 sites.

Narciso: We visit 2 to 3 sites beyond the second reef and out to the fourth. I prefer the fourth. The fishing is good. There is more *colirubia* and *jurel* at night so you fish a lot for them.

Bacilio: (Did not use question)

Eugenio: (Did not use question)

Tuba: 3 to 4 sites.

The next question sought more detail on the typical length of night fishing trips: "How long do you fish at night?"

Simon:	All night. From 8:00pm to 6:00am.
Dionicio:	8 to 10 hours in deeper parts of the third reef. At night, fishermen go to the shallows very little. It is better further out.
Narciso:	All night long.
Bacilio:	(Did not use question)
Eugenio:	All night.
Tuba:	12 hours.

Buen Hombre fishermen traditionally have employed sustainable methods of fishing that appear to derive from a conservation ethic. Interviews with key experts indicate that fishermen recognize the potential adverse effects of indiscriminate fishing practices on reef fish populations. Small fish of all classes are not targeted by fishermen; only rarely are they captured in fish pots. Expert fishermen explain that small fish are avoided in order to allow them to grow to an appropriate size. Economically, small fish are not ideal for consumption or sale because of the low proportion of meat. Larger fish provide higher returns in terms of the amount of protein-rich food compared to the amount of energy expended to catch them. Avoidance of small fish and other seafood species implies that fishermen are cognizant of the effects of overfishing on population reproduction.

The enterprise of fishing entails the dual goals of providing food and income. Consequently, fishermen harvest a diversified supply of seafood. Daily individual catches usually include an array of parrotfish, grouper, snapper, crab, lobster, conch, and other reef fish. The diversity of catch clearly indicates that multiple species are deliberately and commonly sought. Buen Hombre fishermen thus employ deliberate fishing strategies for both subsistence and cash. While fishermen prefer certain species for home consumption, these species are usually part of a diversified catch. It can be argued that diversifying the catch reduces the risk of overfishing certain species.

Data suggest that these strategies can and do change, based on such factors as weather conditions and stress in other sectors of the local economy (Stoffle et al. 1990). These changes can be either short-term (day, week, month) or longer-term (seasonal). Under the current conditions of environmental (drought) and economic (crop failure) stress, Buen Hombre fishermen appear to be intensifying their fishing efforts in terms of (1) length of fishing trip, (2) more intensive exploitation of certain locations along the coral reef, and (3) a concentrated effort to capture species that are in high demand in the market economy.

Local Factors Affecting Fishing Patterns

This section of the chapter describes local factors, both environmental and sociocultural, that influence access to resources and patterns of fishing behavior among the fishermen of Buen Hombre. While factors such as climate are clearly exogenous and beyond local control, its effect, and those of other factors, are discussed here in terms of their impact on the bounded community of Buen Hombre, its residents and their economic pursuits. A subsequent section will deal with the kinds of external social, political and economic factors operating beyond the boundaries of Buen Hombre and how they impinge upon the practice of fishing in the community.

Key expert interviews and focus group discussions with senior fishermen documented a direct relationship between patterns of fishing, the weather, and availability of fishing equipment, especially motors for fishing boats.

Effects of Climate, Seasonality, and Technology

One major factor affecting fishing is weather. Wind and rain play significant roles in decisions regarding whether or not one goes out to fish. If the weather is favorable, the pressure of having to fish long hours and exert great amounts of effort is reduced. On the other hand, when weather conditions are adverse, the lack of larger boats and outboard motors mitigate against going out to the reefs to fish. Boats and motors are too small to be safely handled in strong winds and rough waters. Consequently, fishermen may be more likely to walk along the shore to the point of the lagoon and swim out to fishing spots well inside the inner reef. To compensate for lost subsistence and income on those days when weather conditions are not favorable, fishermen may exert more effort while fishing or target specific species of seafood on those days when the weather is favorable.

Field observations reinforce this hypothesis. Following two successive days in which strong morning winds prevented crews from going out, fishermen fished much longer than on previous trips. One of the authors had participated in fishing with a crew of Buen Hombre fishermen many times during 1989 and 1990, thus providing an accurate sense of the amount of time the fishermen normally spend fishing during a morning outing. These observations correspond with observed and recorded patterns of fishing from 1985 (Stoffle 1986). In the past, first shift fishing trips normally lasted about four hours, from 8:00am to 12 noon. On the day following adverse wind conditions, however, the first shift fished from 8:00 am until around 1:30 pm, an increase of one and a half hours over typical outings. Observations and fishermen's responses indicate that the reason for this change in fishing patterns was due to adverse wind conditions during the morning hours of the two previous days.

Other changes in fishing patterns were observed during the 1990 fieldwork. Usually, fishermen go out to a particular location along the inner reef and attempt to capture a variety of species. The following day, fishermen choose a different location along the reef. During fishing trips in 1990, participant observers noted that the crew went to a particular location during the early morning. After spending a period of time there, the crew moved to another location with the goal of capturing lobster. After spending nearly an hour searching for lobster, the crew then moved to a third location to resume spearfishing.

Fishermen were not observed going to a spot deliberately for lobster during 1989 fishing trips. Usually, lobster were taken spontaneously when encountered to supplement fish caught with spearguns. Likewise, fishermen were not observed fishing exclusively for one type of fish or seafood. During some of the 1990 fishing trips, however, fishermen stayed out longer in order to ensure that adequate amounts of specific fish were captured for sale and consumption.

A biological factor that affects fishing in the coral reef ecozone is a seasonal disease known as *ciguatera*. The disease is apparently contracted by fish that consume algae and other ocean nutrients contaminated with a highly toxic substance. Like PCBs, the levels of toxin accumulated in fish is correlated with the size and type of fish. Buen Hombre fishermen commented that the poisoning is seasonal. The toxin first begins to appear in May, June and July. The condition begins to peak between November and December; by January, February and March it is prevalent. Susceptible fish species are recognized by a blackening that occurs in the skin. It is not clear how many types of fish are affected by this poisoning, but the condition may affect the kinds and amounts of fish caught in a given period.

As is common in the tropics and subtropics, there are pronounced seasonal variations in climate. Dry and wet seasons are characterized by different weather and precipitation patterns, as well as variations in the availability and abundance of specific natural resources. Seasonal variations affect the economic, health, and nutritional status of local rural populations (Chambers 1982; 1983). Most researchers and officials only visit the most isolated rural communities during the dry season, when conditions are most favorable (Chambers 1983).

Seasonal Food Shortage and Fishing Change. During the CIESIN project, ethnographers conducted fieldwork during the rainy season and asked a series of questions aimed at gaining understanding the effects of climatic seasonality and health on fishing patterns and other activities. Senior fishermen were asked, "During what time of the year is it most difficult to obtain food?

Simon: December.

Dionicio: During autumn and winter, September through March.

Narciso: Winter. October, November, December. Also, January and February are the months when we begin work on our farms. This is when agriculture is in the first stage.

Bacilio: December and January.

Eugenio: November, December, and January.

Tuba: October, November, and December.

Late autumn and winter are the times in which fields are prepared and planted. These are also the time of the onset of the rainy season precipitation. While crops are ripening in the fields, people must rely more heavily on purchased goods and marine resources obtained from fishing. Fishermen were asked, "When there are food shortages, how does your manner of fishing change?"

Simon: We help others raise cages, and work on agriculture. We also sell labor to intermediaries, work on farms.

Dionicio: We fish more frequently.

Narciso: I am always changing my manner of fishing. If I need to fish during the night, then I will do that, and if I can get enough during the day, then I don't need to go out and fish at night. If the fishing is bad during the day, I fish at night. If it is good during the day, I fish during the day.

Bacilio: We fish less, because when there is not much food, we don't have a lot of strength to fish.

Eugenio: We fish at night.

Tuba: Yes, I have to change my way of fishing. I will stay closer to shore when fishing. This is because the water is much clearer and not as deep. Like Bacilio, when one is hungry, one cannot go far out to fish because of a lack of energy.

The responses indicate that fishermen are engaged in agricultural labor during the late fall and winter. This labor is both on their own fields as well as wage labor on other farms. Fishing patterns change depending on the fishermen. Some fish more and in more than one shift, while others indicate that hunger and lower levels of energy hamper their ability to expend a lot of effort on fishing. One fisherman suggests that sites closer to shore are used more frequently under these conditions. Fishermen were then asked, "When there is a food shortage does it change where you fish?"

Simon: Yes, I fish at La Pasita.

Dionicio: No.

Narciso: Yes, I change my sites when I am looking for the best spot to find fish.

Bacilio: Yes, we stay in much closer.

Eugenio: Yes, we go to more consistent sites where fish are commonly available.

Tuba: We stay in closer.

Only one fisherman said that he did not change the type of sites he visits. The other five fishermen either maintain their standard pattern of visiting a series of sites. Two of these five clearly stated that they stay much closer to shore during rainy season food shortages.

Previous studies suggest that seasonality affects the type of seafood sought during fishing. This is based on analysis of two years of fish sales records from the summer of 1989 and the spring of 1990 (Stoffle et al. 1990:28-36). Senior fishermen were asked, "When there is a food shortage, do you look for different types of fish?"

Simon: Yes, octopus and *arrigua*.

Dionicio: No. I always fish for the same kinds of fish.

Narciso: No.

Bacilio: We can only catch smaller fish because have to stay in close. I do not have the strength to fish farther out.

Eugenio: No.

Tuba: Yes, there are certain fish farther out, but we can't fish for them because we stay in close. But we look for the same types of fish.

Three of the six fishermen stated that they look for specific types of fish under conditions of seasonal food shortages. This illustrates that fishermen target certain species during times of economic hardship (Stoffle et al. 1990).

Cash Shortages. Changes in fishing patterns are also linked to seasonal shortages of cash. Ethnographers asked fishermen, "During what time of the year do you have the least money?"

Simon: December.

Dionicio: In the winter. December, January, February, and March. The sources of income from fishing and agriculture are not as productive because the weather is bad during the winter. You can't fish.

Narciso: December, January, and February. These are bad months for money. The fishing is worse and you can't make enough money. Agriculture is in process.

Bacilio: August, September, and October.

Eugenio: Winter.

Tuba: October, November, and December. August is a bad time for fishing because it is very dangerous; there are a lot of cyclones and strong storms.

Fishermen were then asked, "When you have only a little money, does the manner in which you fish change?"

Simon: I fish more to make more money.

Dionicio: Yes. I fish more but find less.

Narciso: No. You fish whenever you have the opportunity.

Bacilio: Yes, I will leave early to go fish and stay out later because I need food for the family. I also need money.

Eugenio: I will work harder on my farm.

Tuba: No, I don't change the way I fish. I fish the same all the time.

The next question asked was, "When you only have a little money, does it change where you fish?"

Simon: Yes.

Dionicio: Yes. I will change locations more often in order to find fish.

Narciso: No.

Bacilio: I have to stay in close. It is likely that I will not have food, because of a lack of strength for fishing.

Eugenio: Yes, I go to best sites.

Tuba: Yes, I will go to different sites which have not been exploited as much, so that I can find more fish.

Fishermen were then asked, "When you only have a little money, do you look for different sorts of fish?"

Simon: No, I look for the same kinds of fish.

Dionicio: No. I always look for pargo, mero, cariti, chillo, and langosta.

Narciso: No.

Bacilio: No, I look for the same types of fish.

Eugenio: No.

Tuba: Yes, I will go to an area where I can find bigger fish.

Farm Labor. Previous data indicate that changes in fishing patterns are partially linked to peak periods during the agricultural cycle that require a high degree of labor. All fishermen also own farms of varying sizes. Older fishermen tend to prepare themselves for retirement by investing in land. Fishermen were asked, "When you work a great deal on your farm, does it change the manner in which you fish?"

Simon: Yes, I fish less.

Dionicio: Yes, I do not fish. I only work on the farm.

Narciso: Yes, I fish less often to work on my farm.

Bacilio: Yes, I work to fish every other day, so that I can work on my farm.

Eugenio: Yes, we fish in different sites. We have knowledge of the good sites and where we can find good seafood. We will fish a little more quickly, so that we can get back to the fields and continue working.

Tuba: I will hire a couple of people to work on my farm.

Fishermen were then asked, "When you work a great deal on your farm, does it change where you fish?"

Simon: Yes, sometimes.

Dionicio: (Did not use question)

Narciso: Yes, because I fish less often.

Bacilio: I will stay in close to get a few fish and then come in to work on the farm.

Eugenio: No, I fish in the same places. I fish in close.

Tuba: Yes, sometimes I do, but not much.

Ethnographers then asked, "When you are working a great deal on your farm, do you look for different sorts of fish?"

Simon: No.

Dionicio: (Did not use question)

Narciso: No.

Bacilio: No, I look for the same types of fish every time that I go out.

Eugenio: No.

Tuba: Yes, I do not need to catch as many fish.

Climate and Seasonality. Previous studies documented, as mentioned above, that climatic conditions affect fishing for Buen Hombre fishermen. Ethnographers asked a series of questions designed to more completely understand the effects of climate on patterns of fishing. Senior fishermen were asked, "During the cold season, does the manner in which you fish change?"

Simon: I work in my field, and use lines and cages more often when fishing.

Dionicio: Yes, I fish with a line.

Narciso: Yes, I fish less underwater and do more night fishing.

Bacilio: Yes, the water is colder, so I cannot stay in as long.

Eugenio: We fish with hand lines in the winter, and with the spear gun in the summer. I use the hand line in the winter because it is cold. We catch many fish in the winter with the hand lines.

Tuba: I cannot work as many hours because water is cold.

Fishermen were then asked, "During the cold season, do you change where you fish?"

Simon: Not much.

Dionicio: Yes, I stay within the limits of Buen Hombre. We stay in the area of Buen Hombre during the winter.

Narciso: Yes. I always change sites.

Bacilio: Yes, I will go to fish at a certain spot and then tomorrow I will go somewhere else.

Eugenio: In the winter, we change our spots for fishing. One night we will go to a spot over there in the Silla de Caballo, and the next night we might go over to Sand Key. But we also fish these sites during the summer.

Tuba: Sometimes, because when I go to a place where the water is very dirty, I will look for another place where the water is not as dirty.

Ethnographers then asked fishermen, "During the cold season do you look for different fish?"

Simon: No.

Dionicio: Yes, I look especially for more *cariti* and *colirubia*, but otherwise the same kinds of fish.

Narciso: No.

Bacilio: No.

Eugenio: No.

Tuba: Yes, because sometimes the water is very cold, so I will go to a place more shallow where the water is warmer. Then I will fish for *mero pequeno* (small grouper) and *pulpo* (octopus).

Personal and Family Illness. There is a negative synergy between the rainy (cold) season, human health and nutritional status, and increased poverty (Chambers 1982, 1983). The rainy season is a time when crops are maturing in the fields. Ill health hampers the ability of villagers to work in the fields as well as fishing. Since both agricultural and marine products are sold as commodities to generate income, inability to work means that incomes are often stretched if not exhausted during this period. Consequently, there are frequent shortages of food and cash for buying food and medicine during the rainy season.

The summer dry season can also have adverse effects on humans in terms of drought, and famine, which can lead to shortages of food and cash, and thus higher levels of morbidity. Senior fishermen were asked, "During what time of the year is there the most sickness?"

Simon: The worst time is during dry periods and during times of drought. There is a lot of wind and therefore many colds. During these times there is no water for drinking.

Dionicio: During spring and summer. There is less water and higher contamination. The available water is more contaminated. You can't use the water without boiling it. There is also less food in winter, but people are in better health. There is more illness in the summer.

Narciso: As summer leaves, moving toward winter, there are many sicknesses because it gets cold and that is when people get sick. It is cold which is bad for health.

Bacilio: In the winter.

Eugenio: In August, September, and October. Entering the winter season it is hard to defend against the cold.

Tuba: Between the middle of October and January, there is little food.

Ethnographers then asked, "What types of sickness does the community experience?"

Simon: They suffer from colds and also fever. Everyone.

Dionicio: The most frequent are cold, diarrhea, headaches, and *refriado* (heat exhaustion?).

Narciso: Cold, fever, and *conjunctivitis* -- a sickness people get in the winter.

Bacilio: Cold, fever, and headaches.

Eugenio: Diarrhea, colds, and fever.

Tuba: Diarrhea, fever, and colds.

Fishermen were then asked, "Who suffers the most from sickness: women, children or men?"

Simon: Everybody.

Dionicio: The children suffer the most.

Narciso: Men and women both get sick. Children suffer more frequently from diarrhea and things like that.

Bacilio: The children suffer more.

Eugenio: Children.

Tuba: Everyone suffers a lot from sickness.

These responses suggest that children are most susceptible to disease, particularly during times of seasonal stress, when food and cash are in short supply. Ethnographers then asked a series of questions regarding the impact of illness on patterns of fishing. Senior fishermen were asked, "When someone in your family is sick, does the manner in which you fish change?"

Simon: Yes, when someone is sick, I fish more to earn additional money.

Dionicio: I have to go to the sea more often to cure my son or my wife. To obtain money for medicine to cure them.

Narciso: No.

Bacilio: I fish quickly to get some money, and then go to the doctor to buy medicine.

Eugenio: We have to fish more.

Tuba: I have to fish more.

The amount of time spent fishing is increased, according to five of the six fishermen. Clearly, the objective is to sell the fish caught and use the cash to buy medicine. Fishermen were then asked, "When someone is sick, do you change where you fish?"

Simon: No. Only if I do not encounter fish at some site, I will change to another. But generally all of them are in the vicinity of Buen Hombre.

Dionicio: No.

Narciso: No, I don't change sites.

Bacilio: I stay closer in to shore.

Eugenio: I go to more dependable sites.

Tuba: I change the location many times and fish more rapidly.

Ethnographers then asked, "When someone in your family is sick, do you look for different sorts of fish?"

Simon: No. I fish for the same types.

Dionicio: No.

Narciso: No. I look for the same types of fish, whatever is there.

Bacilio: No.

Eugenio: No, because we always fish for the same fish.

Tuba: We catch whatever we can find.

In the case of illness, the responses suggest that fishermen will fish more often and at a closer distance to shore but, by and large, the same sites are fished and there is no targeting of specific species.

Local resource use and management practices of Buen Hombre fishermen-farmers are currently being threatened by the destructive practices of outsiders. The potential effects of these external factors is discussed below.

External Factors Affecting the Coral Reef Ecozone

The burgeoning tourism industry affects the coral reef ecozone. Even in small-scale resorts near Buen Hombre, there already appears to have been an increase in coral harvesting, collected by tourists as souvenirs. As the industry continues to grow and expand beyond the boundaries of port towns, increasing numbers of tourists will intensify their search for "wilderness" areas, thus subjecting the Buen Hombre coral reef microzone to extreme levels of disruption. Together, tourists, commercial fishing fleets and growing numbers of small-scale fishermen using increasingly destructive technologies have the capability to destroy one of the largest living reef zones in the world.

Like most small-scale fishermen (Cordell 1989a, 1989b, 1989c), the people of Buen Hombre perceive the coastal waters as part of their community territory. Interior village and port city commercial fishermen compete for access to reef and sea resources with fishermen of Buen Hombre. In addition, foreign fishing fleets from Puerto Rico have exploited Dominican waters. In the words of a Smithsonian marine scientist who has observed the practices, large-scale competitors are *reef rapers* (Walter Adey, personal communication 1985) because they use destructive and illegal net fishing techniques. These illegal nets have a small mesh (in some cases, less than one inch), and are known as *chinchorro* nets. Other fishermen dive using compressors, which are hooked up to an air line from boats, and allow them to remain submerged for long periods of time and catch larger numbers of fish.

The Caribbean Fishery Management Council has adopted a fishery management plan for reef fish fisheries of Puerto Rico and the U.S. Virgin Islands that includes regulations on net size. While the Dominican Republic government also has national regulations on fishery practices, the north coast is relatively isolated. Moreover, manpower for enforcement is generally lacking.

Senior fishermen were asked a series of questions regarding their perceptions of the marine environment and the primary threats to its continued survival. Fishermen were asked, "What do you think are threats to the ocean's environment?"

Simon: Chinchorros and compressors.

Dionicio: The sea is used by chinchorros and compressors. Natural things are hurricanes, storms, and earthquakes.

Narciso: For many years I have fished the sea. The most dangerous thing for the sea is chinchorro fishermen using two types of nets -- *de arrastre* (drag nets) and *trasmallo* (boat cast nets), and compressors. Among these three things, the worst is the *chinchorro de arrastre*.

Bacilio: Chinchorros and compressors. These are the worst things for the sea. They take all different types of fish in their nets.

Eugenio: Chinchorros and compressors.

Tuba: Overfishing, too many fishermen, chinchorro nets, and compressors. These things affect a great deal the marine environment.

Fishermen were then asked, "Do you think it is important to protect the marine ecosystem?"

Simon: Yes.

Dionicio: Yes, it is of utmost importance.

Narciso: Surely, it is our struggle to protect the sea and its animals.

Bacilio: Yes, it is very important.

Eugenio: Yes.

Tuba: Yes.

Ethnographers then asked, "Do fishermen (of Buen Hombre) do things to protect the environment?"

Simon: Yes, we fight against net fishing. We do not kill small fish.

Dionicio: Yes, we do not cut coral, we prevent the use of compressors and chinchorros. We do not cut *mangle* (mangrove), we do not take small fish and lobster, and we do not let many other fishermen in from other communities.

Narciso: Yes, we fight against chinchorro fishing and protect against cutting of mangrove and coral. We do not take small fish or lobster. We also teach our children. It is the law, but we can't maintain the applications of the laws we teach.

Bacilio: We do not take small fish, lobster, and avoid killing pregnant lobster. We also teach our children.

Eugenio: We help those who are doing fishing by being teachers.

Tuba: Yes, we do things like not use compressors and chinchorros. We protect the fish by not killing pregnant species and small fish.

Fishermen were then asked, "Do you think that fishermen from other communities are a threat to the ocean environment?"

Simon: Yes, fishermen from Monte Cristi and La Varea.

Dionicio: Yes.

Narciso: Yes, certainly those from Monte Cristi and Castillo, who use chinchorros. We do not consent to the use of chinchorros here for the protection of marine life.

Bacilio: Yes, fishermen from Monte Cristi, La Vereda, and Loma Atravesada. There are also two compressor fishermen in Buen Hombre.

Eugenio: Yes, fishermen from Monte Cristi.

Tuba: Yes, because many fishermen from Monte Cristi and Loma Atravesada come in and are using compressors.

Ethnographers followed that question up with, "How do fishermen limit people from other villages from fishing in the territory of Buen Hombre?"

Simon: Talked with authorities. Talked with fishermen.

Dionicio: We try to work with and get help from outsiders.

Narciso: (Did not use question)

Bacilio: We try and speak with government officials.

Eugenio: We try to do our part and work with government.

Tuba: We prohibit people from other places from coming into Buen Hombre territory. We work with authorities to help control the problem. We accept people coming in and fishing in our territory, but we do not want people who will come in and hurt the marine environment. They need to fish in the same way as the fishermen of Buen Hombre.

Ethnographers then asked a series of questions concerning the impact of destructive technologies such as chinchorros and compressors on marine resources in the coral reef system. Senior fishermen were asked, "Do you think there has been a change in the number of fish along the coral reef?"

Simon: Yes, there are less fish.

Dionicio: Yes, there are much less fish because of chinchorros and compressors.

Narciso: There is a change because people are using new equipment and overfishing the reefs.

Bacilio: Yes, because of the lack of motors, people can't go out as far and for this reason they are overfishing the inner reef.

Eugenio: Yes, there were a lot more fish in the past. There are less fish now because of the chinchorros and the compressors.

Tuba: Yes, there has been a big change, because there are too many fishermen that fish every day.

Fishermen were then asked, "Do you think there has been a change in the plant life of the coral reef?"

Simon: No.

Dionicio: No.

Narciso: I have seen some small changes, but not big ones.

Bacilio: No.

Eugenio: No.

Tuba: No.

Ethnographers then asked, "Do you think there has been a change in the condition of the reef?"

Simon: Yes, it is darker now. There are less fish and the bottom has changed. Some areas are darker and some are more white. Before the reef system was clean, now it is darker.

Dionicio: No, I don't believe the reef is sick, no.

Narciso: The number of fish has changed greatly. 15 to 20 years ago, the sea was very rich with fish, but now, no.

Bacilio: There is more reef growing.

Eugenio: No, I haven't seen a change. The reef is in good health and seems to be growing.

Tuba: It does not seem sick.

These responses show that, while the coral reef itself remains in relatively good condition, biologically, and in fact seems to be expanding, the aquatic lifeforms inhabiting the reef are perceived to be declining as a result of destructive fishing practices.

Finally, each of the senior fishermen was asked, "What do you think is the future of the coral reef system?"

Simon: If we do not stop fishermen with chinchorros, we will not find fish or have resources. But if we can stop the throwing of chinchorros, production will continue.

Dionicio: If we do not control chinchorros and compressor fishing, then the system is going to die.

Narciso: I think if fishermen continue to use compressors and chinchorros, they will destroy the environment. If they kill the largest and smallest fish, they will automatically kill whole generations of fish, right?

Bacilio: With conservation projects the reef will be protected, as well as the mangrove. Everything will be good with the reef if we continue to protect it. The reef will get sick if chinchorro fishermen continue their practice.

Eugenio: We will have to protect the reef. We think that we will have to care for the reef. We cannot do bad things to it. There will be little future if people continue to use chichorros and compressors.

Tuba: If we do not guard and protect the reef, it will disappear. If we protect it, the reef will sustain our community.

The responses of these knowledgeable fishermen, derived from years of experience and observation, speak for themselves. The following section of the chapter describes and analyzes the results of using Landsat TM images to illustrate the effects of seasonality and changing access to technology on fishing patterns.

Satellite Imagery Mapping of Community Territory, Fishing Sites and Patterns

The 1991 fieldwork confirmed and expanded previous data and hypotheses concerning changing patterns of fishing as a result of fluctuations in environmental and economic conditions described above. During the focus group discussions with key senior fishermen, a 1:50,000 scale Landsat TM satellite image was used as a visual aid. The senior fishermen identified the physical boundaries of the community and its territory (land and sea), as well as the numerous named fishing locations visited during typical fishing trips.

Village Territorial Boundaries

Senior fishermen were immediately able to locate their community when shown the 1:50,000 scale Landsat TM image. Because ethnographers recognized that coastal fishing communities define seaward territorial boundaries, the first set of questions directed the senior fishermen to demarcate the marine and terrestrial boundaries of Buen Hombre. The six senior fishermen discussed observable aspects of the image among themselves and quickly reached a consensus on the village territorial boundaries.

The eastern boundary is between 6 and 7 kilometers to the east of the village beach, at a mangrove and beach location known as Sansie. The location is marked by a *canada* or *arroyo*, in this case referring to a deep mangrove channel. The origin of the name is not known. There is speculation among the fishermen that the name is Haitian. From Sansie, the northeastern boundary is 7 kilometers to the north at a point on the fourth reef known as *El Veril*. Water depths at this boundary location are 15 feet on top of the reef itself, plunging to between 40 and 60 feet on either side of it. From the eastern shoreline boundary, it takes anywhere from 1/2 hour to hours, depending on motor quality and travel speed to reach the northeastern terminus of Buen Hombre marine territory.

The western boundary lies 8 kilometers from the Buen Hombre beach, and is known as La Pasa de Silla de Caballo. At this location, there are two visible passages in the reef, one of which leads to the mangrove shallows. The northwestern boundary is 10 kilometers due north from La Pasa de Silla de Caballo, to a point on the El Veril reef where waters range from 36 to 72 feet in depth.

The northwestern boundary point (as well as the others) is a fishing location, and the primary method used here is dropping *nasas* or cages, because the depth of the water limiting one's capacity to snorkel to such depths, and because of frequent lack of access to boats and motors. Fishermen who have cages travel to the site daily if weather conditions permit and waters are calm. It is very likely that oars are most frequently used when boating to the site. Fishermen have obtained cages with small amounts of credit forwarded from a Church Social Services project. Currently, a total of at least 106 cages owned by four fishermen use this deep water boundary location consistently. Interestingly, the bouys that mark cage locations in this area may serve a secondary function as a boundary marker.

There are, therefore, physical and human derived features that demarcate the marine territorial boundaries of the community of Buen Hombre. It is not known whether these are recognized by outsiders. The boundaries are recognized, however, by the village fishermen. Data derived from mapping of fishing site distribution using the Landsat image show that Buen Hombre fishermen do not fish outside of their perceived territorial boundaries.

Senior fishermen were asked about the number of reefs within their territorial waters and plotting them on the map. The purpose for this was twofold. First, ethnographers would be provided with a spatial sense of marine features in Buen Hombre territory, as well as distances between these features. Second, having fishermen point out distinctive features such as reef numbers would enable a fuller understanding of environmental characteristics that were not readily visible on the Landsat image.

The senior fishermen perceive of four reefs; they include the patch reef within the first lagoon just offshore from the Buen Hombre beach and distinguish it from the other barrier reefs. From an ethnographic perspective then, the first barrier reef is labeled the second reef, the second barrier reef is labeled the third reef (the major portion of which is a large crescent-shaped segment), and the distant outer reef, *El Veril*, is labeled the fourth reef. Senior fishermen related distances from the shoreline of the beach to each reef, distances between reefs running north and south, and distances to reef segments running east to west. Distances have significant implications in terms of opportunities and constraints in fishing that is dependent upon, but often lacking, motorized transportation.

Spatial Analysis of Site Distribution and Seasonal Fishing Patterns

On plastic overlays placed on the 1:50,000 TM natural color image, senior fishermen mapped the various fishing sites visited under two hypothetical situations. On one overlay, the senior fishermen were asked to plot the sites normally visited when weather conditions were favorable and access to boat motors and fuel were possible.

Figure 6.1 shows approximately where individual fishermen and crews fish when there is good weather and a motor is available for the boat. Table 6.1 lists in composite form the names and locations of sites typically visited under ideal conditions. Note that fishing sites are widely distributed between the major reefs and from east to west to the boundaries of the Buen Hombre fishing territory. Most of the fishing pressure is on the outer reefs. This pattern of fishing spreads the catch over a wide range of coral reef locations and a wide variety of fish species. This pattern of fishing involves the greatest risks to the fishermen because they are miles from shore were a motor to fail and they must fish in the deepest waters where most sharks are found. Despite heightened person risks to themselves, fishermen say this is the preferred pattern of fishing because it helps preserve the ecosystem.

On a second plastic overlay, the senior fishermen were asked to plot the sites visited when weather conditions were adverse and boat motors or fuel could not be obtained. Figure 6.2 shows where individuals and crews fish when they have these climatic or equipment limitations. Table 6.1 lists the names and locations of sites typically visited under adverse conditions. Note sites concentrated on the inner coral reef. This results in a few locations receiving all the fishing pressure for the entire village and a limited set of fish species being targeted. This pattern involves the least risk to the fishermen, but they recognize that where it to become the only fishing pattern the inshore reef would become over fished and die like they have seen occur elsewhere in the region. For this reason they say this is not an ideal pattern of fishing which is only used when they are forced by adverse environmental or economic conditions.

Figure 6.1. Fishing sites under ideal conditions

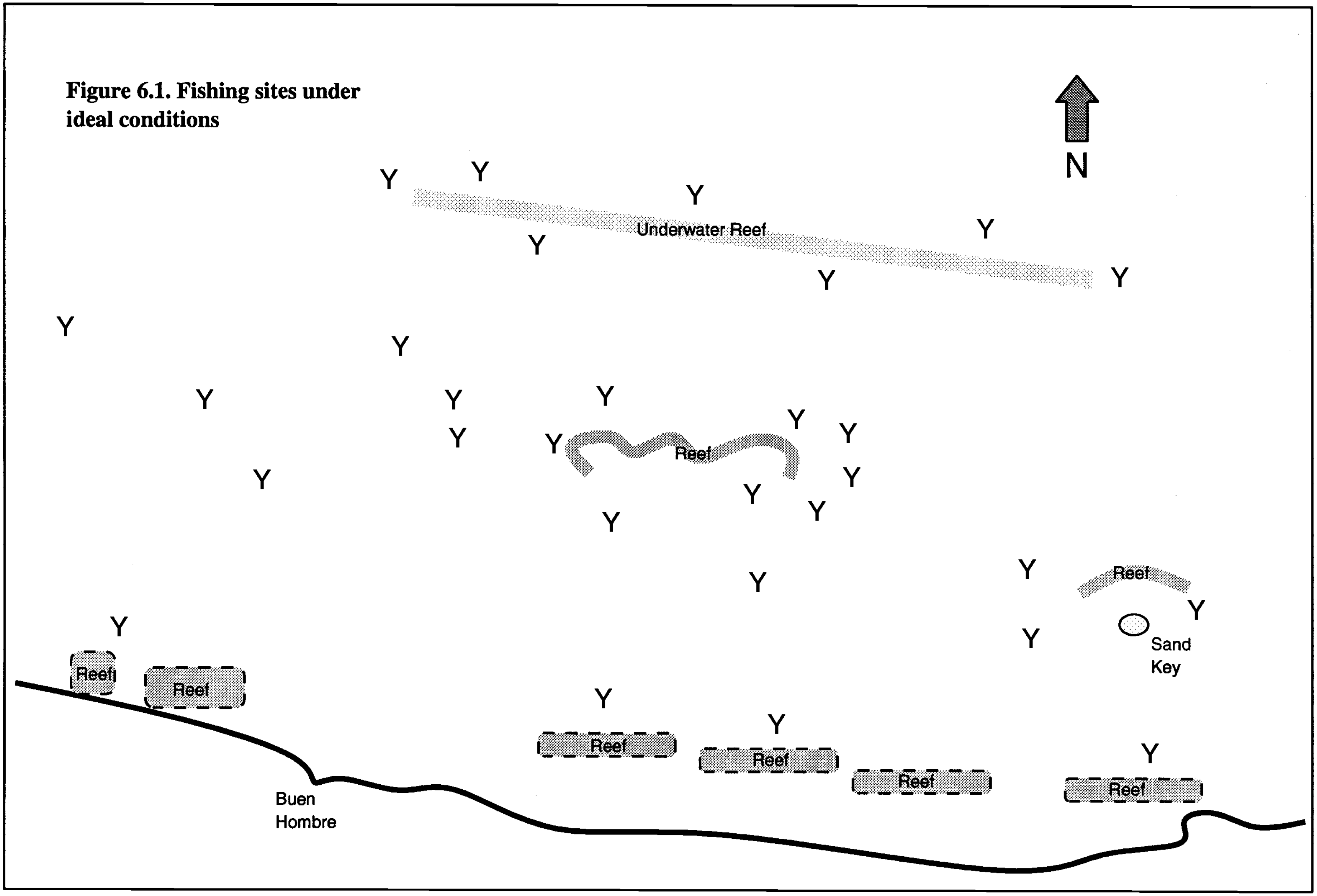


Table 6.1. Name and Location of Fishing Sites Under Ideal Conditions

Fishing Site	Location
El Veril	4th reef
La Banquera de Bolilo	bet. 3rd-4th reef
La Banquera de Buen Hombre	bet. 3rd-4th reef
Morral de Punta Piedra	3rd reef
La Pasa de la Posa	2nd reef
El Banco de Lulu	3rd reef
La Cordillera de Afuera	3rd reef
La Punta Bajo-Cordillera de Afuera	3rd reef
Los Lomos	bet. 3rd-4th reef
La Punta de Arriba-oeste de la Cordollera de Afuera	3rd reef
Los Morrales	bet. 2nd-3rd reef
Atras de Cayo Arena	3rd reef
La Cordillera Primera	1st reef
La Piedra de Tuba	3rd reef
La Cordillera de Cayito	2nd reef

Figure 6.2. Fishing sites under adverse conditions

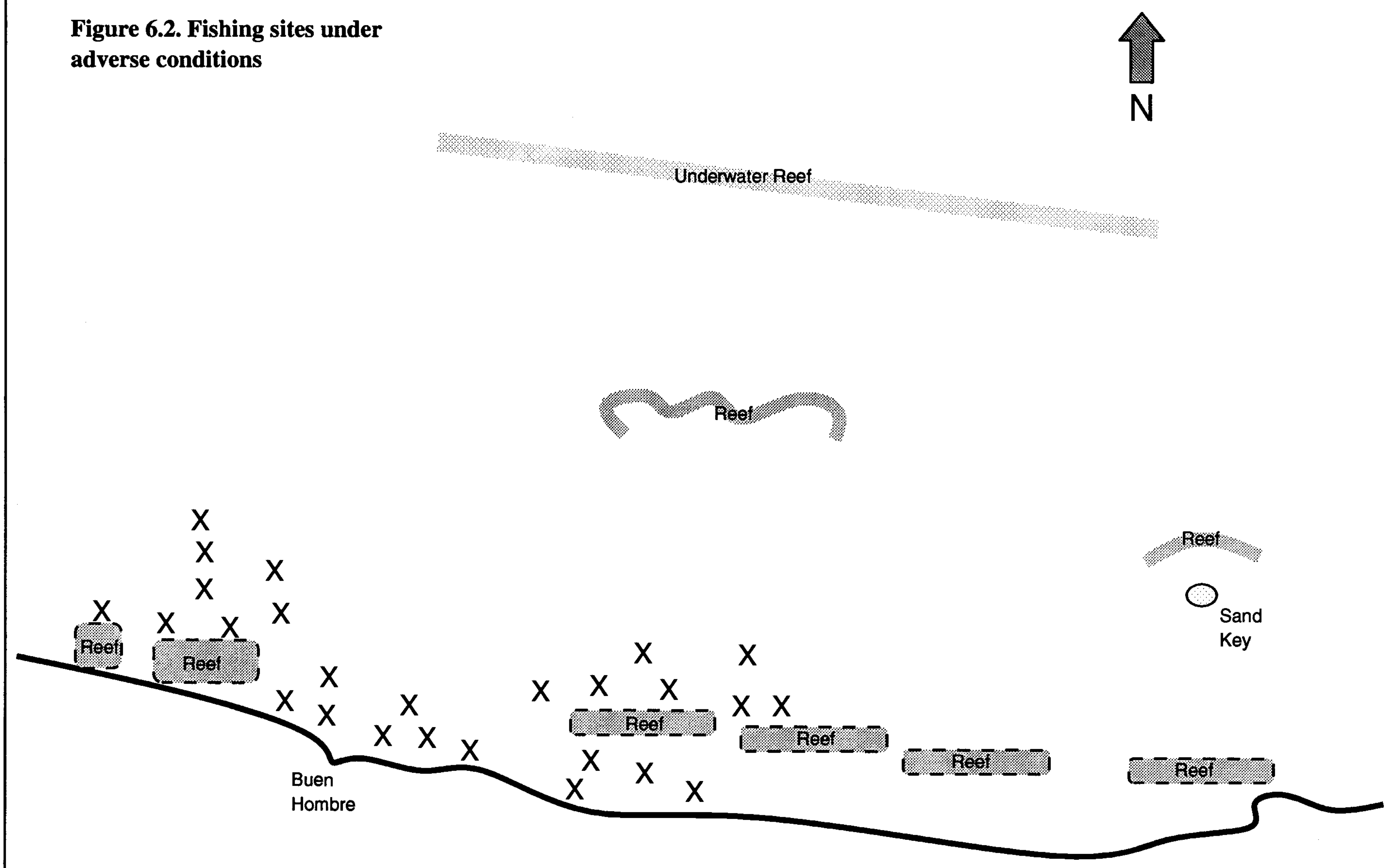


Table 6.2. Name And Location of Fishing Sites Under Adverse Conditions

Fishing Site	Location
La Paseta	2nd reef
Banco de la Pasa	2nd reef
Pasa de la Posa	2nd reef
Frente de Piedra de Buen Hombre	2nd reef
Punta de Piedra	2nd reef
Piedra de Buen Hombre	2nd reef
Banco de Piedra de Buen Hombre	2nd reef
Frente al Paisano	bet. 2nd-3rd reef
Banco de Cayito	bet. 2nd-3rd reef
Piedra de Tuba	bet. 2nd-3rd reef
Playa de los Cocos	inside 2nd reef
Punta de Cordillera Cayito	bet. 2nd-3rd reef
Banco Melliso	2nd reef
Banquito de Chimo	bet. 2nd-3rd reef
Banquito de Dionicio	bet. 2nd-3rd reef
El Banco de Alen	2nd reef
Banco de Mateo	2nd reef
La Piedra de Banco de Mateo	2nd reef
La Piedra Mellisa	2nd reef
La Piedra de la Guasa	2nd reef
Banco de Tuba	2nd reef
Pasadero del Cayito	2nd reef
La Pasita	2nd reef
El Pasadero de la Pasita	2nd reef

The second overlay correlates with data obtained concerning seasonality, particularly the rainy season. Because fishermen-farmers are busy planting their crops, they must buy food until the harvest can be carried out. Because crops have not yet ripened, they cannot be sold nor consumed. The nutritional value of processed foods is not as adequate as agricultural produce. Colder temperatures and frequent rains lead to increased incidence of colds and other illnesses, especially among the young. What cash is available must go for provisioning the household and investing in medication for sick family members. Consequently, access to fishing technology such as boats and motors (and also gasoline to fuel the motors), may be at its lowest point during the rainy winter season. Given that adverse weather (temperature, precipitation, cold water) and economic conditions are likely to be most intense during this time of year, we can expect that the inner reef is more intensively fished, as shown in Figure 6.2 (the second overlay), during the rainy season winter months.

Conversely, we would hypothesize that during the spring and summer months, when crops have been harvested and sold, and when ready cash is available, access to boats, motors, and fuel is easier. Therefore, the number and range of fishing locations would be more dispersed. On the other hand, there is evidence that periodic spring and summer periods of drought result in food shortages. This past summer, the authors received reports from researchers in the field that there had been a series of emergency helicopter food drops in the community.

The utility of Landsat TM satellite imagery in visually demonstrating changing patterns of fishing behavior and distribution of site use was demonstrated to Dominican government officials in the Departments of Natural Resources and Fishery Resources. Such use of satellite imagery can be used to monitor changing conditions (see Chapter Seven). In response officials and local people can collaboratively design and implement programs of development, in terms of the small-scale fishery, and conservation, in terms of protecting natural resources potentially threatened by human activities using data derived from satellite imagery and ethnographic ground truthing fieldwork. It is clear that local fishermen, with long experience in and knowledge of their marine environment, can serve as effective managers of the sustainable development and conservation of their coral reef system.

CHAPTER SEVEN

SEA TRUTHING SATELLITE IMAGERY

Richard W. Stoffle, Joseph Luczkovich, Jeffrey Michalek, Andrew Williams, David Halmo

This chapter reports the results of *sea truthing* a sample of sites selected in order to better understand the interpretative strength of Landsat TM satellite images. To accomplish this goal it was necessary to select sites of a known location for detailed biological and ethnographic study. The exact location of each site was identified through a Global Positioning System receiver. A marine biologist SCUBA-dived at each site to describe the plant and animal life there. The history of human-environment interactions at the site was identified through ethnographic interviews with local fishermen.

Satellite images are composed of information units called *pixels*. The range of light spectrums collected for a pixel is constitute the *pixel signature*. The purpose of sea truthing is to collect information that helps interpret the range of pixel signatures in a satellite image. To accomplish this it is necessary to know the depth of water at that location, the type of plants and geological materials present on the ocean floor. With these data it is possible to train the computer to interpret any particular pixel as to water depth or bottom type. Through this procedure both satellite images can be used to make bathymetric and marine ecology maps. When satellite images are available for different time periods they can be compared and changes in either water depth or bottom type can be visually demonstrated in what is called a *change image*. Because this project is concerned with understanding why ecological changes are occurring, ethnographic interviews were conducted with knowledgeable local people about how humans use the natural resources.

Methods

This analysis defines a sea truthing site as composed of three data components (1) pixel stations, (2) ecological sampling units, and (3) ethnographic interview areas. Each of these site components has a different geographic boundary, although the ecological and ethnographic units tended to correspond to one another. A sea truthing site usually has a number of pixel stations, each of which is 812 meters (28.5 X 28.5) square. Ecological Sampling Units (ESUs) were pixel-sized as well; a new ESU was designated when samples were taken in an area more than 28.5 m from a previous sample. Similarly, ethnographic interviews were conducted at one pixel station within a site, but usually discussed the more extensive ecological sampling area rather than be confined to small the pixel station. The term sea truthing site is used to describe the largest analytical unit for which any ecological or ethnographic data are available.

Each sea truthing site was located by at least one pixel station. At least one ethnographic on-site interview was conducted with local fishermen at the first pixel station within the site area. At three sites, two ethnographic interviews were conducted. When the pixel stations were taken within a ecologically homogeneous zone, the ethnographic information collected at the first pixel station could be extrapolated to the other pixel stations in the site. . When the pixel stations appeared to be ecologically dissimilar based on in situ observation, they were treated as representing separate sea-truthing sites. In all, ethnographic and ecological studies were conducted at 23 sea truthing sites which were located by 50 pixel stations. Seven expert fishermen from Buen Hombre and one fishermen from a village 20 miles to the east, contributed to a total of 25 ethnographic interviews. A group interview involving 6 Buen Hombre fishermen was conducted regarding the deep reef located farthest from the shore. This interview was facilitated by a 1:50K Landsat image that was specially processed by ERIM to show subsurface features in the ocean. This special image made it possible to talk about specific segments of the reeaweven though the whole reef is under water.

The sea truthing occurred between February 13, 1991 and March 5, 1991. The work was conducted using a hand-held Global Positioning System receiver called the Magellan NAV 1000 Pro. The device was field tested using 100 meter tape which was used to measure a distance on the beach. The Magellan was found to be accurate to within one meter. Ocean depths were measured using a Scubapro PDS, a battery-powered sonar device that was shown to be quite accurate. Biological data were collected though observation, sample, and photography. Many samples were identified using scientific field guides; however, samples that could not be positively identified were preserved in alcohol and identified at East Carolina University. Ethnographic data were collected with an instrument that was pretested in January 1991 and revised before returning to the field in February 1991.

Site-By-Site Analysis

This section describes each of the sea truthed sites studied in 1991. The following information is provided for each site: (1) its location and description, (3) its biological and ecological characteristics, and (4) its cultural characteristics and patterns of use by local fishermen. Lists of species of plants, invertebrates and fishes observed can be found in Chapter Five.

La Pasita del Coco (Interview #01, Station D-1)

<u>Location and Description</u>. This site was visited on February 18, 1991. It is located outside of the first barrier reef. Site coordinates are 19 degrees, 51.0923 minutes North latitude, 71 degrees, 18.5654 minutes West longitude. Local fishermen rely on three physical

and visual markers to locate the site. There is a small gap or pass (pasita) in the reef where there is a high point of coral that protrudes above other corals. The beach known as the playa del coco (coconut beach) is directly to the south.

Site Ecology. The bottom type at this site is coral reef. The depth of the water at this site is between 20-30 feet. This was a pass or cut through the first barrier reef from the first lagoon to the second lagoon. The ecological sampling was conducted on the east side of the pass, along a reef wall that started at 25 feet and continued to the surface. Nine species of brown and green algae (*Halimedia opuntia, Caulerpa languginosa, Dictyota mertensii, Lobophora variegata, Sargassum fluitans, S. platycarpum, S. polyceratium, Stypopodium zonale, Turbinaria turbinata*), seven species of hard corals (*Acropora, Montastrea, Diploria, Agaricia, Porites*), four species of soft corals (*Gorgonia sp., Briarium asbestinum, Plexaurella grisea, Plexaura sp.*), and sea anenomes (*Condylactis gigantea*) were observed along this wall. Seventeen species of fishes were observed here, of which the bluehead wrasse (*Thalassoma bifasciatum*) was the dominant. Few large fishes were observed here, but fishermen were spearing gray and yellowtail snapper (*Lutjanus griseus* and *Ocyurus chrysurus*) here on the days we visited. At the base of the wall, the bottom type changed to sparse sand and seagrass (*Thalassia testudinum*) and macroalgae complex.

Site Ethnography. The fisherman interviewed at the site has fished the location for twenty years. The location is used by fishermen from Buen Hombre, fishermen from other coastal villages such as Punta Rucia, fishermen from larger coastal cities such as Monti Cristi, and tourists who visit the area. The location is consistently fished about ten times per month throughout the year. The local fishermen know when fish spawn at this location and in order to protect the reproducing fish, fishermen report that they visit the site less often during the late spring and early summer months. According to the fisherman interviewed at the site, the water is normally clear except for the winter months when turbidity is more of a problem. These water clarity fluctuations are due to currents that are weak much of the year. During the winter months, however, higher winds cause the more turbid water inside the reef to move through the gap.

A number of different species of fish are harvested from this location. Table 7.1 lists the varieties of fish. In addition, donkey dung sea cucumber known as gusano del mar (worm of the sea) is consumed. Over time, fish stocks at this location have generally declined due to the increasing number of fishermen using the site, both local and outsiders. Most recently, weather patterns and equipment breakdowns have resulted in fewer trips to this site. Most significantly, however, outside fishermen using nets have caused a reduction in the fish population at the site. According to the fisherman interviewed, both losses in terms of capture and migration of fish to other similar habitats have occurred as a result of destructive net fishing. Despite net fishing contributing to a reduction in the fish population at the site, there is little degradation of the marine vegetative habitat at the site.

Table 7.1. FISH SPECIES PRESENT/CAPTURED AT LA PASITA DEL COCO SITE

Spanish Name	English Name	Scientific Name
Pargo prieto	gray snapper	*Lutjanus gresius*
cohinua	bar jack	*Caranx ruber*
bocallate	grunt	*Haemulon* sp.
Pargo colorado	dog or red snapper	*Lutjanus* sp.
Pargo tao tao		
cotorra	stoplight parrotfish	*Sparisoma viridens*
mojarra	yellowfin mojarra	*Gerres cinereus*
cabrilla	red hind	*Epinephelus guttataus*
cabrilla negra	rock hind	*Epinephelus adscensionis*
mero	Nassau grouper	*Epinephalis striatus*
colirubia	yellowtail snapper	*Ocyurus chrysurus*
gurrera		
pargo pluma	Porgy	*Calamus* sp.
langosta	Spiny lobster	*Panulirus argus*
centolla	spider crab	*Mithrax spinosissimus*
langostino		

Cayito de Arena (Interview #02, Stations E-1)

Location and Description. This site was visited on February 18, 1991. It is a small, largely submerged sand caye or key located in front of the gap of the reef off the la playa de coco, slightly northeast of the Buen Hombre beach. Site coordinates are 19 degrees, 52.0847 minutes North latitude, 71 degrees, 22.8572 minutes West longitude. Local fishermen find the site by orienting themselves to a road to Los Conucos, an extensive large mangrove and a large rock formation.

Site Ecology. This site is a partially submerged sandbar immediately behind the first barrier reef with waters ranging in depth from two to five feet . The site is a sandy bottom dominated by two species of seagrasses (*Thalassia* and *Syringodium*) and eight species of green, brown and red macroalgae (*Caulerpa languinosa*, *Derbesia* sp., *Dictyota mertensii*, *Halimeda incrassata*, *Penicillus capitatus*, *P. dumetosus*, and *Neogoniolithon strictum*). Seven species of invertebrates (sea anenomes, *Calliactis tricolor*, crabs *Portunus* sp., donkey dung and burrowing sea cucumbers (*Holothuria mexicana* and *H. arenicola*, and sea urchins, *Tripnuestes ventricosus* and *Lytechinus variegatus*) and empty conch shells (*Strombus gigas*) were observed in this shallow water habitat. No live conch were observed here. Four species of fishes were observed here (Ocean surgeon, *Acanthurus bahianus*, slippery dick, *Halichoeres bivittatus*, striped parrotfish, *Scarus croicensis*, and Beaugregory, *Pomacentrus leucosticus*), all very small juveniles.

Site Ethnography. The fisherman interviewed at the site has fished the location for 12 years. This site is intensively used throughout the year by Buen Hombre fishermen, fishermen from the villages of Punta Rucia and La Varea. Depending on how calm the waters are, the site is visited on a daily basis. In a 30 day day period for example, the fisherman interviewed visited the site 27 times. The location is also frequented during night fishing trips. Fishing activity at the site is highest during the months of June, July, and August when the waters are calmest. Fishing visits decline during the colder winter months of November and December. The cool air and water temperatures keep the fish away, according to the respondent. Marine species harvested at the site consist primarily of pulpo (octopus), lambi (conch), langosta (lobster), and mero (grouper). Currents at this site are weak and the water is generally clear throughout the year. Turbidity levels rise in December when surface runoff from mountain rains washes out into the shallow waters. The site contains good habitat for octopus, conch, lobster and grouper .

Tourists also visit the site in relatively large numbers during high season. The shallow waters and sand make the site ideal for tours involving swimming and bathing. Local fishermen attribute a general decline in the abundance of marine species at the site to increasing numbers of tourists and fishermen using the site for recreational and economic purposes. The intensity of activity at the site, according to the fisherman interviewed, has played a role in lowering the rate of reproduction of marine species populations.

Bajio de Cayito (Interview #07, Stations E-2 through E-6)

Location and Description. This site was visited on February 22, 1991. It is referred to as a sandbank or shallows (bajio) near the Cayito de Arena (Little Sand Key) site. The site is located in front of the sand bar just out from the first beach east of Buen Hombre. Six pixel station measurements were taken at different points of the site. Site coordinates at stations E-2 through E-6 are listed below:

*E-2: 19 degrees, 52.1059 min. N. latitude, 71 degrees, 22.8453 min. W. longitude
*E-3: 19 degrees, 52.1366 min. N. latitude, 71 degrees, 22.8273 min. W. longitude
*E-4: 19 degrees, 52.1692 min. N. latitude, 71 degrees, 22.8208 min. W. longitude
*E-5: 19 degrees, 52.2168 min. N. latitude, 71 degrees, 22.7940 min. W. longitude
*E-6: 19 degrees, 52.1110 min. N. latitude, 71 degrees, 22.8779 min. W. longitude

Site Ecology. The water depth at these stations ranged from two to five feet. The bottom type gradually changed from sandy bottom with seagrasses to corraline red algae flat to coral reef habitat along an inshore-to-offshore transect. At the calmest station (E-2, 2.0 feet deep), *Thalassia testudinum* and *Syringodium filiforme* were mixed with ten algal species (dominated by *Halimeda incrassata* and *Penicillus dumetosus*). In 2.5 feet of water, Station E-3 had a mixture of seven seagrass and algal species (*Thalassia testudinum, Halimeda incrassata* and *Penicillus dumetosus* were dominant) along with seven invertebrate species (rose coral, *Mancina aureolata,* and donkey dung sea cucumbers, *Holothuria mexicana*, were the dominant invertebrates). At station E-4 in very shallow water (1.0 foot deep), large areas of the corraline red algae *Neogoniolithon strictum*, *Amphiroa fragilissima* and *A. rigida* were present. In deeper water at station E-5 (2.0 feet deep), the bottom was a shallow barrier coral reef, with 8 species of algae (*Sargassum fluitans* and *Dictyota mertensii* dominant).

Surge and breaking waves characterized this station, and many coral colonies had been toppled here by storm surges. No biological observations were made at E-6.

Site Ethnography. At depths of two to eight feet, these relatively calm waters are generally clear, with the highest degree of clarity occurring during the late spring and summer months (May through August). The bottom type is almost exclusively coral reef, interpsersed with species of aquatic vegetation such as seagrass and sand. The most turbid period occurs in the winter (November through January). Despite this general pattern, the fisherman interviewed at the site indicated that water clarity varies throughout the year. The factors contributing to such variation include runoff from mountain precipitation. Another cause of water turbidity is attributed to sediment deposition from the "River of Monte Cristi" (Rio Yaque del Norte).

The fisherman interviewed at this site has fished the location for 13 years. The site is visited three to four times per week and fishing at the spot is more frequent during the summer months. Cold, rain and turbid water reduce the number of times the site is visited during the winter months. In addition, this location is known for its function as a nursery for juvenile fish, octopus and lobster. Eggs are laid in December; larval and juvenile fishes grow inside the inlet within the reef, and adults move out to the outer reef. When nearly full grown the offspring will repeat the cycle.

Besides local fishermen, fishermen from other villages along the coast also engage in fishing at the site. There are numerous species of fish harvested from this location. Table 7.2 list the species commonly captured by fishermen at the site. The 2-3 feet deep reef portion of the inlet is only fished when breezes are too strong to allow fishing in the deeper waters around the site.

Fishermen perceive that the fish stocks at this site have declined. The fisherman interviewed at the site indicated that the reduction was due to the increase in the number of fishermen using the site.

Table 7.2. FISH SPECIES PRESENT/CAPTURED AT THE BAJIO DE CAYITO SITE

Spanish Name	English Name	Scientific Name
mero	Nassau grouper	*Epinephilus striatus*
pargo riso	Spanish hogfish	*Bodianus rufus*
pargo prieto	Gray snapper	*Lutjanus gresius*
pargo tao tao	?	
pargo mantequilla	coney	*Epinephelus fulvus*
pargo	snapper	*Lutjanus* sp.
chena	Nassau grouper	*Epinephilus striatus*
Mojarra	Yellowfin mojarra	*Gerres cinereus*
cotorra	parrotfish	*Scarus* sp.
varraco		
bocallate	Grunt	*Haemulon sp.*

medico/merico	Surgeonfish	*Acanthurus* sp.
jira	?	
rubia	?	
(maybe same as "colirubia")	yellowtail snapper	*Ocyurus chrysurus*
picua	Great barracuda	*Sphyraena barracuda*
cohinua	Bar Jack	*Caranx ruber*
tiburon	shark	*Carcharodon* sp.

Los Tocones/El Canon de Sansie (Interview #03, Stations K-1, K-2, K-3)

Location and Description. Three pixel stations of this site were visited on February 20, 1991. The site is located at the entrance of and within a mangrove channel 30 meters from the shore with reef another 30 meters to the north, respectively. The coordinates for Los Tocones are 19 degrees, 50.7926 minutes North latitude, 71 degrees, 17.5376 minutes West longitude. The coordinates for El Canon de Sansie are 19 degrees, 50.8806 minutes North latitude, 71 degrees, 18.1117 West longitude. This latter location is named after the community of Sansie. The site is located to the east of Buen Hombre.

Site Ecology. This mangrove channel site is characterized by waters of two feet at the entrance to 10 feet in depth within the channel itself, with mud and seagrass (*Thalassia testudinum*) bottom types. Station K-1 was entirely within a seagrass meadow, outside of the entrance to the mangrove channels. Only *Thalassia* was observed at this site, although most certainly other species were present. No snorkling or SCUBA dives were made at K-1, so a poor sample of the plants was obtained at this site. Cast-net throws yielded no fish. At site K-2, the 10-foot-deep mangrove channel, a snorkling dive was made, but few species were observed. The red mangrove, *Rhizophora mangle*, lined one edge of the channel, and two species of brown algae (*Dictyota* sp. and *Sargassum fluitans*) were growing on prop roots of the mangroves, along with fire sponge (*Tedania ignis*) and other sponges and tunicates. On the bottom of the channel, a thin coating of an unidentified green alga occurred, with scattered litter and detritus from *Thalassia* and *Rhizophora* plants. No fishes were caught in cast nets at this site, but five species were observed hiding and feeding in among the prop roots (sergeant major, *Abudefduf saxatilis*, small unidentified mojarras, *Eucinostomus* sp., yellowfin mojarras, *Gerres cinereus*, gray snapper, *Lutjanus griseus*, and Yellowtail damselfish, *Microspathodon chrysurus*). Mojarras were dominant, although most were juveniles. Site K-3 was in a small cove off the main mangrove channel, with muddy/sandy bottom and sparse vegetation (*Thalassia*, *Halimeda monile*), and many burrowing (*Holothuria arenicola*) and donky dung sea cucumbers (*H. mexicana*).

Site Ethnography. Turbid water and fluctuating strength of currents depending on the tides. Highest degrees of turbidity occur in the winter months December through March, when there are frequent rains and brisk winds. Turbidity also is a result of runoff from mountain precipitation. Wind and rain are minimal during the months of April, May and June.

The fisherman interviewed at this site is from Punta Rucia. He has fished the location for many years. He and his crew, as well as fishermen from other coastal villages such as Estero Hondo and Punta Rucia, visit the spot most frequently during April, May and June when wind and rain are infrequent. Trips to the site are reduced during August and September and winter as the frequency of winds and rain increases. The site is frequently visited during night fishing trips. Four species of fish were mentioned as being harvested from the location. These are listed in Table 7.3.

Fish stocks were said to be lower than before. He said that this was due to the use of more and more varied types of equipment such as chinchorro nets by an increased number of fishermen using the site.

Table 7.3. FISH SPECIES PRESENT/CAPTURED AT THE LOS TOCONES/CANON DE SANSIE SITE

Spanish Name	English Name	Scientific Name
Sabalo	Tarpon	*Megalops atlanticus*
robalo	Snook	*Centropomus undecimalis*
pargo prieto	Gray snapper	*Lutjanus griseus*
pargo sama	Mutton snapper	*Lutjanus analis*

Higuerito/Bajio de Sansie (Interviews #4, #23, Station L-1)

Location and Description. This site was visited on February 20, 1991 and on March 2, 1991. It is located at the entrance to the Canon de Sansie site, from which the site derives its name, at the opening of the mangrove channel. Site coordinates are 19 degrees, 51. 0210 minutes North latitude, 71 degrees, 18.6393 minutes West longitude.

Site Ecology. The water depth at the site is three to six feet deep with bottom types of sand and seagrass (*Thalassia*). The bottom is very silty, due to the bioturbation of burrowing sea cucumbers, *Holothuria arenicola*, which create large mounds (40 cm diameter) of fecal pellets and reworked sediments around the mouth of the burrow. Ten species of plants were observed at this site, including several notable new species of algae (*Acetabularia calyculus*, *Avrainvillea longicaulis*, *Dictyosphaeria cavernosa*, *Laurencia intricata*, *Rhipocephalus phoenix*) as well as three species of *Halimeda* (*incrassata*, *monile*, and *opuntia*) and *Penicillus capitatus*. Four queen stromb (also called conch or lambi) adults, *Strombus gigas*, were collected here alive, the only station where they were observed living. Four species of fishes, Anchovy, *Anchoa* sp., slippery dick, *Halichoeres bivittatus*, an undidentified goby, *Gobiosoma* sp., and conchfish, *Astrapogon stellatus*, were observed here. Four conchfish were collected living symbiotically inside the mantle of the queen strombs. In general, fishes here were small and not very abundant.

Site Ethnography. The waters are calm, characterized by weak currents and generally clear. Periods of high turbidity occur in August, September and October, due to breezes which move turbid water from well inside the channel out to the opening. The waters are clearest from December to March. Two fisherman were interviewed at the site. One fisherman is from Buen Hombre and the other from Punta Rucia. Both have fished the location for over 20 years. According to the fisherman from Buen Hombre, the site is most frequently visited during the winter months when the waters are clearest. Visits number about eight to ten per month. It is at this time that octopus are most abundant. In summer the site is visited less often due to turbid waters.

According to the fisherman from Punta Rucia, the primary method of fishing at the site is with chinchorro nets. Normally, the site is visited two times per week, or eight times per month, by the respondent and his crew. During February and March, May and June, and November through December, fishing conditions are generally optimal due to the lack of wind. These winds pick up during July, August, and September, which results in fishermen experiencing increased difficulty in casting their nets. Consequently, the site is visited less often during these months.

Buen Hombre fishermen use the site as well as fishermen from the villages of Cope, Sabana Cruz, Punta Rucia, Estero Hondo and Rancho Manuel. Urban fishermen from Monte Cristi using chinchorros (set nets) also use the site.

A large number of marine species are harvested at this location. Table 7.4 lists the varieties of seafood captured. The large numbers of fishermen using the site, however--especially the urban chinchorro fishermen out of Monte Cristi--have contributed to a reduction in the abundance of seafood species at the site, according to both of the fishermen interviewed.

Table 7.4. FISH SPECIES PRESENT/CAPTURED
AT THE HIGUERITO/BAJIO DE SANSIE SITE

Spanish Name	English Name	Scientific Name
lambi	Queen stromb (conch)	*Strombus gigas*
pulpo	octopus	*Octopus* sp.
picua	Great barracuda	*Sphyraena barracuda*
bocallate	Grunt	*Haemulon* sp.
candil	Squirrelfish	*Holocentrus* sp.
langosta	Spiny lobster	*Panulirus argus*
raya	Stingray	*Dasyatis* sp.
chucho	Spotted eagle ray	*Myliobatus goodei*
vallombe	?	
sardina	Redear sardine	*Harengula humeralis*
robalo	snook	*Centropomus undecimalis*
mojarra	yellowfin mojarra	*Gerres cinereus*
mojarra blanca	white mojarra	*Eucinostomus* sp.?
pargo prieto	Gray snapper	*Lutjanus griseus*
lisa	mullet	*Mugil* sp.
boqueron	striped anchovy	*Anchoa hepsettus*
mijua	dwarf herring	*Jenkinsia lamprotaenia*

mero de yerba	"grouper of the grass"	*Mycteroperca* sp.?
memejuelo	?	
chichote	conch	

La Piedra de Buen Hombre (Interview #05, Station A-1, A-2)

Location and Description. This site was visited on February 15 and 20, 1991. Site coordinates are 19 degrees, 52. 6033 minutes North latitude, 71 degrees, 24.9774 minutes West longitude about 25 meters off the northeast point of the westernmost part of the rockIt is easily identified by a large formation of rock La Piedra de Buen Hombre (rock of the good man) situated near shore and extending about 30 feet above the surface of the water. The site derives its name from the legend that a shipwrecked sailor was rescued and provisioned by one of the area residents prior to the founding of the village. The sailor proclaimed the area La Costa de Buen Hombre (the coast of the good man). The site is located to the west-northwest of the Buen Hombre beach.

Site Ecology. The site is characterized by water five to twenty feet in depth, and bottom types that range from seagrass to coral barrier reefs. Station A-1 was a transect that crossed several pixels extending out from Buen Hombre Rocks to the barrier reefs approximately 200 m offshore. There were 18 species of plants observed along this transect, including all three species of seagrasses (*Thalassia testudinum, Syrinogium filiforme*, and *Halodule wrightii*). *Halodule* occurred closest to shore, but *Thalassia* was dominant throughout the transect. Fifteen species of green, red and brown macroalgae were observed at this site, seven in the seagrass meadows (*Amphiroa fragilissima, Caulerpa languinosa, C. paspaloides, Avrainvillea rawsonii, Halemeda monile, Penicillus capitatus*), the remaider on the coral reef (*Dictyota mertensii, Stypopodium zonale, Lobophora variegata, Turbinaria turbinaria, Padina gymnospora, and Sargassum polyceratium, Derbesia sp., Ventricaria ventricosa*). In this area, large (20-30 m diameter) "blowouts" occurred in the seagrass substratum. In these blowouts, the depth of the bottom would drop abruptly from 2-5 feet to 15-20 feet. These are probably due to storm surges that ripped away the rhizomes of the stabilizing seagrasses. Seagrass (*Thalassia*) had recolonized these blowout zones, indicating that the storm damage had occurred some time ago. The invertebrates in this area where also very diverse with 19 species observed. Staghorn coral, *Acropora cervicornis*, elkhorn coral, *Acropora palmata*, two species of brain coral, *Diploria* sp., boulder coral, *Montastrea annularis*, and rose coral, *Manicina aureolata*, were the dominant hard coral species on the barrier reef, which was fairly shallow (5 feet) and experienced a good deal of wave energy. Toppled colonies of elkhorn and staghorn corals were observed on the barrier reef. This is again likely to be due to the storm damage. All coral species seemed to be growing rapidly to rebuild the reef. Very little evidence of coral bleaching was observed. It was mainly confined to a few colonies of *A. palmata* in very shallow water. This bleaching condition has been shown to occur on in this species in shallow water due to abnormal warming of the surface water or nutrient loading stress. Five species of soft corals (Knobby candelabrum, *Eunicea mammosa*, sea fans, *Gorgonia* sp., porous false plexura, *Pseudoplexura porosa*, and sea feathers, *Pseudopterogorgia bipinnata* and *Pseudopterogorgia acerosa*) were observed growing on the walls leading down from Buen Hombre rocks into deep water and on the barrier reef. There were also some patchy outcrops of hard and soft corals just offshore from the Buen Hombre rocks, but inside the barrier reef. Twelve species of fishes were observed at this site, including blue tang, *Acanthurus coeruleus*, bar and yellow jacks, *Caranx ruber* and *C. bartholomaei*, Porcupine fish, *Diodon hystrix*, bluestriped grunt, *Haemulon scirus*, squirrelfish, *Holocentrus* sp., Cocoa damselfish, *Pomacentrus variabilis*, spotted goatfish, *Psuedupeneus maculatus*, parrotfish, *Scarus* sp., and Bluehead wrasse, *Thalassoma bifacsiatum*. An unidentified shark was observed roughly ten meters from the boat during the on-site visit.

Site Ethnography. The fisherman interviewed at this site has fished the location for 20 years. In addition to his crew, other fishing crews from Buen Hombre and crews from the communities of Los Uveros, La Cana, Las Aguitas, and La Loma Atravesada also fish at the location. Urban fishermen from Monte Cristi also fish at the site. Most fishing trips to the site are made during the month of April, when the water is said to be clearest. The site is visited less frequently during the period from November through February because of high water turbidity. Currents around the site fluctuate between weak and strong. Stronger currents are more common during rains. Turbidity of water is highest during late fall and winter (November through February). The rainy season brings runoff from mountain precipitation during these months.

Numerous species of seafood are harvested at this site. Table 7.5 lists the variety of species captured. Abundance of these varieties has decreased, mostly due to the increased number of fishermen. According to the fisherman interviewed, the biggest threat to fishing at this site is fishing by crews using small sweep nets (chinchorros de arrastre) who come from Monte Cristi.

Table 7.5. FISH SPECIES PRESENT/CAPTURED AT THE PIEDRA DE BUEN HOMBRE SITE

Spanish Name	English Name	Scientific Name
bocallate	grunt	*Haemulon* sp.
mero	Nassau grouper	*Epinephilis striatus*
pargo prieto	gray snapper	*Lutjanus griseus*
pargo amarillo	schoolmaster	*Lutjanus apodus*
madama	?	
mojarra	yellowfin mojarra	*Gerres cinereus*
cariti sierra	king mackerel	*Scombermorus cavalla*
langosta	spiny lobster	*Panulirus argus*
langostino	?	
centolla	spider crab	*Mithrax sculptus*
bayombe	?	
raya	stingray	*Dasyatis americana*

Piedra de Tuba (Interview #06, Station O-1)

Location and Description. This site was visited on February 22, 1991. It is named after the fisherman who was interviewed at the site, owing to the fact that as a young fisherman he "discovered" and frequented the spot, where he encountered abundant lobster and fish. It is located on the point of the reef with two large coral heads at a spot aligned with the mountain peak located south of Buen Hombre at 19 degrees, 52.4948 minutes North latitude, 71 degrees, 23.5239 minutes West longitude.

Site Ecology. This site is characterized by water thirty-four feet deep and bottom types consisting of healthy, diverse patch reef with six species of hard coral (Leaf lettuce coral, *Agaricia agaricites*, brain corals, *Colpophyllia natans* and *Diploria labyrinthiformis*, cactus coral, *Isophyllia sinuosa*, fire coral, *Millepora* sp., and boulder coral, *Montastrea annularis*) surrounded by sand. Varieties of algae (*Dictyota* sp., corraline red algae, *Halimeda opuntia*, *Penicillus* sp.) are also present at the site. Eight species of fishes were observed here (including blue tang, *Acanthurus coerulis*, gulf surgeonfish, *A. randalli*, sharpnose puffer, *Canthigaster rostrata*, Red hind, *Epinephelus guttatus*, cleaner goby, *Gobiosoma genie*, Threespot damselfish, *Pomacentrus planifrons*, striped parrotfish, *Scarus croiensis*, princess parrotfish, *S. taenopterus*, stoplight parrotfish, *Sparisoma viride*, bluehead wrasse, *Thalassoma bifasciatum*.

Site Ethnography. The fisherman interviewed at this site has fished the location for 22 years. As mentioned, he first found the spot as a young fishermen and encountered numerous lobster and fish species. Currently, he, his crew, other crews both from Buen Hombre and nearby communities of Punta Rucia and La Loma Atravesada fish at the site. The respondent and his crew stop at the site to fish about five times per month, most frequently during the spring and summer months (April through August). The reason given is that the water is clearer at this time of the year. The number of visits is reduced during November, December and January because of cold temperatures and turbidity. The currents are generally weak at the site, but during the months of December through January, the rains increase the currents and thus the turbidity of the water. Water turbidity is said to vary a good deal throughout the year.

A wide variety of fish and other seafood is harvested from this site, including lobster and crab. Table 7.6 provides a full list of species captured as told to ethnographers during the interview.

The abundance of fish was said to have declined at the site. This was due to the increased number of fishermen using the site.

Table 7.6. FISH SPECIES PRESENT/CAPTURED AT THE PIEDRA DE TUBA SITE

Spanish Name	English Name	Scientific Name
pargo riso	spanish hogfish	*Bodianus rufus*
bocallate	grunt	*Haemulon* sp.
pargo colorado	dog snapper	*Lutjanus jocu*
guinea	spotted drum	*Equetus punctatus*
mero	Nassau grouper	*Epinephelus striatus*
cabrilla	red hind	*Epinephelus guttatus*
langosta	spiny lobster	*Panuliris argus*
centolla	spider crab	*Mithrax sculptus*
langostino	?	
pulpo	octopus	*Octopus vulgaris*

La Pasa de la Posa/Boca de la Pasa de la Posa (Interviews #8, #15, #18, Station Q-1)

Location and Description. This site was visited on February 23, 1991 and February 26, 1991. Site coordinates are 19 degrees, 53.2400 minutes North latitude, 71 degrees, 25.6017 minutes West longitude. It derives its name from the depth of the water (posa, pool) in a small cove or inlet (ensenada). The site is located where the beach ends, aligned with a stone outcrop on the mountain known as El Peregon, which is used as a reference point.

Site Ecology. This site is characterized by a deep channel through the barrier reef reaching 45 to 55 feet in depth with bottom types consisting mainly of sponge reef and muddy, silty sediments. No plants were observed on this site, probably because it is beyond the depth at which light penetrates. The water clarity was murky at this site on the day we visited. Six species of sponge were identified, and these dominated the bottom cover on the reef (tube sponge, *Aplysina fistularis*, *Erylus* sp., *Haliclona viridis*, gray cornucopia sponge, *Niphates digitalis*, *Ptilocaulis spiculifer*, and Basket or tub sponge, *Xestospongia muta*). Leaf lettuce coral, *Agaricia* sp., was the only species of hard coral at this station. Sea rods, *Plexaurella grisea*, were the only type of soft coral and were rare. A shell from a mollusc, Lima scabra tenera was also collected. Fishes observed were the clown wrasse, *Halichoeres maculipinna*, sharpnose puffer, *Canthigaster rostrata*, and nassau grouper, *Epinephelis striatus*.

Site Ethnography. Two fishermen were interviewed at this site. Both have fished the location for 20 years. They and their fishing crews currently use the site, along with fishermen from other villages and cities such as La Vereda, El Manantial, Loma Atravesada, and Monte Cristi. Because of the depth of water and variable weather, the number of fishing trips to the site varies. The site is most frequently visited in spring and summer (April through September), during which time there is less rain and the water is said to be clearer. During the colder, wetter months of October through December, the number of trips is reduced. High degrees of water turbidity and strong currents also contribute to the reduction in fishing trips to the site. Water clarity fluctuates throughout the winter, but is generally always clear in the summer months. Turbidity due to runoff precipitation from the mountains and currents increase beginning in September and persisting through December, January and February. Currents are strong to the east and west. The site provides habitat for numerous species of fish and other seafood species.

Numerous species of fish and other seafood are harvested from this location. Table 7.7 provides a list of these species derived from interviews with both fishermen. Harvests reach their high point during the late spring and summer because of the warmer water temperatures during this period.

Both fishermen noted that the abundance of fish at the location has declined due to increased numbers of fishermen using the site. These include urban chinchorro fishermen. In addition, because of the relatively deep waters, the site is also exploited by fishermen using compressor technology.

Table 7.7. FISH SPECIES PRESENT/CAPTURED
AT LA PASA DE LA POSA/BOCA DE LA PASA DE LA POSA SITE

Spanish Name	English Name	Scientific Name
pargo prieto	gray snapper	*Lutjanus gresius*
pargo tao tao	?	
pargo sama	mutton snapper	*Lutjanus analis*
pargo riso	spanish hogfish	*Bodianus rufus*
chivica	?	
bocallate	grunt	*Haemulon* sp.
cotorra	parrotfish	*Sparisoma* sp.
mojarra	yellowfin mojarra	*Gerres cinereus*
vallobez	?	
madama	?	
varraco	?	
merico	Surgeonfish	*Acanthurus* sp.
pejesol	?	
langosta cucaracha	slipper lobster	*Scyllarides* sp.
jaiba marina	crab	
centolla	spider crab	*Mithrax spinosissimus*
langostino	?	
arrigua	freckled soapfish	*Rypticus bistrispinus*
mero	Nassau grouper	*Epinephelus striatus*
jurel	jack	*Caranx* sp.
cariti	king mackerel	*Scomberomorus cavala*
candil	squirrelfish	*Holocentrus* sp.
merico	surgeonfish	*Acanthurus* sp.
colirubia	yellowtail snapper	*Ocyurus chrysurus*
bemejuelo	?	

La Posa (Interview #9, Station R-1)

Location and Description. This site was visited on February 23, 1991. It is a shallow reef located in what was termed an estuary (ria) of the mangrove, between two channels and near the deep mangrove channel. It is adjacent to the La Pasa de la Posa site, where the beach and mangrove merge. The site coordinates are 19 degrees, 53.2312 minutes North latitude, 71 degrees, 25.6981 minutes West longitude.

Site Ecology. . This site is characterized by shallow waters of three to five feet in depth with bottom types consisting mainly of hard corals (*Montastrea annularis, Acropora palmata, Acropora cervicornis, Porites porites, Porites furcata, Millepora* sp., *Diploria* sp, *Colpophyllia* sp.) and soft corals (*Plexaurella grisea, Psuedopterogorgia acerosa, Eunicea mammosa*) interspersed with sponges (*Haliclona rubens, H. viridis*) and aquatic plants such as turtle grass (*Thalassia testudinum*) and macroalgae (*Stypopodium zonale, Dictyota mertensii, Caulerpa* sp.). The site provides habitat for numerous species of fish (surgeonfishes, *Acanthurus coeruleus, A. randalli*, wrasses, *Thalassoma bifasciatum, Halichoeres* sp., parrotfishes, *Scarus croiensis, S. taeniopterus*, and damselfishes, *Pomacentrus planifrons*).

Site Ethnography. The fisherman interviewed at this site has fished the location for 28 years. Fishermen from the communities of La Vereda, Los Uveros, and Las Aguitas also fish in this location, as well as other crews from Buen Hombre. Because of variable weather, the number of fishing trips to the site varies. The site is most frequently visited in spring and summer (May through August), during which time there is less rain and the water is said to be clearer. During the colder, wetter months of November through February, the number of trips is reduced. High degrees of water turbidity and variable currents also contribute to the reduction in fishing trips to the site.

Numerous species of fish and other seafood are harvested from this location. Table 7.8 provides a list of these species derived from interviews with both fishermen. Harvests are highest during the late spring and summer.

The fisherman noted that the fish populations have declined at this site. He attributed the decline to net fishing as a primary cause of fish depletion at the site.

Table 7.8. FISH SPECIES PRESENT/CAPTURED AT LA POSA SITE

Spanish Name	English Name	Scientific Name
bocallate	grunt	*Haemulon* sp.
pargo tao tao	?	
pargo prieto	gray snapper	*Lutjanus griseus*
pargo colorado	dog snapper	*Lutjanus jocu*
pargo pluma	porgy	*Calamus* sp.
pargo blanco	?	

pargo riso	Spanish hogfish	?
vallombez	?	?
mojarra	yellowfin mojarra	*Gerres cinereus*
mero	Nassau grouper	*Epinephelus striatus*
langosta	lobster	*Panuliris argus*
jaiba centolla	crab	
candil/candi	squirrelfish	*Holocentrus* sp.
pulpo	octopus	*Octopus* sp.

El Canal de la Posa (Interview #10, Station S-1)

Location and Description. This site was visited on February 23, 1991. It is located to the south of La Posa at the front of the mangrove where the deep channel terminates and the mangrove and sandy beach merge. The site coordinates are 19 degrees, 53.0595 minutes North latitude, 71 degrees, 25.7861 minutes West longitude.

Site Ecology. This site is characterized by turbid waters reaching a depth of 24 feet. The turbidity is a result of the silt and mud that make up the dominant bottom types. There were no plants of any kind at this site. No fish were observed here, although it was very turbid (visibility 3-4 feet), so that if fish were present, they would have been difficult to see. There were no large invertebrate colonies like the sponges and corals that were observed at other stations. In fact, the only indicators of life at this station were the numerous openings to polychaete worm burrows (0.5 cm diameter opening) in this soft sediment. Although an attempt was made to identify these worms, none were collected in the bottom sample taken.

Site Ethnography. The fisherman interviewed at the site has fished the location for 11 years. In addition to crews from Buen Hombre, fishermen from several other coastal communities use the spot for fishing. These communities include Las Aguitas, La Vereda, Los Uveros, Las Canas and El Manantial. The site is most often used during the spring and summer, when the water is relatively clearer and there is less breeze. In December, however, the water is very cloudy because of stronger breezes accompanying fronts bringing rain.

Table 7.9 lists the varieties of fish species that are harvested at this location. The depletion of fish stocks in this location were attributed to the larger numbers of fishermen using the site. The increased use of small nets for fishing was also given as a cause leading to decline in the fish populations at the site.

Table 7.9. FISH SPECIES PRESENT/CAPTURED
AT THE CANAL DE LA POSA SITE

Spanish Name	English Name	Scientific Name
vallombe	?	
bocallate	grunt	*Haemulon* sp.
colirubia	yellowtail snapper	*Ocyurus chysurus*
merito/mero	Nassau grouper	*Epinephelus striatus*

pargo prieto	gray snapper	*Lutjanus griseus*
cotorra	parrotfish	*Sparisoma viride*
cofre	boxfish, trunkfish	
memejuelo	?	
chivica	?	
pulpo	octopus	*Octopus* sp.

La Cordillera Afuera (Interview #11, Stations X-1, X-2, X-3)

Location and Description. Three pixel stations of this site were visited on February 25, 1991. It is located inside the second reef on a crescent formation. Its name derives from the site's location (cordillera referring to the chain of reef, afuera to its location "outside" the first reef). The site coordinates are 19 degrees, 53.6801 minutes North latitude, 71 degrees, 21.4943 minutes West longitude.

Site Ecology. This group of stations was located on and ajacent to a coral reef (part of the second barrier reef system) that was surrounded by relatively deep water, but was very shallow on the reef crest. The waters at this site range in depth from three feet (at X-3) on the barrier reef proper to twenty feet where the boat was anchored (at X-1), slightly inshore of station X-3. Site X-2 was extremely deep (47-55 feet) and the bottom sloped off into even deeper water heading inshore; consequently, no dives were conducted at X-2, but surface snorkling and satellite fixes were obtained there. The visibility was excellent at all these sites, because the bottom (and types of algae present) were visible from the surface at X-2, in approximately 50 feet of water. Site X-1 was comprised of sandy bottom with a sparse cover of vegetation, mostly green macroalgae (*Halimeda monile, H. incrassata, Avrainvillea longicaulis, Penicillus capitatus, Udotea occidentalis*) and coralline red algae (*Amphiroa rigida*), but no seagrass species. The species composition of the vegetation at site X-2 was comprised of similar species, but dominated by the larger green algal forms (*Udotea* and *Avrainvillea*). At site X-3, the shallowest station on the reef proper, a diversity of plant and animal life was observed. The reef was composed of hard corals, the dominant species being boulder coral, *Montastrea annularis*, staghorn coral, *Acropora cervicornis* (some alive, but many toppled and dead colonies), elkhorn coral, *Acropora palmata* (dead colonies only), finger coral, *Porites porites*, and tan lettuce-leaf coral *Agaricia agaricites*. The boulder corals here were the most massive observed during our visit. There were extensive areas of soft corals interspersed among the hard corals, mainly knobby candelabra, *Eunicea* sp., sea rods, *Plexaurella* sp., and sea fans, *Gorgonia* sp. Plants at this site included the dominant brown algae that colonized the dead coral reef substratum (*Turbinaria tricostata, Dictyota* sp., *Lobophora variegata*), the green algae (*Halimeda opuntia, Rhipocephalus phoenix*), and the coralline red algae *Amphiroa rigida*. In addition, there were areas covered with colonial sea anenomes (*Zooanthus sociatus*) and giant anenomes (*Condylactis gigantea*). Also present were sea urchins (*Diadema antillarum, Echinometra lucunter*), a basket star (*Astrophyton muricatum*), and christmas-tree polychaete worms (*Spirobranchus giganteus*). The fishes at this site were very diverse (15 species): Nassau grouper (*Epinephelus striatus*), coney (*Epinephelus fulvus*), blue striped grunt (*Haemulon scirus*), damselfish (*Microspathodon chrysurus, Pomacentrus* sp.), stoplight parrotfish (*Sparisoma viride*), bluehead wrasse (*Thalassoma* *bifasciatum*), squirrelfish (*Holocentrus adscensionis*), foureye butterflyfish (*Chaetodon capistratus*), ocean surgeon (*Acanthurus bahianus*), slippery dick (*Halichoeres bivittatus*), an unidentified goby (*Gobiosoma* sp.), bar jack (*Caranx ruber*), and yellowfin mojarra (*Gerres cinereus*). The fishes here appeared to be larger and more abundant than at the inshore reef stations, especially the groupers.

Site Ethnography. The fisherman interviewed at this site has fished the location for 20 years. Besides fishing crews from Buen Hombre, fishermen from Punta Rucia, La Vereda, Loma Atravesada, and Monte Cristi also fish at the site. The site is most intensively used in the spring and summer months when currents, water clarity, and wind conditions are more favorable to sailing without a motor. The number of trips are limited in the winter because of adverse weather. Frequent lack of motors prevents fishermen from visiting the site.

The site once supported large stands of aquatic vegetation. The water is generally clear, but because of seasonal variation in the strength of the currents, clarity also fluctuates. Turbidity is higher in winter, because of runoff from mountain rains and deposition by rivers flowing out into the coastal waters from Puerto Plata to the east and Monte Cristi to the west. Turbidity is lower in late spring and summer. The site provides habitat for numerous seafood species.

Many fish species and other types of seafood are harvested from this site. Table 7.10 lists the varieties of marine life captured at the site. The abundance of seafood harvested has decreased because of increased exploitation by larger numbers of fishermen. Significantly, the aquatic plants and coral that provide habitat for fish has been degraded as well. According to the fisherman interviewed at the site, the location once supported relatively dense aquatic plant life. He noted that fishermen have extracted the vegetation and coral to sell to intermediaries based in Santo Domingo. So in addition to the loss of animal species, this site represents one of the few examples of a marine location exploited for its aquatic plant resources, resulting in a deteriorated habitat for marine animals.

Table 7.10. FISH SPECIES PRESENT/CAPTURED AT LA CORDILLERA DE AFUERA SITE

Spanish Name	English Name	Scientific Name
cotorra	parrotfish	*Scaridae*
mojarra	yellowfin mojarra	*Gerres cinereus*
cabrilla	red hind	*Epinephelus guttatus*
bocallate	grunt	*Haemulidae*
langosta	spiny lobster	*Panulirus argus*
centolla	spider crab	*Mithrax spinossisimus*
lambi	queen conch	*Strombus gigas*
madama	?	
pargo tao tao	?	
pargo pluma	porgy (pluma)	*Calamus* sp.
merico	surgeonfish	*Acanthuridae*
chivito	?	

jira	?	
mero	Nassau grouper	*Epinephelus striatus*

La Punta de la Cordillera de Afuera (Interview #14, Station W-1)

Location and Description. This site was visited on February 25, 1991. It is located at the point (punta) of the second, outside reef. The site coordinates are 19 degrees, 53.7680 min. North latitude, 71 degrees, 21.7255 minutes West longitude.

Site Ecology. This site was a beautiful hard and soft coral reef that showed a high degree of equitablity among coral species. It was a flat region of the second reef in 20 feet of water. The bottom was dominated by boulder coral (*Montastrea annularis*), brain coral (*Diploria strigosa*), and mustard hill coral (*Porites asteroides*), but staghorn coral (*Acropora cervicornis*), fire coral (*Millepora* sp.), and finger coral (*Porites porites*) occurred here as well. The soft corals were striking in terms of their diversity, with nine species occurring: slimy and smooth sea feathers (*Psuedopteragorgia americana* and *P. acerosa*), sea fans (*Gorgonia* sp.), tan bushy soft coral (*Plexaura flexulosa*), knobby candelabrum (*Eunicea mammosa*), sea blade (*Pterogorgia* sp.), false sea rod (*Psuedoplexaura* sp.), deadman's fingers (*Briarium asbestinum*) and sea plumes (*Muriceopsis flavida*). These soft corals were widely distributed among the site, not clumped together as at the inshore stations. Additional bottom cover was occupied by sponges (*Haliclona viridis* and *Siphonodictyon coralliphagum*). Plant species in this area were the brown macroalgae (*Dictyota mertensii, Sargassum fluitans*, and *Stypopodium zonale*) and one species of green algae (*Halimeda opuntia*). Fishes were abundant, especially the coney (*Epinephelus fulvus*), a type of grouper, which was extremely abundant here on the day we visited. These fish did not seem to avoid the divers as much as fish at the inshore stations. Nine species of fish were observed here: coney, striped parrotfish (*Scarus croiensis*), yellowtail snapper (*Ocyurus chrysurus*), yellowhead wrasse (*Halichoeres garnoti*), bluehead wrasse (*Thalassoma bifasciatum*), blue tang (*Acanthurus coeruleus*), ocean surgeon (*Acanthurus bahianus*), stoplight parrotfish (*Sparisoma viridens*), and yellowtail damselfish (*Microspathodon chrysurus*). The site provides habitat for numerous species of marine animals.

Site Ethnography. The fisherman interviewed at this site has fished the location for nearly 25 years. The site is primarily fished by people of Buen Hombre. Other fishermen also fish at the site, however, the respondent mentioned that use by others was infrequent. The site is most commonly fished when the water is clearer, calmer and warmer during the months April through August. The spot is less frequently visited during the period December through March, when the water is colder and more turbid. The waters are generally clear and calm except for the winter months (December through February). Currents during this time are varied.

As with most locations on the outer reef, numerous types of fish are harvested. Table 7.11 lists the types captured. This site can be a risky place to fish, since barracuda and shark are encountered around the outer reef.

The fisherman interviewed at the site noted that there has been a decrease in the number of fish harvested from the location. The decrease was attributed to more intensive use by more fishermen.

Table 7.11. FISH SPECIES PRESENT/CAPTURED AT LA PUNTA DE LA CORDILLERA AFUERA SITE

Spanish Name	English Name	Scientific Name
pargo	snapper	*Lutjanidae*
cotorra	parrotfish	*Scaridae*
varraco	?	
colirubia	yellowtail snapper	*Ocyurus chrysurus*
bocallate	grunt	*Haemulidae*
mero	Nassau grouper	*Epinephelus striatus*
candil	squirrelfish	*Holocentrus* sp.
tortuga	sea turtle	
centolla	spider crab	*Mithrax spinossisimus*
cofre	boxfish, trunkfish	
arrigua	freckled soapfish	*Rypticus bistripinus*
langosta	spiny lobster	*Panulirus argus*
carel	?	
chivo	?	
cariti	king mackerel	*Scomberomorus cavalla*
picua	great barracuda	*Sphyraena barracuda*
tiburon	shark	*Carcharodon* sp.

Los Morrales (Interviews #12, 13, Stations V-1, V-2)

Location and Description. This site was visited on February 25, 1991. The coordinates are 19 degrees, 52.7884 minutes North latitude, 71 degrees, 22.8628 minutes West longitude. It is located about 6 kilometers east of the Buen Hombre beach, 2.5 kilometers offshore, in the second lagoon. The site is recognized by aligning a gap in the mountains near Punta Rucia with a grouping of blackish rock surrounded by white sand and gulfweed (sargazo) seagrass.

Site Ecology. These sites are located near a patch reef in waters between 44 to 48 feet in depth. Two sites were visited here: V-1 was mostly sparse seagrass, green macroalgae and sand; V-2 was the patch coral reef at the eastern end of the site. Satellite positions and depth readings were taken only for site V-1. There was an obvious "halo" effect around this site, i. e., there was a clear zone of bare sand (no vegetation) surrounding the patch reef, in between site V-1 and V-2. These "halo" effects where they have been observed elsewhere are caused by herbivorous fishes that leave the reef to feed, but only venture away from protection of the reef a short distance. This "halo" was described by the Buen Hombre fishermen as well. V-1 was outside of the "halo". Vegetation at V-1 consisted of turtle grass (*Thalassia testudinum*), and a diverse array of green algae (seven species in the genera *Udotea, Avrainvillea, Rhipocephalus, Penicillus*, and *Halimeda*). No fish or invertebrates were observed at V-1. At V-2, the patch reef was a mixture of hard corals (*Montastrea* *annularis, Diploria strigosa, Millepora alcicornis, Isophyllia sinuosa, Agaricia agarites*, and *Porites porites*). Banded sea lillies (*Tropiometra carinata*) were common, as were purple bush sponge (*Haliclona viridens*), tube sponges (*Aplysina fistularis*) and boring red sponge (*Cliona delitrix*). An unidentified colonial tunicate was also common at this site. Fishes observed here included many blue chromis (*Chromis cyaneus*), coney (*Epinephelus fulvus*), bicolor damselfish (*Pomacanthus leucosticus*), stoplight parrotfish (*Sparisoma viride*), striped parrotfish (*Scarus croiensis*), bluehead wrasse (*Thalassoma bifasciatum*). Buen Hombre fishermen shot a hogfish (*Lachnolaimus maximus*) and a schoolmaster (*Lutjanus apodus*) at this patch reef while we were diving.

Site Ethnography. Two fishermen were interviewed at this site. Both have fished the location for 20 years. Fishermen from nearby villages also use the spot in addition to those from Buen Hombre. The site is fished most frequently during late spring and summer when the waters are clearer and warmer. It is visited less often during the winter months (December through March) because of higher turbidity and colder water temperatures. One fisherman said that he fished at the location an average of seven times per month. The waters are seasonally warm, calm and clear in the late spring and summer, cold, rougher and more turbid in the winter, due to ocean current patterns.

Fishermen harvest numerous types of seafood at this location. These are listed in Table 7.12. One fisherman noted that sea turtle (tortuga) is encountered at this site. The size of fish and other marine populations are seen as having diminished in size, noticable even in the last year. This was attributed to more fishermen using the site, particularly those using compressors that increase the amount of time a fisherman can remain submerged, thereby increasing the amount of seafood captured. One fisherman added that increased exploitation by net fishermen prevent fish from returning. This is likely due to the habitat destruction, notably tearing up of seagrass beds, caused by the nets.

Table 7.12. FISH SPECIES PRESENT/CAPTURED AT LOS MORRALES

Spanish Name	English Name	Scientific Name
pargo pluma	porgy	*Calamus* sp.
pargo riso	hogfish	*Lachnolaimus maximus*
pargo amarillo	schoolmaster	*Lutjanus apodus*
varraco	?	
bocallate	grunt	Haemulidae
arrigua	freckled soapfish	*Rypticus bistripinus*
candil	squirrelfish	*Holocentrus* sp.
mero	Nassau grouper	*Epinepheleus striatus*
chivo	?	
centolla	spider crab	*Mithrax spinosissimus*
cariti	kingfish	*Scomberomorus cavalla*
cohinua	bar jack	*Caranx ruber*
colirubia	yellowtail snapper	*Ocyurus chrysurus*
picua	great barracuda	*Sphyraena barracuda*

carel	?	
delfin (dorado)	dolphin (fish)	*Coryphaenus* sp.
tortuga	sea turtle	
jurel	jack	*Caranx* sp.
guinea	spotted drum	*Equetus punctatus*

La Pasa de la Silla de Caballo/Silla de Caballo (Interviews #16, 17, Station Y-1)

Location and Description. This site was visited on February 26 and 27, 1991. It is located offshore of the coastal community of La Vereda. The formation of the mountain in front of the community resembles the saddle of a horse (silla de caballo), from which the site gets its name. The site is a small passage or channel. No site coordinates could be taken for this site due to the satellites not working.

Site Ecology. This is a coral reef site on the second barrier reef with a depth range of two feet on the reef crest to over 36 feet inshore of the reef; there is a very steep reef back and front. Vegetation at this site is dominanted by five species of brown alage [*Dictyota* (2 species), *Stypopodium zonale* and *Sargassum* (2 species)] with some green alage (*Halimeda, Avrainvillea*) and coralline red algae (*Amphiroa*) mixed in. There were large areas of toppled elkhorn coral, *Acropora palmata*, on which *Dictyota* and *Sargassum* grew extensively. The Buen Hombre fishermen call these plants pino and sargazo. There were a diversity of coral species at this site (living *Acropora palmata, Millepora* sp., *Psuedoplexaura* sp., *Agaricia* sp., *Eunicea* sp., *Montastrea annularis, Psuedoterogorgia americana, Gorgonia* sp., *Plexaura* sp., *Porites porites, Porites asteroides, Montastrea cavernosa*, and *Diploria strigosa*). Fishes observed at this site were bluehead wrasse, *Thalassoma bifasciatum*, stoplight parrotfish, *Sparisoma viride*, striped parrotfish, *Scarus croiensis*, blue tang, *Acanthurus coeruleus*, honey gregory, *Pomacentrus diencaeus*, rainbow wrasse, *Halochoeres pictus*, cleaner gobie, *Gobiosoma genie*, bar jack, *Caranx ruber*, spotted trunkfish, *Lactophrys quirter*, squirrelfish, *Holocentrus* sp., gray angelfish , *Pomacanthus arcuatus*, blue-spotted damselfish, *Microspathodon chrysurus*, sargent major, *Abedefduf saxatilis*, blue chromis, *Chromis cyaneus*, and the great barracuda, *Sphyraena barracuda*). Clearly this was one of the most diverse areas in terms of coral species (8 species of hard corals and 5 species of soft corals) and fishes (16 species).

Site Ethnography. Two fisherman were interviewed at this site. Both have fished the location for 20 years. In addition to Buen Hombre fishing crews, fishermen from the communities of La Vereda, Monte Cristi, and interior villages on the other side of the mountains fish at the site. The site is visited on an average of four to five times per month by the respondent and his crew. Fishing is more common at the location during late spring and summer when the waters are clearer and warmer. Conversely, colder and more turbid waters reduces the number of trips made to the site during the winter.

The fishermen of Buen Hombre harvest many varieties of fish and other seafood species from the site. A list of the kinds of species captured at the site is presented in Table 7.13. The decline in fish stocks at the location, according to the fisherman interviewed, is due to the growth in the number of fishermen using the site with more and varied kinds of technology, including nets and compressors.

Table 7.13. FISH SPECIES PRESENT/CAPTURED
AT LA PASA DE LA SILLA DE CABALLO/SILLA DE CABALLO SITE

Spanish Name	English Name	Scientific Name
bocallate		
pargo pluma		
pargo prieto		
pargo colorado		
cotorra		
mero	grouper, sea bass	
cariti		
colirubia		
candi		
bocallate		
arrigua		
pulpo	octopus	
bulgao	stocky cerith snail?	
varraco	hogfish	
picua	barracuda	
lambi	conch	
centolla	spider crab	
langosta	lobster	

Bajio de lo Jengibre (Interview #19, Station Z-1)

Location and Description. This site was visited on February 27, 1991. It is located near the end of the Buen Hombre beach in the first lagoon. Its coordinates are 19 degrees, 53.1107 minutes North latitude, 71 degrees, 25.9789 minutes West longitude.

Site Ecology. This is a unique, ecologically heterogeneous round patch reef site approximately 45 meters in width. Its uniqueness is evidenced both in the name by which it is referred (bajio means shallows or sandbank, jengibre means ginger), and its ecological makeup. The site gets its name from an abundance of crustious red, rose or coraline algae, known locally as jengibre. The waters range from a very shallow two feet to three feet in depth with bottom types consisting of the red coral, Thalassia seagrass and sand. The waters are calm and clear throughout the major part of the year. During the winter months of December through February, turbid water washes in from a nearby channel. Consequently, the deeper waters of the site area are turbid much of the year. The site provides habitat for several species of fish and other marine animals.

Site Ethnography. The fisherman interviewed at the site has known of the location for 20 years. Interestingly, the fishermen of Buen Hombre do not fish at the spot, according to both fishermen interviewed. Fishermen using chinchorro nets from Monte Cristi, however, exploit the site. One fisherman mentioned that he has observed the ecological condition of the site for 20 years.

Several species of marine life either inhabit the site or pass through during migrations. Table 7.14 lists the species present at the site. In the deeper portions of the site, the most significant animals passing through is the manatee and sea turtle. It seems likely that the shallows of the site serve as a nursery and feeding ground for several species of marine animals, and it is apparent that Buen Hombre fishermen avoid fishing the location for this reason. Nevertheless, one fisherman noted that the abundance of marine life has declined at the site, and he attributed these losses to exploitation by chinchorro fishermen.

Table 7.14. FISH SPECIES PRESENT/CAPTURED AT THE BAJIO DE JENGIBRE SITE

Spanish Name	English Name	Scientific Name
cofre	boxfish, trunkfish	
pulpo	octopus	
candil		
langosta	lobster	
mojarra	mojarra	
merito/mero	grouper, sea bass	

Canal de lo Mangle (Interview #20, Station Z-2)

Site Location and Description. This site was visited on February 27, 1991. It is known locally as simply a mangrove channel (canal de lo mangle). It is located out from a cano or narrow channel known as cano de mongo. Site coordinates are 19 degrees, 53.1409 minutes North latitude, 71 degrees, 26.1378 minutes West longitude.

Site Ecology. The waters at this site are 13 feet in depth with bottom types consisting of extensive Thalassia seagrass, green algae, mud and sand. The waters are calm but turbid throughout the major part of the year. During the winter months of December through February, turbid water washes in from the mangrove. Consequently, the waters of the site area are turbid much of the year. The site provides habitat for several species of fish and other marine animals.

Site Ethnography. The fisherman interviewed at the site has known of the location for 20 years. Fishermen from Monte Cristi, however, exploit the site with trasmallo and chinchorro de arrastre nets. The fishermen of Buen Hombre do not fish at the spot because they do not use these types of nets.

Several species of marine life either inhabit the site or pass through during migrations. Table 7.15 lists the species present at the site. The most significant animals passing through is the manatee and sea turtle. It seems likely that the shallows of the site serve as a nursery and feeding ground for several species of marine animals, and it is apparent that

Buen Hombre fishermen avoid fishing the location for this reason. Nevertheless, the fisherman noted that the abundance of marine life has declined at the site, and he attributed these losses to exploitation by chinchorro fishermen.

Table 7.15. FISH SPECIES PRESENT/CAPTURED AT THE CANAL DE LO MANGLE SITE

Spanish Name	English Name	Scientific Name
jurel	yellow jack, mackerel	
picua	barracuda	
cariti		
bemejuela		
pargo prieto		
pargo sama		
ballumve		
mojarra	mojarra	
cohinua		
bocallate		
colirubia		
mero	grouper, sea bass	
cofre	boxfish, trunkfish	
tortuga	sea turtle	
manati	manatee	

Cayo Arena (Interview #21, Stations AA-1, AA-2, AA-3)

Location and Description. This site was visited on March 1, 1991. It is a small raised sandy island or key east-northeast of the Buen Hombre beach, off the coast of the community of Sansie. Coordinates for three pixel stations were taken. These are listed below:

*AA-1: 19 degrees, 52.2221 min. N. latitude, 71 degrees, 18.3523 min. W. longitude (land)
*AA-2: 19 degrees, 52.2363 min. N. latitude, 71 degrees, 18.4145 min. W. longitude
*AA-3: 19 degrees, 52.2528 min. N. latitude, 71 degrees, 18.3165 min. W. longitude

Site Ecology. The island and immediate environs are characterized by waters ranging in depth from five to eighty feet in depth with bottom types of mixed sand, coral and seagrass. Currents are weak around the island, but water turbidity is highly variable throughout the year, particularly during the rainy season (November through February). The site provides habitat for many species of fish and other seafood species.

Site Ethnography. The fisherman interviewed at this site has fished the location for 20 years. The site is used by fishermen from nearby coastal communities of Punta Rucia, Loma Atrevesada and La Vereda. The site is more frequently visited during late spring and summer (May through August), when the ocean waters are calm. Because of calm waters during this time, the fairly distant site can be reached by fishermen without a motor. The number of visits to the site is reduced during the period November through March for two reasons. First, rougher waters necessitate the use of a motor, which is not always possible, to reach the site. Secondly, the waters are said to be colder and more turbid during this time of the year because it is the rainy season. The fisherman interviewed at the site attributed the higher turbidity to runoff of precipitation and deposition of sediments flowing out to the area from the rivers near Puerto Plata, Catillo--a community near Punta Rucia, Luperon, and the Rio Yaque del Norte near Monte Cristi.

Many types of fish and seafood species are harvested from the site. These are listed in Table 7.16. Varieties of shellfish such as crabs, lobster, and conch are found at the site. In addition, a conch-type shellfish known locally as <u>bulgao</u> is seasonally present in May when the waters are calm.

The abundance of seafood resources at this site were said to have declined for two reasons. First, a growing number of fishermen use the site. More significantly, many of these fishermen employ <u>chinchorro</u> nets and compressors, destructive technologies in a fragile microenvironment. Second, there has been a rapid increase in the number of tourists who visit the site to engage in recreational activities such as swimming, boating and snorkeling. Consequently, it was explained by the fishermen that the intensification of both kinds of activities, conducted by growing numbers of people, will eventually put the site and the resources it supports at a greater risk of degradation and eventual destruction.

Table 7.16. FISH SPECIES PRESENT/CAPTURED AT THE CAYO ARENA SITE

Spanish Name	English Name	Scientific Name
bocallate		
cabrilla	cabrilla	
pargo colorado		
pargo tao tao		
cotorra	parrotfish	
lambi	conch	
centolla	spider crab	
langosta	lobster	
jaiba marina	crab	
madama		
bulgao		

Palo de la Garza (Interview #22, Station P-1)

<u>Location and Description</u>. This site was visited on March 2, 1991. It is located near a mangrove channel in proximity to the entrance to the <u>canon</u>, or deep water portion of the channel. The site coordinates are 19 degrees, 50.9434 minutes North latitude, 71 degrees, 18.8561 minutes West longitude. The name derives from the fact that the location is frequented by a population of herons.

Site Ecology. This site is characterized by waters ranging from a shallow four to five feet to twelve feet deep with typical mangrove bottom types composed of seagrass and mud. Currents are generally weak, but water turbidity is variable. High degrees of turbidity are more common during the rainy winter months (November through February) when the muddy bottom is stirred up as the mangrove waters rise. Water is clearer during late spring and summer. The site provides habitat for many varieties of fish.

Site Ethnography. The fisherman interviewed at the site has fished the location for 20 years. In addition to his crew and others from Buen Hombre, the site is also used by fishermen from the communities of El Cope, Punta Rucia, Estero Hondo, and Sancho Manuel. Tourists also visit the location as a recreational activity.

Fishing trips to the site are more frequently carried out in late spring and summer, when the waters are said to be clearer. During the rainy winter months (November through February), the turbidity of the water limits the amount of visits to the site by fishermen.

Many varieties of seafood are taken from the site. Table 7.17 provides a list of the fish and other seafood species. According to the fisherman interviewed, the abundance of seafood at this location has decreased. He attributed the decline to increased use of the site by a larger number of fishermen.

Table 7.17. FISH SPECIES PRESENT/CAPTURED
AT THE PALO DE LA GARZA SITE

Spanish Name	English Name	Scientific Name
pargo prieto		
picua	barracuda	
sabalo	shad	
robalo	bass	
mojarra	mojarra	
vallombe		
lisa	striped mullet	
boqueron	small sardine	
mejua		
bocallate		
chucho	herring-like fish	
raya	ray, skate	
langosta	lobster	
centolla	spider crab	

Pasa de lo Grullone (Interview #24, Stations N-1, N-2)

Location and Description. Two pixel stations of this site were visited on on February 21, 1991 and again on March 2, 1991. The site is located to the west of a nearby channel of the same name that extends to the shore. The site coordinates are 19 degrees, 51.6751 minutes North latitude, 71 degrees, 22.1171 minutes West longitude. Another pixel station had coordinates of 19 degrees, 51.6900 minutes North latitude, 71 degrees, 22.2518 minutes West longitude.

Site Ecology. The two pixel stations of this site are characterized by water ranging from four to 13 feet in depth with a bottom type of seagrass interspersed with patch reef, coral and algae. Currents are weak at the site, but turbidity of water varies with the season, being clearer during late spring and summer, and becoming increasingly turbid in the fall and winter (November through February) due to rainfall runoff from the mountains. The site provides habitat for numerous species of fish and other marine animals.

Site Ethnography. The fisherman interviewed at the site has fished the location for 20 years. Fishermen from other coastal villages, including La Vereda, Sabana Cruz, and Punta Rucia, as well as urban fishermen from Monte Cristi, use the spot for fishing in addition to Buen Hombre fishermen. Tourists also visit the site as a form of recreational activity.

Fishing at the site is carried out more frequently during the months of May through July. The water is said to be clearer during this time. Turbid waters during the rainy winter season reduces the number of trips fishermen make to the spot.

Numerous species of fish and shellfish are harvested from the location by fishermen. Table 7.18 provides a list of these species. The abundance of fish numbers has decreased due to increasing numbers of fishermen using the site. Chinchorro fishermen's nets make a large contribution to destroying habitat for seafood populations. In fact, the fisherman interviewed at the site noted that a species of fish known as macabi (banana fish) has disappeared from the location entirely. This is the only instance where the fishermen mentioned that a type of fish has become "extinct" or fished out completely at a site.

During the first site visit on February 21, ethnographers had the opportunity to observe a crew of chinchorro fishermen engaging in fishing. Divers obtained a satellite fix of coordinates at each end of the chinchorro net and then went down to observe mesh size and contents.

The net approached 125 to 175 meters in size, spread out in a circular formation much like a beach seine net, in waters ranging from four to eleven feet deep. From the margins of the net the mesh size decreased from three inches to less than one inch at the narrow or "caught" end, where there was a bag attached into which captured fish eventually swam. That chinchorro net usage results in indiscriminate and destructive catches was evident from the contents of the net, observed by divers. The net had snared a six-inch porcupine fish, a six-inch spiny lobster, and numerous juvenile bicolored damselfish, parrotfish, and spotted goatfish. Virtually all of these fish were less than 50 millimeters to two inches in length.

Table 7.18. FISH SPECIES PRESENT/CAPTURED
AT THE PASA DE LO GRULLONE SITE

Spanish Name	English Name	Scientific Name
pargo pluma		
pargo sama		
cohinua		
jurel	yellow jack, mackerel	
mojarra	mojarra	
guaguancho		
lambi	conch	
langosta	lobster	
centolla	spider crab	
bocallate		
candil		
memejuelo		
mero	grouper, sea bass	
vallombe		
agujon		
balaju		
colirubia		
chivo	goatfish	
chivica		
palometa	palometa	
macabi*	bonefish	

*extinct at site

La Punta del Muerto (Interview #25, Stations M-1, M-2, M-3, M-4)

Location and Description. Four pixel stations comprising this site were visited on February 20, 1991. An ethnographic interview was conducted on March 2, 1991. It is located at the end of a beach along the Buen Hombre harbor. Site coordinates for station M-2 are 19 degrees, 52.1559 minutes North latitude, 71 degrees, 24.2170 minutes West longitude. The coordinates for the other pixel stations are listed below:

*M-1: 19 degrees, 52.0130 min. N. latitude, 71 degrees, 24.1127 min. W. longitude
*M-3: 19 degrees, 52.1244 min. N. latitude, 71 degrees, 24.0524 min. W. longitude
*M-4: no coordinates taken--satellites down

The site derives its name from an occasion in which a person from another area drowned and the body was found floating at the site.

Site Ecology. This site is characterized by shallow waters about four feet deep with bottom type of mixed coral, seagrass and sand. The water is more or less clear and calm throughout the major part of the year. The only time it is consistently cloudy is in December, due to the rains. The site provides habitat for numerous species of seafood.

Site Ethnography. The fisherman interviewed about the site participated in the ecological assessment and collection of samples. He has fished the location for 11 years. In addition to Buen Hombre fishermen, fishermen from the communities Las Canas, Los Conucos, and Los Uveros also use the spot for fishing. The site is used most frequently from May to August when the waters are warmer and clearer. During the rainy season month of December, the water is consistently cloudy, and therefore less trips are made to the site.

A large number of fish and other seafood species are harvested from the site. These species are listed in Table 7.19. According to the fisherman interviewed at the site, the abundance of fish and shellfish has declined at the site. He attributed the decline of fish populations at the site primarily to the use of chinchorro nets by increasing numbers of fishermen.

Table 7.19. FISH SPECIES PRESENT/CAPTURED AT THE LA PUNTA DEL MUERTO SITE

Spanish Name	English Name	Scientific Name
bocallate		
sabalo	shad	
mero	grouper, sea bass	
langosta	lobster	
pargo sama		
pargo riso	Spanish hogfish	
pargo manchila		
pargo mantequilla		
pargo tao tao		
arrigua		
candil		
cotorra	parrotfish	
colirubia		
centolla	spider crab	
cofre	boxfish, trunkfish	
pulpo	octopus	
lambi	conch	

Other Marine Sites Visited

The section below describes sites that were visited during the course of the fieldwork for the purpose of collecting biological samples and making ecological assessments. No ethnographic interviews were conducted at these sites, because the majority of them are more proximal to Punta Rucia than Buen Hombre. Still, the site descriptions help to characterize a larger coastal marine area along the north coast.

La Pasa (Stations B-1, B-2, B-3)

Site Location and Description. Three pixel stations of this site were visited on February 17, 1991. The boat captain from Punta Rucia referred to the site as La Pasa. Site coordinates are listed below:

*B-1: 19 degrees, 50.2986 min. N. latitude, 71 degrees, 14.2956 min. W. longitude
*B-2: 19 degrees, 50.3856 min. N. latitude, 71 degrees, 14.3201 min. W. longtiude
*B-3: 19 degrees, 50.3768 min. N. latitude, 71 degrees, 14.3259 min. W. longitude

Site Ecology. The site is a large seagrass bed near the Discovery Bay hotel. Water depth at the above pixel stations is 13 feet, 11 feet, and 35 feet, respectively. Station B-1 was a seagrass bottom, with turtlegrass, *Thalassia*, dominant. Green algae species (*Penicillus dumetosus, Halimeda incrassata, Avrainvillea longicaulis*, and *Rhipocephalus phoenix*) were also present. There was a soft coral patch reef just to the east of this station. Fishes observed included *Sparisoma croicensis, Ocyurus chrysurus, Halichoeres bivittatus*, and *Halichoeres radiatus*. Station B-2 was a seagrass bottom, with equal abundance of turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*) present. Five species of gren macro-algae were also collected here (*Udotea cyanthiformes, Penicillus dumetosus, Halimeda incrassata, Halimeda monile,* and *Cladocephalus luteofuscus*). Many juvenile striped parrorfish, *Sparisoma croicensis*, were observed hiding in the seagrasses at this site. This was also a high surge area on the day we visited. Station B-3 was a sparse seagrass bottom, with low densities of *Thalassia* and *Syringodium* present. Much of the bottom was open sand. A green macroalgae, *Udotea flabellum* was also observed here. No fishes or invertebrates were noted at this site.

The sites described below are listed by station number only. No names for them were elicited from local fishermen.

Stations F-1 and F-2

Site Location and Description. The two pixel stations of this site were visited on February 19, 1991. They are near the Discovery Bay hotel in Punta Rucia. Site coordinates are listed below:

*F-1: 19 degrees, 50.3524 min. N. latitude, 71 degrees, 12.9602 min. W. longtiude
*F-2: 19 degrees, 50.3871 min. N. latitude, 71 degrees, 12.9776 min. W. longtiude

Site Ecology. These two stations are located in the first lagoon off the hotel. Water depth ranges from four-and-a-half to eight feet at the two stations, respectively. Bottom types are seagrass and sand. Station F-1 was dominated by 2-4 m^2 patches of seagrasses (*Halodule wrightii* and *Thalassia*) with green macroalgae *Penicillus capitatus* interspersed in a large area of open sand. Swimming crabs, *Portunus* sp., yellowtail snapper, *Ocyurus chrysurus*, and barbu, *Polydactylus virginicus*, were caught here in a cast net. Station F-2 was a large patch of *Thalassia testudinum* and *Syringodium filiforme*. Also present were green algae, *Halimeda monile, Rhipocepahlus phoenix, Avrainvillea nicricans, Udotea cyanthiformis, U. occidentialis, Penicillus capitatus*, and *Cladocephalus leuteofuscus*. Brown algae, *Turbinaria turbinata* and *Sargassum fluitans*, were also present. No invertebrates or fishes were observed at F-2.

Station G-1

Site Location and Description. A seagrass meadow near the Discovery bay Hotel.

*G-1: 19 degrees, 50.2055 min. N. latitude, 71 degrees, 13.9953 min. W. longtiude

Site Ecology. Turtlegrass, *Thalassia testudinum*, was the dominant bottom cover at this site. Five species of green algae were also present (*Penicillus capitatus, Halimeda incrassata, Culerpa lanuginosa, Avrainvillea longicaulis*, and *Dictyosphaeria cavernosa*). Very few fish were observed here, mostly juvenile parrotfish.

Stations H-1 and H-2

Site Location and Description. The two stations are located in front of the Discovery Bay Hotel, and the boat captain from the hotel called the site "Morete". Station H-1 was a Thalassia seagrass meadow and H-2 was a small patch reef nearby. Coordinates:

*H-1: 19 degrees, 50.3638 min. N. latitude, 71 degrees, 14.5548 min. W. longtiude
*H-2: 19 degrees, 50.3524 min. N. latitude, 71 degrees, 14.5615 min. W. longtiude

Site Ecology. H-1 was dominated by *Thalassia testudinum* in 17 feet of water. No detailed sampling was made at this site. Station H-2 was a patch reef in the middle of the seagrass meadow. depth here was 4 - 7 feet. Brown algae *Lobophora variegata* and *Turbinaria turbinata* were common on the reef. Boulder coral, *Montastrea annularis*, staghorn coral, *Acropora cervicornis*, fire coral, *Millepora* sp., yellow porous coral, *Porites asteroides*, green cactus coral, *Isophyllia sinuosa*, grooved brain coral, *Colpophyllia natans*, were present. Soft corals were very common at this station and included sea rods, *Plexaurella* sp., knobby candelabrum, *Eunicea mammosa*, sea fans, *Gorgonia* sp., seafeathers, *Pseudopterogorgia bipinnata*, and deadman's fingers, *Briarium asbestinum*. Yellow tube sponges, *Aplysina fisturlaris*, were also common. Fishes observed at this station included yellowhead wrasse, bluehead wrasse, striped parrotfish, stoplight parrotfish, redfin parrotfish, yellowtail sanpper, squirrelfish, spotted trunkfish, spotted goatfish, threespot damselfish, beaugregory, and sergeant major.

Station I-1

Site Location and Description. This is a seagrass meadow station in the first lagoon. Coordinates:

*I-1: 19 degrees, 50.4045 min. N. latitude, 71 degrees, 14.7607 min. W. longtiude

Site Ecology. The depth at the site is 6 feet. *Thalassia testudinum* and *Syringodium filiforme* are both dominant seagrasses at the site. Also present are green macroalgae *Halimeda monile* and *Avrainvillea* sp. The brown alga *Dictyota* sp. was also observed. Invertebrates present at this site included sea eggs, *Tripnuestes ventricosus*, burrowing sea cucumbers, *Holithuria arenicola*, and large flower coral, *Mussa angulosa*. No fishes were observed.

Stations J-1 and J-2

Site Location and Description. These stations are near the Discovey Bay HOtel, but furthest offshore. J-1 was located near a large patch reef, which was at J-2. Coordinates:

*J-1: 19 degrees, 50.5445 min. N. latitude, 71 degrees, 14.9369 min. W. longtiude
*J-2: 19 degrees, 50.5685 min. N. latitude, 71 degrees, 14.9138 min. W. longtiude

Site Ecology. Station J-1 was a sparse seagrass and macroalgae bottom, with a lot of open sand in 24 feet of water. This site had *Thalassia* present, but was dominated by *Halimeda opuntia* and *H. monile*. Station J-2 was a very large coral patch reef. The site aws shallow on top of the reef (2 feet) where many toppled coral colonies (*Acropora cervicornis*) were observed. The reef sloped rapidly into 20 feet of water toward J-1. Brown algae species were dominant at this station, including *Lophophora variegata, Sargassum* sp., and *Turbinaria turbinata*. Boulder coral, *Montastrea annularis*, was the dominant hard coral, but brain coral, *Diploria labyrinthiformis*, fire coral, *Millepora* sp., and staghorn coral, *Acropora cervicornis* were present. Sea rods, *Plexaurella* sp., were common. Fishes observed were brown chromis, Spanish hogfish, trumpetfish, yellowhead wrasse, bluehead wrasse, sharpnose puffer, fairl basslets, blue-striped grunts, paleback goby, yellowline goby, striped parrotfish, neon goby, blue tang, damselfishes, squirrelfish, and Nassau grouper. This was a very diverse patch reef.

The sites described below are all located near the playa del coco, east of Buen Hombre beach.

Station T-1

Site Location and Description. This site was visited on February 24, 1991.

*T-1: 19 degrees, 50.3422 min. N. latitude, 71 degrees, 20.9842 min. W. longtiude

Site Ecology. This station is a seagrass meadow, dominated by *Thalassia testudinum*. Eight species of green algae were present as well. Burrowing sea cucumbers and anenomes were obserevd here. Fishes observed were striped parrotfish, gobies, and damselfishes.

Stations U-1 and U-2

Site Location and Description. The two pixel stations of this site were visited on February 24, 1991. Coordinates:

*U-1: 19 degrees, 52.3149 min. N. latitude, 71 degrees, 23.3507 min. W. longtiude
*U-2: 19 degrees, 52.3394 min. N. latitude, 71 degrees, 23.3127 min. W. longtiude

Site Ecology. Station U-1 is a seagrass meadow in 13 feet of water, dominated by *Thalassia testudinum*. It was not sampled extensively. Adjacent to this site was U-2, which was a coral patch reef surrounded by *Thalassia* meadows. There was a good deal of dead, toppled staghorn coral, *Acropora cervicornis,* on this reef in 2 feet of water suggesting storm damage occurs frequently. Brown alage species dominated at this site (*Turbinaria turbinata, Dictyota mertensii, Sargassum platycarpum, Stypopodium zonale, Lobophora variegata*). Green algae (*Halimeda incrassata, Penicillus dumetosus*) and red coralline algae (*Amphiroa rigida*) also occurred here. Coral species were dominated by boulder coral, *Montastrea annularis*, brain coral, *Diploria* sp., rose coral, *Manicina areolata*, and staghorn coral. Soft corals included sea rods, *Plexaurella* sp., knobby candelabra, *Eumicea* sp., and sea feathers, *Psuedopterogorgia bipinnata*. Other invertebrates observed include the reef squid, *Sepioteuthis sepiodea*, fireworm, *Hermodice carunculata*, carpet anenome, *Palythoa caribaeorum*, purple finger sponge, *Haliclona viridis*, and sea egg, *Tripnuestes ventricostus*. Fishes observed included bluehead wrasse, yellowhead wrasse, striped parrotfish, stoplight parrotfish, three-spot damselfish, bluestriped grunt, french grunt, butterflyfishes, blue tang, baracuda, and trumpetfish. A screen from the Smithsonian *Mithrax* crab mariculture pilot project, implemented in Buen Hombre (1985-1987), was found at the station U-2 (see Stoffle 1986; Stoffle, Halmo and Stoffle 1991).

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

Richard W. Stoffle and David B. Halmo

This chapter discusses the results of the CIESIN Dominican Republic pilot project. The results are examined in the context of the issues of interest to CIESIN for the purpose of fulfilling its mission to provide access and use of various categories of human dimensions of global change information through its CIESIN Data and Research Center (CDRC). The collection of remote sensing, marine ecological, meteorological, and ethnographic data in the coastal community of Buen Hombre suggests a number of alternative approaches to data collection, analysis, storage, retrieval, and availability.

The goals of the pilot project research were to (1) test the utility of satellite technology in identifying and monitoring global changes in coral reefs and associated coastal marine ecosystems, (2) identify the human dimensions of coral reef and coastal marine changes. Based on previous research, we selected a coral reef ecosystem on the north coast of the Dominican Republic as a test case.

The research tasks employed to achieve these goals were (1) expand baseline data on the dynamics of human interaction with the coastal marine environment at the local level, (2) establish a field-based test site for long-term monitoring of the effects of such interactions, and (3) integrate findings into the design of national coastal resource policy by transferring information and monitoring technology products to local level and host country government users. Earth and social scientists engaged in collaborative research. Such collaboration yielded new, integrated approaches to the study of human and environmental dimensions of change in coral reef and coastal marine ecosystems.

Both of the overall goals of the project were achieved. Data analysis indicates that satellite technology is useful for monitoring relatively small-scale changes in the coral reef and mangrove ecozones. Field observations and data collection strongly suggest that both human and environmental factors play significant roles in global coral reef and coastal marine change. Multidisciplinary analysis of these data is leading to the formulation of a model that can explain many of these changes.

A summary of pilot project results in the areas of information technology, integrated science, and knowledge transfer, is presented in the following section. The third section presents recommendations to CIESIN for addressing global coral reef change issues as part of its CDRC mission. The final section presents recommendations for future pilot project research needed to further understand the human dimensions of global change in coastal marine ecosystems.

Summary of Pilot Project Results

Information Technology

This study expanded the application of remote sensing technology to include study of the marine system, which includes tidal shore (mangrove, beach, lagoon) and coral reef ecozones. In order to interpret historic, macrolevel patterns of use and change within both the marine and terrestrial ecozones, ERIM processed and prepared a set of three state-of-the-art satellite image products. In addition, the project acquired 1:43,000 scale 1983 aerial photography of the Buen Hombre area in order to enhance land use change information, derived from remote-sensing data.

The first satellite image is a recent geocoded 20 kilometer by 20 kilometer Landsat Thematic Mapper (TM) image of the Buen Hombre and north coast areas. This natural color image shows in maximum detail the existing land use and infrastructure for the local area covered by village decision making processes. It covers the two terrestrial ecozones near the village in addition to the tidal shore and coral reef ecozones. It provides a highly detailed "map" upon which land and marine resource use patterns were recorded in collaboration with local people in the field.

The second satellite image is a composite Landsat TM image which provides detailed bathymetry information for a 40 km portion of the coast centered on Buen Hombre. This bathymetry image serves a number of functions, including providing accurate water depth information for the coastal ecozone and a chart of the inner and outer coral reefs.

The third image is a Landsat TM change image, covering the same 40 km by 40 km area as the second image, over a five to eight year period. This image graphically indicates the locations and nature of the coastal marine and coral reef changes that have occurred during this period of time.

Panchromatic aerial photography was used to document land and marine conditions and use patterns. These photos were used for comparison with the current conditions. Land use maps were produced based on the aerial photography and satellite imagery.

Integrated Science

The collaborative research undertaken during this project combined remote sensing technology with in-field ethnographic, marine biological and meteorological research in order to identify and map marine zones of interaction. Collaboration between remote sensing scientists, meteorologists, the marine ecologist, and ethnographers began at the earliest stages of the project, including the design of the research, and continued throughout its duration.

Ethnographers shared their background knowledge of the study area and the human ecological dynamics in the study community. Remote sensing scientists educated ethnographers about satellite imagery, their variety of formats, spectral ranges, and the procedures by which raw satellite data are processed to produce geocoded images. Regular seminars were held at ERIM with remote sensing scientists. Researchers were able to view the scene from the perspectives of a number of spectral bands on the computer before the image was printed. Anticipated integrated science products that might result from the research were discussed.

Seminars were also held at UM with meterologists and an agricultural sociologist. These weekly seminars focused on approaches to reconstructing the meteorological history of the north coast area and its impact on agricultural production changes derived from oral history. As data were collected, researchers met to discuss what types of weather statistics were most appropriate for analysis. Plans were also laid for installing temperature and precipitation gauges in the community. Community members were trained to record daily temperature and precipitation data. Regular interactions with the marine ecologist by telephone and mail occurred throughout the project.

The multidisciplinary team of scientists also collaborated in collecting field data in the study community. It is important to note here that government agency representatives also visited the study area and participated in marine site visits and focus group discussions with local fishermen.

Field schedules and methodology were jointly designed and implemented. Draft manuscripts of findings were shared for review purposes. Through this interaction process, knowledge sharing and transfer occurred among members of the team so that each could become somewhat conversant in the perspectives, methods, data, and findings of the other's discipline. In other words, integration of disciplinary scientists was a deliberate part of the research design and operational procedures, and not simply an *ex post facto* integration of findings from independently collected data. This method is, in our view, the cornerstone of interdisciplinary, integrated science.

Linking remote sensing images with observed marine resource use activities resulted in the identification of ecozones and resources at risk. Once identified, human use and impact data were brought to bear on policy-relevant recommendations to host country government resource managers and decision-makers. The data also served to inform community level decision-makers of options regarding the management of their resources. This demonstrates a positive role for EOS-era data in affecting local, national and international decision-making and policy formulation.

It was important for the purposes of this project to identify the types of natural resources that are differentially affected by change caused by environmental and human factors. In order to accomplish this, marine resources of numerous types were scientifically inventoried, recorded, and evaluated using the Landsat image as a basemap.

A marine ecologist and local expert fishermen worked with ethnographers and remote sensing scientists to produce inventories of marine species in the coral reef and mangrove ecozones from over 50 pixel station locations. This was accomplished by using a portable global positioning device. Depth measurements were made with a hand-held sonar device and used to generate the Landsat bathymetry image produced by ERIM. Single and multiple-pixel locations or sites were "seatruthed." Interview data collected from key expert senior fishermen regarding marine ecozone resource use were used to help identify and map marine resources at risk of overuse and degradation at each site.

General ethnographic interviews with local fishermen indicate that Buen Hombre fishermen traditionally have employed sustainable methods of fishing that appear to derive from a conservation ethic. Although they tend to avoid small fish and other seafood species in their diverse fishing patterns, seasonal stresses in other economic sectors, as well as weather, force fishermen to violate this ethic by targeting certain high-value species through more intensive fishing in the inner coral reef.

Although a Caribbean-wide coral bleaching event occurred during the 1980s (especially 1986 and 1987) and appears to be continuing (Glynn 1991), very little bleaching was observed in and around Buen Hombre. In addition, satellite change imagery did not reveal widespread brightening of the bottom (increasing reflectivity) between 1985 and 1989 that would have been expected if coral bleaching occurred, but rather local changes to the bottom distribution of coral and seagrasses. Increased bottom reflectivity was evident in the change imagery at localized areas of the inshore reef and seagrass stations, but much less was observed at offshore reef stations in comparable water depths. A single large region appeared to have brightened where no reefs were apparent, and this area was not seatruthed during the 1991 visit. The causes of these local changes are still not completely known, but appear to be more closely tied to natural storm-induced disturbance, fishing activity (destruction of seagrasses and corals by bottm-dragging nets, anchor damage)tourist visits (removal of coral species, anchor damage), commercial removal of valuable coral species (i.e., black corals), and nearby land use practices (farming, deforestation that may have increased sedimentation and nutrient input rates.

In order to understand past changes in the local environment, meteorologists at U-M conducted document and weather records searches to produce a meteorological history of the study area. Data from secondary sources permitted analysis of cycles of typical meteorological conditions and fluctuations through time. This information was compared with oral history data elicited from key village consultants.

Integrated Data Products

To summarize, the following integrated data products derived from this project:

* One 20 x 20 km Landsat TM geocorrected natural color image covering the immediate Buen Hombre village area, 1:50,000 scale

* One 40 x 40 km Landsat TM bathymetry image covering the marine ecozones, 1:50,000 scale

* One Landsat TM 1985-1989 change image (with one partial image illustrating 1975-1985 changes), 1:50,000 scale

* One set of 1983 1:43,000 scale aerial photography

* One set of socioeconomic survey data on human ecological and ethnographic aspects of fishing and marine resource use patterns

* One set of ethnographic and ecological survey data for over 50 pixel station sites "sea truthed" in the marine ecozones

* Annual and monthly precipitation records for Monte Cristi, near Buen Hombre, 1933-1990; comparative temperature and precipitation data for additional Dominican and Haitian stations from literature searches

* Ecological and biological inventories of species in marine ecozones (coral reef, mangrove), including algae, invertebrates, fishes, corals, aquatic vegetation, sponges, etc. for over 50 pixel station sites "sea truthed" in the marine ecozones

* One set of overlay maps for image (locally produced) of seasonal fishing patterns in marine ecozones

These products can be delivered to the CDRC in a number of formats. The integrated results of the project constitute this final report. In addition, copies of (1) raw data in the form of socioeconomic surveys, marine ecology inventories, pixel station lists with coordinates, monthly and annual precipitation and temperature statistics, (2) natural color, bathymetry and temporal change images, as well as aerial photography and topographic maps, and (3) overlay basemaps showing seasonal fishing patterns can also be delivered in addition to the final report of integrated findings. Copies of viewgraphs, overheads, and field photos can also be delivered as appropriate.

Knowledge Transfer

Researchers established a collaborative working relationship with Dominican government officials in the Department of Fishery Resources (Office of the Secretary of Agriculture), Department of Natural Resources, scientific organizations and local people to document and analyze patterns of human-environment interactions in the coastal marine ecozones. The pilot project team engaged in this cooperative effort with the specific purpose of transferring knowledge and information products to both local-level community and host country government user groups.

The introduction of satellite image products to local community decision makers and the Department of Fishery Resources, the Department of Natural Resources, and private scientific research organizations initiated the knowledge transfer process as an objective of this project. The multidisciplinary data that was generated through collaborative research with local people, government officals, and scientific organization representatives has had quick policy impacts. Representatives of conservation organizations and government resource management agencies brought the issues of illegal fishing, territorial fishing boundaries, and conservation of north coast coral reefs to the national forefront as a result of the focus group discussions conducted during the fieldwork. This was accomplished by broadcasting radio programs about the study area. In addition, the Undersecretary of the Department of Natural Resources visited Monte Cristi to verbally re-enforce restrictions on illegal net fishing in the village by urban fishermen. Moreover, Department of Natural Resources representatives empowered Buen Hombre fishermen with informal law enforcement authority, including the authority to incarcerate fishermen using illegal *chinchorro* nets. Buen Hombre fishermen have, since that time, patrolled their waters and have had at least four confrontations with *chinchorro* fishermen. As a result, *chinchorro* use has stopped within the territorial waters of Buen Hombre.

Ethnographic and ecological data collected at the local level with the aid of products of remote sensing technology have thus served to inform policymakers who, in turn, have translated that information into policy action. The action has served to empower local fishermen with the authority to manage their coastal fishery and enforce legal strictures prohibiting illegal activities. The Dominican Republic case illustrates in microcosm the utility of integrated science research, technology and knowledge transfer in resolving environmental disputes.

Recommendations for CIESIN Data and Research Center

The research team involved in the CIESIN Dominican Republic pilot project achieved significant results in the areas of information technology, integrated science, and knowledge transfer. At the same time, however, the pilot project researchers were asked by CIESIN to address problems and prospects in these three areas to best inform the CDRC. Because this project was specifically concerned with the impacts of human activities on coral reef and coastal marine ecosystems, recommendations on the kinds of products and services the

CDRC should offer to prospective users (scientists, policymakers, and the public) are made in this context.

* We recommend that change in worldwide coastal marine and coral reef ecosystems become a global change focus for the CDRC. To achieve this, we recommend that a coastal marine ecosystems component be added to the Land Use Issues Center within the CDRC.

* We recommend that a longitudinal CDRC data collection and research program on coral reef and coastal marine ecosystems focus on a representative sample of sites.

* We recommend that CIESIN and the CDRC develop and implement a networking system with national ministries or agencies concerned with global change in coral reef and coastal marine ecosystems (e.g., Ministries of Natural Resources, Fisheries, etc.) to identify issues and assist in accessing or obtaining data sets.

* We recommend that national and international research organizations such as the Global Coral Reef Alliance and the Center for Marine Conservation, the International Union for the Conservation of Nature (IUCN), the Island Resources Foundation, the National Oceanographic and Atmospheric Administration (NOAA) and Sea Grant should also be included in the network. Establishing network relationships with host country scientists, educators, agency officials and policymakers will be an important step in gaining access to and use of data.

* We recommend that CIESIN sponsor a CDRC international conference on the current global status of coral reef and coastal marine ecosystems. The purpose of the conference should be to draw together world experts on global change in these ecosystems to identify and prioritize representative locations where coral reef systems are at risk. These endangered locations would be prioritized for each major world region (Africa, Latin America, Caribbean, Asia, Pacific).

* We recommend that one result of the recommended conference be the selection of a sample of representative "crisis" sites, mutually selected by world scientific experts and host country government agency representatives for integrated study and monitoring by the CDRC. The sites should be representative examples of the nation, geographic region, and the world. Sites should be selected based on a number of criteria established before and during the conference. Additional sites could be nominated to the list of endangered global coastal sites. This process would replicate the World Heritage Sites program of the IUCN.

* We recommend that another result of the conference be specification of the kinds of data needed for documenting and monitoring the parameters of global change in coral reef and coastal marine ecosystems. Useful data sets would likely include world and site-specific (1) seasonal fish catch-per-unit-effort statistics for all fishing methods

used (gill and trammel nets, pound nets, cast nets, trawls, chinchorros or beach seines, spearguns, traps, hook and line, explosives, poisoning), (2) coastal mariculture and aquaculture production statistics, (3) habitat destruction statistics (e.g., mangrove, seagrass, coral areal loss or gains, (4) meteorological statistics (see below), (5) biodiversity inventories, (6) monthly water quality measurements (temperature, salinity, dissolved oxygen, nitrate and phosphate concentrations, turbidity, sedimentation rates, pesticides and organic pollutants, (7) water current data, (8) data on international tourism in coastal areas, and (9) regional level data on patterns of socioeconomic and marine resource use activities by coastal populations.

* Once a representative sample of "coastal crisis sites" is selected, we recommend that satellite data be obtained (from past scenes to the most up-to-date image) and new data generated from satellite technology (current image) for each crisis site in the sample. The CDRC should have the capacity to process and geocorrect satellite data tapes, and produce images. This implies that topographic maps and nautical charts for each crisis site be obtained (original or copy).

* Meteorological data should be collected and disaggregated by month for as many stations regions incorporating the crisis sites as are available. This kind of data will be significant for assessing the effects of seasonality and microclimatic variations (e.g., by altitude and geography) on coral reef and coastal ecosystems.

* We recommend that CIESIN and the CDRC look into and evaluate the utility of new hardware and software technologies that permit satellite remote image analysis both in-house and in the field for coral reef and coastal marine areas. There are some relatively new programs on the market, notably Geographic Access and Information Analysis (GAIA) program software, which allow the display, manipulation and analysis of a variety of earth images (full SPOT and Landsat scenes) on an Apple Macintosh platform. ER Mapper 3.0 is another example. Evaluation packages, consulting and training are available. The purposes of these software technologies is to enhance ground truthing and rapid reporting of results from the field as well as to bring earth image analysis to the desktop of scientists and others. We also recommend that CIESIN investigate alternative databases to GIS systems to speed up learning curves for non-expert users who need to acesss and use such databases on coral reef and coastal marine ecosystems.

* Much of the data that would come from developing countries may or may not be computerized. We recommend that the datasets be stored in a variety of formats, including paper hard copy, until a user friendly system of access and use is developed. Data entry should be initiated so that all data sets would eventually be electronically accessible.

Many environmental issues are global in nature, yet differ greatly on local scales. Interdisciplinary collaboration between earth and social scientists, integrating remote sensing, ethnography, marine ecology and meteorological analysis, and transferring knowledge and technology to new host country user groups in order to enhance local decision-making and agency policy action was successful in the Dominican Republic case. Consequently, we recommend that CIESIN make a long-term commitment to longitudinal research in existing pilot project sites as well as targeting new sites for long-term studies.

Recommendations for Future Research

We believe that several of these recommendations can be further realized by CIESIN funding integrated scientific research in existing and new pilot locations. Our purpose here is to elaborate on what continued research in coastal marine ecosystems would entail, and to propose a project research agenda that would lead to further understanding of the human dimensions of environmental change in coastal marine ecosystems worldwide.

Proposed 1992 Project

The goals of the 1992 project will be to (1) identify additional human and ecological variables to be built into a three-tiered model that explains global changes in coral reef and coastal marine ecosystems and identify coastal crisis sites, (2) test the model in two sites to assess the model's universality of application, and (3) help to organize and implement an international conference on the global status of coral reef and coastal marine ecosystems.

International Conference on the Global Status of Coastal Marine Ecosystems

The international conference will convene a group of international experts in the social, biological and earth sciences of coastal marine and coral reef ecosystems. It is anticipated that experts will be invited from as many nations as is feasible and manageable. Participants will include representatives of national and international environmental research organizations such as the Global Coral Reef Alliance and the Center for Marine Conservation. Host country government agency resource managers will be invited as well.

The objectives of the international conference are anticipated to include: (1) session presentations on the current status of coral reef and coastal marine ecosystems in Asia, Africa, Latin America, and the Pacific; (2) identification of major human and environmental variables (e.g., overfishing, coral bleaching and ocean warming, international tourism) involved in global changes in these ecosystems; (3) establishment of disciplinary working groups for identification of human, ecological and other variables for inclusion in each of the tiers of the model; (4) integration of tiers for the model and identification of coastal crisis sites based on criteria deriving from the working group discussions; and (5) development of an agenda for research and action in the coastal crisis sites.

Modelling Global Change in Coral Reef and Coastal Marine Ecosystems

A "three-tiered" model, composed of social, biological, and atmospheric tiers integrated into a single global change model in coral reef and coastal marine ecosystems will be developed as an output of the conference. Each disciplinary working group of scientists will be responsible for one tier of the model; for example, social scientists will focus on adding or elaborating upon human variables in the Social Process Diagram. Marine ecologists will do the same for oceanographic and biological factors, and meteorologists and remote sensing scientists will refine operational considerations of atmospheric factors. Because all of elements are interconnected, the overlap will necessitate collaboration between disciplinary scientists in constructing the three-tiered model. The tiers will then be integrated into a single model of global change in coral reef and coastal ecosystems. This effort will serve to replicate the Bretherton Wiring Diagram in one specific domain of global change phenomena.

In addition to achieving these general objectives, the 1992 project proposes to conduct earth and human science field research in at least two pilot project locations. Continued research in pilot sites will serve to test the model in existing pilot locations and assess its utility in additional pilot sites.

1992 Pilot Project Sites

Dominican Republic

The 1992 project proposes to continue research in the Dominican Republic pilot site of Buen Hombre and surrounding areas, particularly the urban center of Monte Cristi. The purposes of this research are to (1) collect comparative data on environmental knowledge, values and attitudes toward the marine environment among urban fishermen, (2) groundtruth the terrestrial portion of the Landsat TM image to assess the nature of changes in land and terrestrial resource use, and (3) conduct marine ecological fieldwork to verify the accuracy of the bathymetric map and collect additional data on fish populations in the coral reef ecosystem to further understand degrees of degradation in biological terms.

Policy Results of Knowledge Transfer

It is believed that knowledge transfer of integrated science products will continue to serve to enhance the policy and local decision making processes in more specific ways. The 1991 project delivered satellite products which led to policy actions on the part of Dominican government agency personnel to restrict *chinchorro* fishing in Buen Hombre. *Chinchorro* fishing in Buen Hombre waters has ceased as a result of local prohibition and official restriction. Issues of mangrove clearing and tourist impact, however, have not been addressed. Transfer of integrated science products and interpretive information may serve to lead to additional policy actions on the part of host country natural resource managers. Therefore, collaborative field research among scientists, government agency personnel and local people using the Landsat TM image resulted in the translation of that information into policy action.

Host country participants have not seen all of the integrated products of the 1991 research. Dominican Republic government agency personnel and village leaders anticipate receiving additional integrated science products to enhance natural resource management policy decisions. The 1991 project produced a number of integrated science projects derived from processing satellite data into images. These images include (1) a vector threshold change image at a scale of 1:50,000, showing changes in coral reef and mangrove ecozones proximal to Buen Hombre, (2) a seven category, color-coded bathymetric image map, and (3) a land use map generated from visual interpretation of 1983 panchromatic aerial photography and the Landsat TM satellite image. These products will be transferred to host country government representatives and local community leaders. ERIM and University of Arizona scientists will conduct focus group discussions with government officials and community leaders to explain the information contained in the change image products. Such discussions will assist in the decision making process.

The purpose of this knowledge and product transfer is to establish a long-term monitoring program to evaluate the effects of policy actions on the condition of the coral reef ecosystem. As an example, if the cessation of *chinchorro* fishing is permanent, we should be able to see a gradual recovery of seagrass meadows that appear brightened in the vector threshold change image through annual monitoring with satellite imagery. Any change detected in newly processed monitoring images would be seatruthed with ethnographic and marine ecology fieldwork. Such monitoring with satellites, ethnography and marine ecology would also permit the identification of new areas of *chinchorro* activity. Likewise, the effects of policy actions regarding tourist impacts on Sand Key should be visible through monitoring the recovery (or further degradation) of patch reefs on the southwest side of the Key through the use of satellites, ethnography and marine ecology. This would strengthen the utility of satellite remote sensing in the evaluation of environmental monitoring and natural resource management policy.

Values Survey Among Urban Fishermen

A major finding of the 1991 study is that local fishermen in Buen Hombre generally employ sustainable methods of fishing that appear to derive from a conservation ethic. Conversely, urban chinchorro fishermen did not appear to share such an ethic given the technology used and the wasteful disposal of a large portion of the catch. These observations lead to the hypothesis that, phrased using concepts from the Social Process Diagram, differences in fund of knowledge and experience lead to differences in the types of impacts that are made by local people who have a sense of ownership and inter-generational commitment to the ecosystem and outsiders such as urban fishermen and tourists. In short, differences in values and attitudes toward the ecosystem and its resources influence differences in practices with regard to use of the ecosystem and harvesting its resources.

One purpose of the 1992 ethnography study will be to interview a representative sample of urban fishermen in Monte Cristi. The interviews will focus on their values and attitudes toward the ecosystem, knowledge of reef and mangrove ecosystems, and technologies used in harvesting marine resources. Comparing the two sets of attitudinal data will illustrate cultural and economic influences on behavior with regard to the coastal ecosystem.

Groundtruthing Land Use Change

Another objective of the 1992 project will be to increase understanding of changes in land use, including the agricultural economy and terrestrial resource use, and their effects on marine resource use. The Landsat TM image and the land use map generated from aerial photo and satellite interpretation will be used as basemaps for ground truthing a sample of pixel stations in the terrestrial ecozones. Terrestrial resource use data, especially the use of plants for food, medicine and manufacture, will be collected by conducting ethnobotanical interviews in pixel stations using the global positioning system. Terrestrial ecozone and resource use maps will be generated for overlay on the Landsat image. A temporal change image will be produced by ERIM to illustrate changes in the terrestrial ecozones.

Marine Ecology and Bathymetric Verification

Marine ecology will also play a role in the 1992 project. The bathymetric image requires field verification in order to be useful for decision-making (see Chapter Two). The global positioning system and hand held sonar devices will be used to double-check a sample of pixel station locations visited in 1991. Depth measurement will be compared to the bathymetric image to verify the accuracy of the image. This will serve to increase the utility of the map as an information product for decision-making in discreet marine microzones of the Buen Hombre area.

A minimum of three "changed" areas that have significantly brightened or increased their reflectivity based on satellite change imagery (from 1985-1989) should be characterized more completely to determine the causes of the brightening of the bottom imagery. Expert fishermen should be consulted and interviewed when selecting the sites so that personal observations of the history of the sites can be recorded. Such areas should be compared with nearby "control" or "reference" areas where brightening has not occurred. Measurements of underwater radiometry, underwater photography, and percentage cover of seagrasses, algae, sand, and corals should be made in both the changed and the control areas to allow a more precise correlation of bottom type with satellite radiometry. In addition, a species inventory is needed in the changed areas not previously visited, listing the plants, invertebrates, and fishes present. Population abundance of selected fishery species (groupers, snappers, parrotfish, jacks, lobster, conchs, and octopus) are needed in both changed and control areas. Population abundances of these fishery organisms should be compared in areas of heavy fishing pressure (i.e., reefs near the village of Buen Hombre).

The marine ecologist will conduct demographic and population structure analysis of reef fish populations in a sample of pixel locations in the inner and outer reefs of the Buen Hombre coral reef system. Size-specific measurements of local and urban fish catches will be recorded on a daily basis for a variety of fish species, especially grouper and snapper. This will provide further comparative data on the impact of different technologies on fish harvesting as well as the reproductive capacity of fish populations.

From these studies, it can be determined if fish stocks are declining due to fishing pressure from the village or other factors that may be responsible for the bottom "brightening" seen in the satellite change imagery. Finally, long-term monitoring of the physical and chemical parameters at these changed and control sites should begin for inclusion in a CDRC/Land Use Issue Center coastal marine data base for this site. Measurements that should be taken on a monthly basis are water temperature, salinity, nutrient (nitrate and phosphate) concentrations, and sedimentation rates. These samples may be taken by local fishermen so that community members play a role in determining the health of the coastal ecosystem.

North Coastal Haiti

The relatively good condition of the Buen Hombre coral reef system points up the need for a controlled comparative analysis of a similar coastal area or areas in which environmental degradation has reached critical proportions. A controlled comparison will increase our understanding of the actual condition of the Buen Hombre reef in comparative perspective. We therefore propose to replicate the 1991 coastal marine study in north coastal Haiti.

The north coast of Haiti has been selected for several reasons. First, data sets on fish catch, types of fish caught, and size of fish is available from both the Baie de Fort Liberte and adjacent coastal waters. A development sociologist who has collected fish catch data in the area reports that the small size of fish (as small as one to three inches) and meager daily catches are two indicators of a degraded coastal ecozone (Brass 1991). Secondly, there is scientific documentation linking deforestation, sedimentation and the degraded condition of the coral reef off the north coast of Haiti. One purpose of the Haitian project will be to confirm this information through groundtruthing and seatruthing fieldwork. The need to collect first hand field information is evidenced by the fact that no records of fish landings are kept in Fort Liberte (Brass 1991). Consequently, the research team will need to collect its own data.

General Approach

For the Haiti site of Fort Liberte, project scientists will conduct in-field natural resource inventories for the marine ecozones under study, and combine satellite imagery, derived from remote sensing technology, with ground-based fieldwork to identify and map zones of human-environmental interactions. The data generated from this research will serve as a baseline from which to monitor changes in human-environment interactions.

During the follow up visit to the Buen Hombre project site, researchers expect to begin assessing the potential replication of the project on the north coast of Haiti. Preliminary discussions will occur between researchers and Haitian government officials concerning the country's desire to have such information. Planning of this replication will provide comparative data and test the universality of the applications of this technology and the local and national socioeconomic responses to it. It is expected that a site visit to the north coast study area and preliminary data collection will begin at this time.

Remote Sensing Technology (ERIM)

This study proposes to replicate the application of remote sensing technology in the marine ecozones of Fort Liberte, which includes tidal shore (mangrove, beach, lagoon) and coral reef ecozones. In order to interpret historic, macrolevel patterns of use and change within both of the marine ecozones, the Environmental Research Institute of Michigan (ERIM) will prepare a set of three state-of-the-art satellite image products. In addition, it will seek to acquire historical aerial photography of the Fort Liberte area in order to extend land use change information, derived from remote-sensing data.

The first satellite image will be a recent 20 kilometer by 20 kilometer edge sharpened Landsat TM image of Fort Liberte and its immediate environs. This natural color image will show in maximum detail the existing land use and infrastructure for the local area covered by village decision making processes. It will cover the two terrestrial ecozones near the village in addition to the tidal shore and coral reef ecozones. It will provide a highly detailed "map" upon which to map existing marine resource use patterns in collaboration with local people in the field.

The second satellite image will be a composite Landsat TM image which provides detailed bathymetry information for a 40 km portion of the coast centered on Fort Liberte (see Nordman et al. 1990). This composite bathymetry image will serve a number of functions, including providing accurate water depth information for the coastal ecozone and a chart of the inner and outer coral reefs. The land portion of the image will clearly show areas of existing forest, agricultural land, mangroves, and areas that have been cleared of vegetation.

The third image will be a Landsat TM categorized change image, covering the same 40 km by 40 km area as the second image, over a five to eight year period. This image will graphically indicate the locations and nature of the land use and land cover changes that have occurred during this period of time. With its natural color background, changes from vegetative to non-vegetative states will be indicated. It is expected that this image will also illustrate albedo changes in the coral reef such as "bleaching" or "whitening."

Finally, historical aerial photography will be used to document earlier land and marine conditions and use patterns. These historic photos will be used for comparison with the current conditions.

Ethnographic Study of Marine Resource Use

It is important to identify the types of natural resources that are differentially affected by change. A marine ecologist and local expert fishermen will work with ethnographers to produce inventories of marine species in the coral reef and mangrove ecozones. Depth measurements will be made for the purpose of generating the Landsat bathymetry image that will be produced by ERIM. Areas of degradation also will be "sea truthed." Interview data collected from a random sample of fishermen regarding marine ecozone resource use will be used to help identify and map marine areas at risk of overuse and degradation. Data from local and national fish catch records will be collected and analyzed.

Reconstruction of Climatic History

In order to understand past changes in the local environment, meteorological researchers will conduct document searches to produce a climate history of the area. Data from secondary sources will permit analysis of cycles of typical meteorological conditions and fluctuations through time. This information will be compared with oral data elicited from key village consultants.

Anticipated Results

It is anticipated that interdisciplinary analysis of the data generated from using remote sensing and ethnographic field methods by earth and social scientists engaged in collaborative research will lead to a deeper understanding of the interdependence of human and environmental factors involved in change in coastal marine areas. The anticipated results of the Haitian research are described below.

The anticipated results of the Haiti research activities will be the completion of a current baseline environmental assessment of a 40km x 40km area centered on Fort Liberte. Identical data sets derived from the 1991 Dominican Republic project will emerge from the Haiti research.

Field ethnography will produce natural resource inventories and use maps for the marine ecozones. Both western science maps and local research perception inventories and use maps will be generated. These will be used to sea-truth satellite images. Surface resource and use-pattern maps will be designed to serve as overlays on the Landsat TM and bathymetry basemaps produced by ERIM. When all the data sets have been integrated into a computerized database, it is anticipated that specific images can be produced by ERIM, showing specific resources and changes in specific areas.

Field maps of marine ecozones will reflect variations in sea depth, coral species and conditions, scientific, common and locally-named categories of reef-fish and shellfish populations. These species will be overlayed on the Landsat bathymetry basemap. Field data maps will serve to sea-truth macrolevel patterns apparent from the satellite basemap.

The Landsat TM temporal change image, derived from combining image data from two dates, will provide a macroview of the marine and land use changes that have occurred. Comparison with historical aerial photos and oral history data will further serve to provide a longer term temporal perspective of environmental changes and ecozone use patterns.

The climatic history of the Fort Liberte area will be reconstructed as comprehensively as possible from literature searches and records, and oral history of environmental change elicited from village elders. It is anticipated that long-term trends and short-term fluctuations in climate can be determined.

The introduction of these products to local community decision makers and fishery resource managers and the Ministry of Agriculture of government of Haiti will initiate the knowledge transfer process as an objective of this project.

To summarize, the following products will derive from the Haiti portion of the project:

*One 20 x 20 km Landsat TM color image covering the immediate Baie de Fort Liberte area

*One 40 x 40 km Landsat TM bathymetry image covering the marine ecozones (e.g., coral reefs and marine ecozones of interest)

*One Landsat TM categorized change image

*One set of aerial photography (if available)

*One set of socioeconomic survey data on marine resource use patterns

*Surface and subsurface resource maps for marine ecozones (coral reef, mangrove)

Additional World Sites

The longer-term vision of our research team's CIESIN activities involves replications of the Dominican Republic pilot project in as many as three additional developing country coastal ecosystems. Potential sites would include the Pacific coast of Oaxaca, Mexico, two island nations in Micronesia, and the borderlands upper Gulf of California between Baja California and Sonora, Mexico. Each of these locations is characterized by a unique and important aspect of coral reef and coastal marine ecosystems that would serve to test the utility of satellite technology in monitoring global changes.

The purpose of replications in additional world sites would be to assess the rapidity with which satellite, marine ecological, meteorological, and ethnographic data can be collected and translated into useful global change information for local decisionmakers and national policymakers. The replications would constitute "rapid appraisals" of global change conditions in the coral reef and coastal marine ecosystems at these sites.

Rapid appraisals in these sites would include assessing the utility of recent innovations in software. These packages allow in-field analysis of earth image data and management of ethnographic data as a significant research task.

The additional rapid replications will test the universality of the applications of these methods and technologies for coral reef and coastal marine monitoring, and the local and national policy responses to it. Each of these locations is briefly described below.

The Coast of Oaxaca, Mexico

The study area on the coast of Oaxaca, from 15' 45" to 16' 30" north and from 97' 0" to 98' 0" west corresponds to the district of Juquila. The district is bounded to the south by the Pacific Ocean, to the west by the Rio Verde, and to the north by the Rio Atoyac. The district covers some 4,266 km2 and is divided into 12 municipalities and contains some 30 communities. The area has a population of approximately 80,000.

Along the coast is a complex coastal marine ecosystem with coral reefs, beaches and sand dunes, cliffs, peninsulas, and bays, lagoons and mangroves, and river deltas. Because two ocean currents meet along the coast--one from the Gulf of California and the other from north of the equator--the waters are rich in plankton and marine life.

Several lagoons are also found along this section of the coast. One of the most important of these is the lagoon of Chacahua, around which has been established a national park and game preserve called Parque Nacional Lagunas de Chacahua (Gonzalez y Sanchez L. 1961; Marquez n.d.). The area is home to alligators, iguanas, a great variety of tropical and migratory birds, and turtles. Turtle populations and hatcheries are being adversely impacted by fisherfolk and egg collectors. The park area has been subject to increased encroachment by spontaneous colonists since the mid 1930s. The settler population within the park tripled from 480 in 1970 to 1,247 in 1979 (Marquez n.d:81).

The nearby city of Puerto Escondito is an international resort, with a population of 12,000. With regular air service, and paved highways linking it to Acapulco and the capital city of Oaxaca, its 25 hotels register some 45,000 visitors a year. A commercial fishing fleet operates out of Puerto Escondito, one of eight fleets operating along the Oaxacan coast. It ranks fifth, catching some 700 metric tons annually. In recent years, however, catches have been declining. The industry has been described as an "irrational commercial fishery inside the lagoons" (Marquez n.d:81).

Researchers at the University of Arizona have access to a long-term ethnographic data base regarding the land based economy and the culture of the district (Greenberg 1981, 1989). Data sets include topographic maps, archival documents of the area's history since the Spanish Conquest, and contemporary socioeconomic data. Rapid research in the coastal zone will serve to assess changes occurring in the zone from a perspective of the entire ecosystem, including marine and terrestrial components.

Micronesia

Micronesia is an area in the central and western Pacific that contains over 2100 isalnds. About 750 of these islands are inhabited by sedentary, permanent human populations. The islands range from small, low coral atolls to relatively large volcanic islands with high interior mountains.

Most of the islands are surrounded by coral reefs with deep lagoons. Two islands are potential areas for further coral reef research. The islands comprising Truk Lagoon in the Federated States of Micronesia are surrounded by the largest lagoon in the Pacific. The Japanese used Truk as the headquarters of their Pacific fleet, which was subsequently destroyed by American air attacks in 1944. Over 70 Japanese ships now rest at the bottom of the lagoon, providing some of the best shipwreck scuba diving in the wolrd, as well as a significant environment for fish and other marine species.

Despite the inviting environment, the Truk Lagoon coral reef system is dying due to destructive fishing practices of the Trukese people. Truk has the largest population density of any of the Micronesian islands. This, in combination with an intensive fish export system, has resulted in the destruction of the habitat. Fishing methods on the reef include dynamite and old World War II-era explosives scavenged off the sunken Japanese ships in the lagoon.

Approxiamtely 700 miles east of Truk are the islands that make up Yap State in the Federated States of Micronesia. The main island of Yap has one of the lowest population densities in Micronesia as a result of pre-World War II population loss caused by diseases and a high infant mortality rate. Yap is often identified as being one of the most conservative, traditional of all Micronesian societies. Yap also has an on-going and complex reef tenure system that serves as one method of conserving the coral reef ecosystem and marine resources. Yap has also taken steps to limit and monitor the rapidly increasing number of sport divers visiting the island to experience the "pristine" diving environment.

An anthropologist at the Bureau of Applied Research in Anthropology has developed a cultural and environmental resource database program for the Micronesian Resources Study (MRS), funded by the NPS. The program runs as a normal MacIntosh application and follows the Human Interface Guidelines as published by Apple, Inc. The program can be adapted to PC machines. The program was designed to be a comprehensive source of information about the cultural resources of Micronesia. It was designed for both non-academic and academic oriented use. Data entry and retrieval are easy for users with minimal English proficiency.

The MRS database is currently being used by the Micronesian historic preservation officers (HPOs) in the Republic of Palau, the Federated States of Micronesia (Yap, Truk, Pohnpei, and Kosrae), and the Republic of the Marshall Islands. Each HPO has the database installed on their own equipment in their office. The database can hold the following types of information: (1) comprehensive archeology site forms for known prehistoric and historic sites in Micronesia. Each form has over 70 categories of information. Linked to the site forms are site drawings and site photographs. Each site can be connected to a specific spot on a topographic map shown on the monitor; (2) coastal resource atlas maps. Each map has 21 categories of coastal resources. Also included are photographs and text of the main marine resources found at the location; (3) ethnobotany information with photographs, line art, and text for culturally important plant species found at the location; (4) a full-text on-line reference system of ethnographic literature, allowing for context searching. This type of database and technology can be easily and relatively inexpensively transferred to host government users.

Integrated research at the Micronesian sites would replicate the Dominican Republic-Haiti pilot project more so than the other world sites. This is due to the fact that the Micronesia study would compare and contrast changes in two coral reef ecosystems in the same geographical region (Micronesia), one that is in relatively good condition owing to the local tenure system and sustainable management, and the other at serious risk of being killed due to destructive practices.

Upper Gulf of California, Baja California and Sonora, Mexico

This study area is comprised of approximately 20,000 km2 in the upper Gulf of California. The "triangular" upper Gulf marine study area is bounded by the communities of El Golfo de Santa Clara and Puerto Penasco, Sonora to the north and southeast, respectively, and San Felipe, Baja California on the southwest (Robles 1991). This semiarid region is composed of highly diverse plant and animal communities and unique endangered marine plant and animal populations, notably the *vaquita* and the *totuaba*, which have been severely impacted by the fishing industries operating in the area. Conflicts among commerical shrimp trawlers, artisanal fishermen, sport fishermen and tourists have added to impact on the ecosystem.

The islands of this area have been described as of great biological value, being among the most pristine archipelagoes left on earth. In addition, the area is part of the migratory bird flyway associated with the Colorado River and delta ecosystem. The northern portion of the Gulf is especially sensitive to disruption and pollution because it is dominated by internally circulating rotary tidal currents.

The culture history of this area is as interesting and diverse as the natural and physical environment. The Seri people occupied the central coast of Sonora, *Tohono O'odham* (Pima Bajo) occupied the northern Sonora coast, and the Colorado River delta was occupied by the Cocopah and the Quechan. The region was important during the Spanish colonial period and has been important to Mexican people since then. Some or all of these human groups live in the region today and so would be considered as *resident populations*.

Currently, basic research that would be essential in this region is being conducted by scholars in both Mexico and Bureau of Applied Research in Anthropology at the University of Arizona. Much of the Mexican research is occurring at the Instituto Technologico y de Estudios Superiores de Monterrey (Monterrey Tech). BARA social scientists have conducted marine research in the region, largely focused on the shrimp industry and peasant farming communities.

The goals of this replication will be to (1) better understand the existing interactions between resident peoples and natural resources in this area, (2) identify past and existing development and pollution factors that have changed and are impacting this ecosystem, and (3) suggest natural resource management alternatives to mitigate adverse impacts and facilitate positive impacts.

A primary objective of this study is to test the utility of satellite technology in identification and monitoring of shrimp trawler net paths in the shallow, turbid harbor waters of the upper Gulf. Disturbance of seagrass beds should be visible from space.

Anticipated Results

For each of the additional world sites, data sets and integrated science products will be generated for use as information for local and national decision making.

Field ethnography will produce natural resource inventories and use maps for the marine ecozones. Both western science maps and local research perception inventories and use maps will be generated. These will be used to sea-truth satellite images. Surface resource and use-pattern maps will be designed to serve as overlays on the Landsat TM and bathymetry basemaps produced by ERIM. When all the data sets have been integrated into a computerized database, it is anticipated that specific images can be produced by ERIM, showing specific resources and changes in specific areas.

Field maps of marine ecozones will reflect variations in sea depth, coral species and conditions, scientific, common and locally-named categories of reef-fish and shellfish populations. These species will be overlayed on the Landsat bathymetry basemaps. Field data maps will serve to sea-truth macrolevel patterns apparent from the satellite basemaps.

Landsat TM vector threshold change images, derived from combining image data from two dates, will provide a macroview of the marine and land use changes that have occurred. Comparison with historical aerial photos and oral history data will further serve to provide a longer term temporal perspective of environmental changes and ecozone use patterns.

The climatic history of the areas will be reconstructed as comprehensively as possible from literature searches and records, and oral history of environmental change elicited from village elders. It is anticipated that long-term trends and short-term fluctuations in climate can be determined.

REFERENCES CITED

Alaka, M. A.
1968 Climatology of Atlantic Tropical Storms and Hurricanes. ESSA Technical Report WB-6. Washington, DC: U.S. Dept. of Commerce.

Alpert, Leo
1941 The Areal Distribution of Mean Annual Rainfall over the Island of Hispaniola. Monthly Weather Review 69(7):201-204.

Anderson, James
1976 Land Use Mapping and Data Compilation in the U.S.G.S. In Innovations in Land Use Management. W. Dando and G. Johnson (eds.). Grand Forks, ND: University of North Dakota Press.

Armstrong, Thomas
1987 In Their Own Way: Discovering and Learning Your Child's Personal Learning Style. Los Angeles: J. P. Tarcher, Inc.

Black, Jan Knippers
1986 The Dominican Republic: Politics and Development in an Unsovereign State. Boston: Allen & Unwin.

Bryson, Reid A. and Peter M. Kuhn
1961 Stress-Differential Induced Divergence with Application to Littoral Precipitation. Erkunde XV (4):287-294.

Bunkley-Williams, Lucy and Ernest H. Williams, Jr.
1990 Global Assault on Coral Reefs. Natural History (April), 47-54.

Buxton, C. D. and M. J. Smale
1989 Abundance and Distribution Patterns of Three Temperate Marine Reef Fish (Teleostei: Sparidae) in Exploited and Unexploited Areas of the Southern Cape Coast. Journal of Applied Ecology 26: 441-451.

Caribbean Fishery Management Council
1985 Fishery Management Plan, Final Environmental Impact Statement, Reeffish Fisheries of Puerto Rico and the U.S. Virgin Islands. Caribbean Fishery Management Council.

Chambers, Robert
1982 Health, Agriculture, and Rural Poverty: Why Seasons Matter. Journal of Development Studies 18(2):217-238.

1983 Rural Development: Putting the Last First. London: Longman.

Chandhary, D. and M.J.B.K. Rao
1982 Breeding Rice Varieties for Dryland and Drought-Prone Areas of India. In Drought Resistance in Crops with Emphasis on Rice. Pp. 265-272. Los Banos, Philippines: International Rice Research Institute.

Clark, William C.
1987 Scale Relationships in the Interactions of Climate, Ecosystems, and Societies. In Forecasting in the Social and Natural Sciences. K. Land and S. Schneider (eds.) New York: Reidel Publishing Company.

Colin, Patrick L., Douglas Y. Shapiro, and Deborah Weiler
1987 Aspects of the Reproduction of Two Groupers, *Epinephelus guttatus* and *E. striatus* in the West Indies. Bulletin of Marine Science 40(2):220-230.

Comitas, Lambros
1973 Occupational Multiplicity in Rural Jamaica. In Work and Family Life: West Indian Perspectives. L. Comitas and D. Lowenthal, eds. Pp. 157-174. New York: Anchor.

Consortium for International Earth Science Information Network (CIESIN)
1991 Information for a Changing World: Strategies for Integration and Use of Global Change Information. Executive Summary of a report submitted to Congress. Saginaw, MI: CIESIN.

1991 Findings and Recommendations on Using Scientific Data in Response to Global Change. Consortium for International Earth Science Information Network (CIESIN). Saginaw, MI: Saginaw Valley State University. July.

Cook, Sherburne F. and Woodrow W. Borah
1971 Essays in Population History, Volume 1. Mexico and the Caribbean. Berkeley: University of California Press.

Cordell, John
1989a Introduction: Sea Tenure. In A Sea of Small Boats. J. Cordell, ed. Pp. 1-32. Cultural Survival Report No. 26. Cambridge: Cultural Survival, Inc.

1989b Social Marginality and Sea Tenure in Bahia. In A Sea of Small Boats. J. Cordell, ed. Pp. 125-151. Cultural Survival Report No. 26. Cambridge: Cultural Survival, Inc.

1989c (ed.) A Sea of Small Boats. Cultural Survival Report No. 26. Cambridge: Cultural Survival, Inc.

Craik, W., R. Kenchington, and G. Kelleher
1990 Coral Reef Management. In Coral Reefs. Ecosystems of the World, Vol. 25. Z. Dubinsky, ed. Pp. 453-467. Amsterdam: Elsevier.

Cripps, Louise, L.
1979 The Spanish Caribbean: From Columbus to Castro. Boston: G. K. Hall & Co.

Crosby, Alfred W.
1972 The Columbian Exchange: Biological and Cultural Consequences of 1492. Westport: Greenwood Press.

1986 Ecological Imperialism: The Biological Expansion of Europe, 900-1900. Cambridge: Cambridge University Press.

Da Mota, F.S.
1980 Meteorological Aspects of Rice Production in Central and South America: Current and Future. In World Meteorological Organization and International Rice Research Institute, Agrometeorology of the Rice Crop. Pp. 9-18. Los Banos, Philippines: International Rice Research Institute.

Daniells, J.W.
1986 Determining Patterns of Soil Water Use by Bananas. Acta Horticulturae 175:357-359.

de Vel, Oliver Y. and William Bour
1990 The Structure and Thematic Mapping of Coral Reefs using High-Resolution SPOT Data: Applications to the Tetembia Reef (New Caledonia).

Dobyns, Henry F.
1976 Brief Perspective on a Scholarly Transformation: "Widowing" the Virgin Land. Ethnohistory 23:95-104.

1978 Ethnohistory and Human Resource Development. Ethnohistory 25(2):103-120.

1983 Their Number Become Thinned: Native American Population Dynamics in Eastern North America. Knoxville: University of Tennessee Press.

Dohmen, Kevin
1990 Learning Styles. Learnings.

Drozdov, A. V.
1990 Coastal Zone in the Global Environment Monitoring System. In Proceedings of the International Conference on Global Natural Resource Monitoring and

Assessments: Preparing for the 21st Century. Pp. 346-353. Bethesda, MD: ASPRS.

Ewen, Charles, R.
1988 The Short, Unhappy Life of a Maverick Caribbean Colony. In Archeology (July/August), 41-46.

Fassig, Oliver L.
1929 A Tentative Chart of Annual Rainfall over the Island of Haiti-Santo Domingo. Monthly Weather Review 57(7):296.

Fuson, Robert, H. (translator)
1987 The Log of Christopher Columbus. Southhampton: Ashford Press Publishing.

Gardener, Howard
1983 Frames of Mind: Theory of Multiple Intelligences. New York: Basic Books.

Georges, Eugenia
1990 The Making of a Transnational Community: Migration, Development and Culture Change in the Dominican Republic. New York: Columbia University Press.

Glantz, Michael H.
1987 Drought and Economic Development in Sub-Saharan Africa. In Drought and Hunger in Africa: Denying Famine a Future. M. Glantz, ed. Pp. 37-58. New York: Cambridge University Press.

Glynn, Peter W.
1991 Coral Reef Bleaching in the 1980s and Possible Connections with Global Warming. Trends in Ecology and Evolution 6(6):175-179.

Goenaga, C., and M. Canals
1990 Island-wide Coral Bleaching in Puerto Rico: 1990. Carribean Journal of Science. 26 (3-4):171-175.

Gonzalez, Ambrosio and Victor Manuel Sanchez L.
1961 Los Parques Nacionales de Mexico: Situacion Actual y Problemas. Mexico: Instituto Mexicano de Recursos Naturales Renovables, A. C.

Goodson, Gar
1985 Fishes of the Atlantic Coast. Stanford: Stanford University Press.

Greenberg, James B.
1981 Santiago's Sword: Chatino Peasant Religion and Economics. Berkeley: University of California Press.

1989 Blood Ties: Life and Violence in Rural Mexico. Tucson: University of Arizona Press.

Grigg, R. W. and S. Dollar
1990 Natural and Anthropogenic Disturbance on Coral Reefs. In Coral Reefs. Ecosystems of the World, Vol 25. Z. Dubinsky, ed. Pp. 439-450. Amsterdam: Elsevier.

Grimes, Churchill B.
1987 Reproductive Biology of the Lutjanidae: A Review. In Tropical Snappers and Groupers: Biology and Fisheries Management. J. Polivina and S. Ralston (eds). Pp. 240-294. Boulder: Westview Press.

Gupta, P.C. and J.C. O'Toole
1986 Upland Rice: A Global Perspective. Los Banos, Philippines: International Rice Research Institute.

Hastenrath, Stefan
1976 Variations in Low-Latitude Circulation and Extreme Climatic Events in the Tropical Americas. Journal of the Atmospheric Sciences 33(2):202-215.

1984 Interannual Variability and the Annual Cycle: Mechanisms of Circulation and Climate in the Tropical Atlantic Sector. Journal of the Atmospheric Sciences 112(6):1097-1107.

1985 Climate and Circulation of the Tropics. Dordrecht: D. Reidel Publishing Co.

Hoetink, H.
1982 The Dominican People, 1850-1900: Notes for a Historical Sociology. Baltimore: John Hopkins University Press.

Hudson, William D.
1991 Photo Interpretation of Montane Forests in the Dominican Republic. Photogrammetric Engineering & Remote Sensing 57 (1), 79-84.

Huke, R.E.
1976 Geography and Climate of Rice. In Climate and Rice. Pp. 31-50. Los Banos, Philippines: International Rice Research Institute.

Jennings, Francis
1975 The Invasion of America: Indians, Colonialism, and the Cant of Conquest. New York: Norton.

Kaplan, Eugene, H.
1982 A Field Guide to Coral Reefs: Caribbean and Florida. Peterson Field Guide Series. Boston: Houghton Mifflin Company.

Kolb, David
1984 Experiencial Learning: Experience as the Source of Learning and Development. New Jersey: Prentice-Hall, Inc.

Kuhn, William R., C. Autrey-Hunley, E. Kasischke, M. Trichel, R. Coppola, and J. Lousma
1991 Integrating Diverse Data Sets for Policymakers. Unpublished manuscript. Saginaw, MI: CIESIN.

Lahey, James F.
1973 On the Origin of the Dry Climate in Northern South America and the Southern Caribbean. In Coastal Deserts: Their Natural and Human Environments. D.H.K. Amiran and A. W. Wilson, eds. Pp. 75-90. Tucson: University of Arizona Press.

Lang, James
1988 Inside Development in Latin America: A Report from the Dominican Republic, Colombia, and Brazil. Chapel Hill: University of North Carolina Press.

Lillesand, T.M. and R.W. Kiefer
1987 Remote Sensing and Image Interpretation. New York: John Wiley and Sons, Inc.

Littler, Diane S., Mark M. Littler, K. E. Bucher, and J. N. Norris
1989 Marine Plants of the Caribbean: A Field Guide from Florida to Brazil. Washington, DC: Smithsonian Institution Press.

Manooch, Charles S., III
1987 Age and Growth of Snappers and Groupers. In Tropical Snappers and Groupers: Biology and Fisheries Management. J. Polivina and S. Ralston (eds). Pp. 329-373. Boulder: Westview Press.

Marshall, E.J.
1988 Passive Bathymetry at ERIM. Ann Arbor: ERIM Proprietary Report.

Mather, John R. (ed.)
1964 Average Climatic Water Balance Data of the Continents, Part VI. North America (Excluding United States). Publications in Climatology 7 (2). Centerton, NJ: C.W. Thornthwaite Associates.

McNeill, William H.
1976 Plagues and Peoples. New York: Anchor/Doubleday.

Michalek, Jeffrey L.
1991 Remote Bathymetry in the Manitou Passage of Northern Lake Michigan Using Landsat-5 Thematic Mapper Data. Unpublished Master's Thesis, University of Michigan, Ann Arbor, MI.

Mintz, Sidney W.
1974 Caribbean Transformations. Baltimore: Johns Hopkins University Press.

Montilla, Tomas
1991 Summary Report of the Buen Hombre Coast. Manuscript. March 4.

Morgan, David L.
1988 Focus Groups as Qualitative Research. Beverly Hills, CA: Sage Publications.

Morris, Percy A.
1975 A Field Guide to Shells of the Atlantic and Gulf Coasts and the West Indies. Peterson Field Guide Series. Boston: Houghton Mifflin Company.

Munro, J. L., V. C. Gaut, R. Thompson, and P. H. Reeson
1973 The Spawning Seasons of Caribbean Reef Fishes. Journal of Fish Biology 5: 69-84.

National Aeronautics and Space Administration (NASA)
1986 Earth System Science, Overview: A Program for Global Change. Washington, DC: Earth System Sciences Committee, NASA Advisory Council.

Neuman, Charles J., George W. Cry, Eduardo L. Caso, and Brian R. Jarvinen
1978 Tropical Cyclones in the North Atlantic Ocean, 1871-1978. Asheville, NC: National Oceanographic and Atmospheric Administration, National Climatic Center.

Nordman, M.E., L. Wood, J.L. Michalek, and J.J. Christy
1990 Water Depth Extraction from Landsat-5 Imagery. Paper presented at the 23rd International Symposium on Remote Sensing of Environment, Bangkok, Thailand, 18-25 April.

Parrish, James D.
1987 The Trophic Biology of Snappers and Groupers. In Tropical Snappers and Groupers: Biology and Fisheries Management. J. Polivina and S. Ralston (eds). Pp. 405-463. Boulder: Westview Press.

Polcyn, F.C., W.L. Brown, and I.J. Sattinger
1970 Measurement of Water Depth by Remote Sensing Techniques. Report 8973-27-F, The University of Michigan.

Portig, W.H.
1976 The Climate of Central America. In World Survey of Climatology 12. Pp. 405-451. Amsterdam: Elsevier.

Purdy, Barbara A.
1988 American Indians after A.D. 1492: A Case Study of Forced Culture Change. American Anthropologist 90 (3):640-655.

Reed, W. W.
1926 Climatological Data for the West Indian Islands. Monthly Weather Review 54(4):133-160.

Riehl, Herbert
1979 Climate and Weather in the Tropics. London: Academic Press.

Robbins, Richard C. and G. Carleton Ray
1986 A Field Guide to the Atlantic Fishes of North America. Peterson Field Guide Series. Boston: Houghton Mifflin Company.

Roberts, L.
1990 Warm Waters, Bleached Corals. Science 250:213.

Robles, Alejandro
1991 Propuesta para la Elaboracion de una Plan de Desarollo, Conservacion y Manejo Integral de los Recursos Bioticos del Alto Golfo de California. Manuscript. Guaymas, Sonora: Instituto Technologico y de Estudios Superiores de Monterrey.

Rosenblat, Angel
1976 The Population of Hispaniola at the Time of Columbus. In The Native Population of the Americas in 1492. William Denevan, ed. Madison: University of Wisconsin Press.

Samples, Robert
1980 Open Mind, Whole Mind.

Seavey, Charles A.
1991 The Geographical and Intellectual Context of Mapping at the Time of Columbus. Paper presented at the symposium on Northern New Spain: Hispanic and Native American Perspectives, September 7, 1991, University of Arizona, Tucson, AZ.

Shapiro, Douglas, Y.
1987 Reproduction in Groupers. In Tropical Snappers and Groupers: Biology and Fisheries Management. J. Polivina and S. Ralston (eds). Pp. 295-327. Boulder: Westview Press.

Simmonds, N.W.
1966 Bananas. London: Longmans Green and Co., Ltd.

Smith, Nigel
1980 Anthrosols and Human Carrying Capacity in Amazonia. Annals of the Association of American Geographers 70:553-566.

Soto, M.
1985 Bananos: Cultivo y Comercializacion. San Jose, Costa Rica: Universidad de Costa Rica.

Stansel, J.W.
1980 The Impact of World Weather Change on Rice Production. In World Meteorological Organization and International Rice Research Institute, Agrometeorology of the Rice Crop. Pp. 143-151. Los Banos, Philippines: International Rice Research Institute.

Stoffle, Richard W.
1986 Caribbean Fishermen Farmers: A Social Assessment of Smithsonian King Crab Mariculture. Research Report Series, Survey Research Center. Ann Arbor: Institute for Social Research.

Stoffle, Richard W., David B. Halmo, Brent W. Stoffle, Andrew L. Williams, and C. Gaye Burpee
1990 An Ecosystem Approach to the Study of Coastal Areas: A Case from the Dominican Republic. Paper presented at the International Symposium on Population-Environment Dynamics, University of Michigan, October 1-3.

Stoffle, Richard W., David B. Halmo, and Brent W. Stoffle
1991 Inappropriate Management of an Appropriate Technology: A Restudy of Mithrax Crab Mariculture in the Dominican Republic. In Sociocultural Aspects of Small-Scale Fisheries in Developing Countries. John Poggie and Richard

Pollnac, eds. Pp. 131-157. Kingston: International Center for Marine Resource Development, University of Rhode Island.

Stoffle, Richard W., F. Jensen and D. Rasch
1987 Cultural Basis of Sport Anglers' Response to Reduced Lake Trout Catch Limits. Transactions of the American Fisheries Society 116(3):503-509.

Stokes, F. Joseph
1984 Divers and Snorkelers Guide to the Fishes and Sea Life of the Caribbean, Florida, Bahamas, and Bermuda. Philadelphia: Academy of Natural Sciences of Philadelphia.

Tanis, F.J. and W.A. Hallada
1984 Evaluation of Landsat Thematic Mapper Data for Shallow Water Bathymetry. 18th International Symposium on Remote Sensing of Environment, Paris, France.

Tanis, F. J. and H. J. Byrnes
1990 Optimization of Multispectral Sensors for Bathymetry Applications. International Symposium on Remote Sensing of Environment, Bangkok, Thailand, 18-25 April.

Thornton, Russell D.
1987 American Indian Holocuast and Survival: A Population History Since 1492. Norman: University of Oklahoma Press.

U.S. Army Map Service
1961 Dominican Republic Road Map, 1:250,000, Sheet 1, Edition 2-AMS.

Van Genderen, J.L., B. Lock, and P. Vass
1978 Remote Sensing: Statistical Testing of Thematic Map Accuracy. Remote Sensing of Environment 7:3-14.

van Willigen, John and Billie R. DeWalt
1985 Training Manual in Policy Ethnography. Special Publication No. 19. Washington, DC: American Anthropological Association.

Vargas Marquez, Fernando
nd Parques Nacionales de Mexico y Reservas Equivalentes. Mexico: Instituto de Investigaciones Economicas, UNAM.

Vazquez de Espinosa, Antonio
1942 Compendium And Description of the West Indies, Book Two. Miscellaneous Collections Vol. 102. Washington, DC: Smithsonian Institution.

Viola, Herman J. and Carolyn Margolis (eds.)
1991 Seeds of Change: Five Hundred Years Since Columbus. Washington, DC: Smithsonian Institution Press.

Wernstedt, Frederick L.
1961 World Climatic Data. Latin America and the Caribbean. Ann Arbor: Edwards Bros.

Weil, Thomas, et al.
1973 Area Handbook for the Dominican Republic. Washington D.C.: U.S. Government Printing Office.

Wilkinson, Leland
1988 SYSTAT: The System for Statistics. Evanston, IL: SYSTAT, Inc.

Williams, Eric
1944 Capitalism and Slavery. Chapel Hill: University of North Carolina Press.

Wilson, Samuel M.
1990 Hispaniola: Caribbean Chiefdoms in the Age of Columbus. Tuscaloosa: University of Alabama Press.

Wolf, Eric R.
1966 Peasants. Englewood Cliffs: Prentice Hall.

LIST OF CONTRIBUTORS

C. Gaye Burpee is a doctoral candidate in the department of Crop and Soil Sciences, Michigan State University, East Lansing, Michigan.

David B. Halmo is an Applied Anthropology Extern, Bureau of Applied Research in Anthropology, University of Arizona, Tucson, Arizona.

William R. Kuhn is a Professor of Atmospheric, Oceanic, and Space Sciences, University of Michigan, Ann Arbor, Michigan, and director of the Human Dimensions of Global Change section of CIESIN.

Raymond Laurin is a remote sensing and soils specialist at the Environmental Research Institute of Michigan, Ann Arbor, Michigan.

Joseph Luczkovich is a marine biologist in the Department of Biology and Institute for Coastal Marine Resources, East Carolina University, Greenville, North Carolina.

Jeffery Michalek is a remote sensing and bathymetry specialist at the Environmental Research Institute of Michigan, Ann Arbor, Michigan.

Donald J. Portman is a Professor of Atmospheric, Oceanic, and Space Sciences at the University of Michigan, Ann Arbor, Michigan.

Brent W. Stoffle is a graduate student in the Department of Sociology and Anthropology, East Carolina University, Greenville, North Carolina.

Richard W. Stoffle is an Associate Research Anthropologist in the Bureau of Applied Research in Anthropology, University of Arizona, Tucson, Arizona.

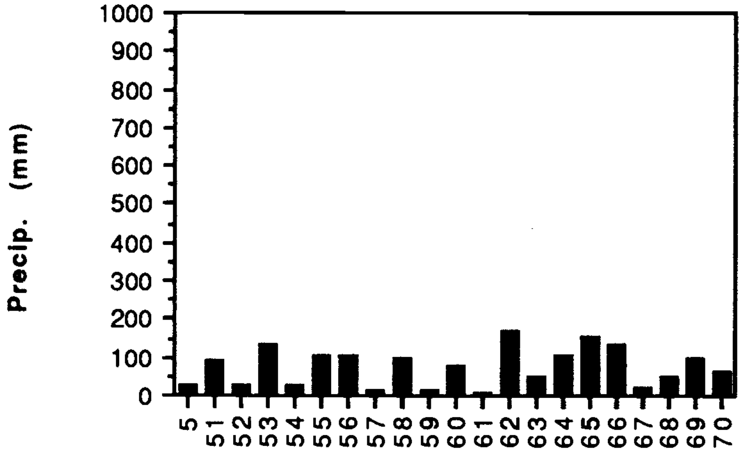
Thomas W. Wagner is a remote sensing expert at the Environmental Research Institute of Michigan, Ann Arbor, Michigan.

Andrew Williams is a doctoral candidate in the Department of Anthropology, University of Michigan, Ann Arbor, Michigan.

David Willson is a graduate student in the Department of Atmospheric, Oceanic, and Space Sciences, University of Michigan, Ann Arbor, Michigan.

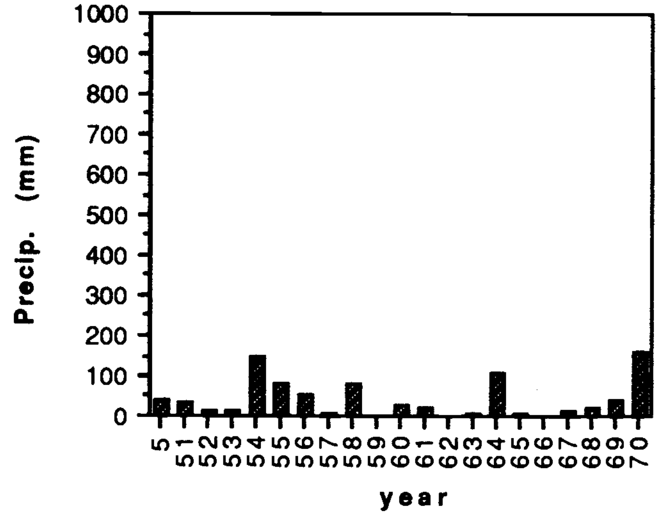
APPENDIX: TWENTY YEAR RAINFALL RECORDS FOR DOMINICAN REPUBLIC AND HAITIAN STATIONS

Jan. Precip. - Monte Cristi

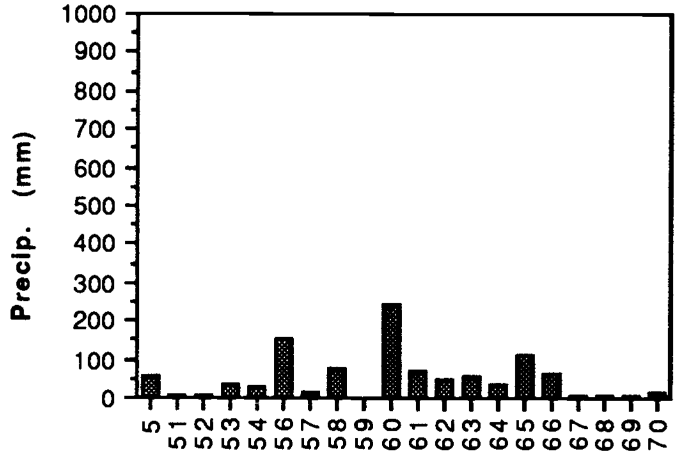


** 5 represents a 7 year average from Mather, ed. (1961)

Feb. Precip. - Monte Cristi

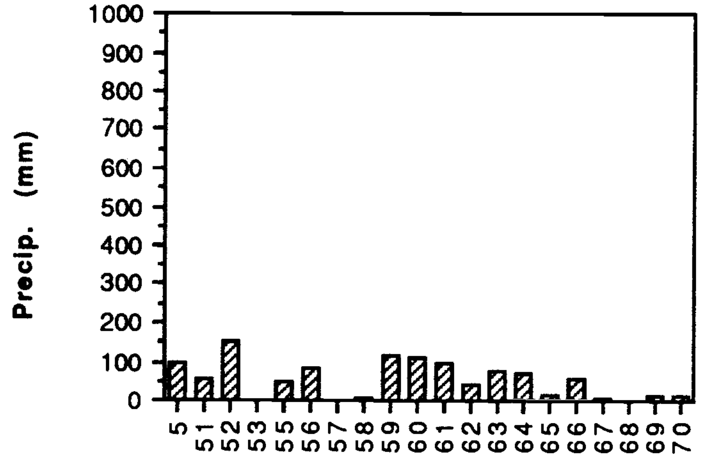


Mar. Precip. - Monte Cristi



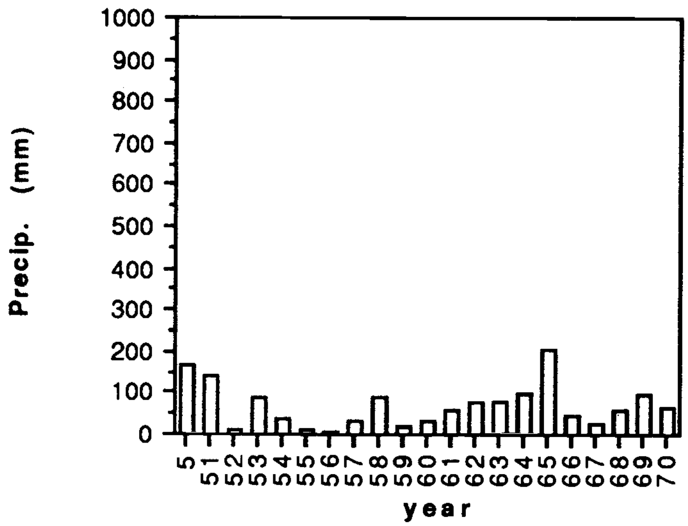
** 1955 data missing

Apr. Precip. - Monte Cristi

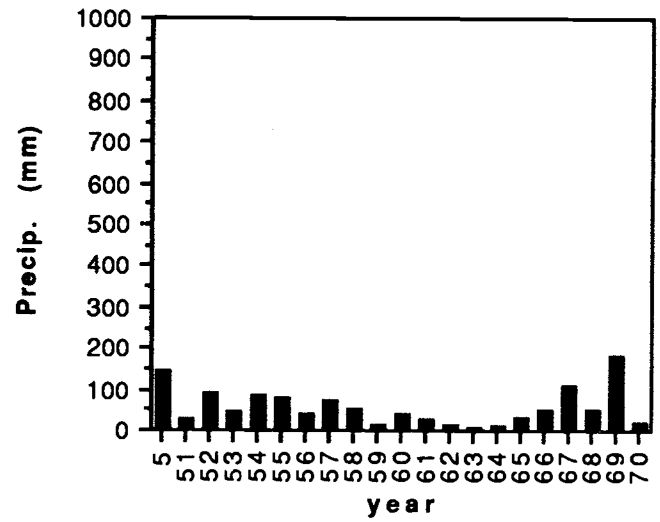


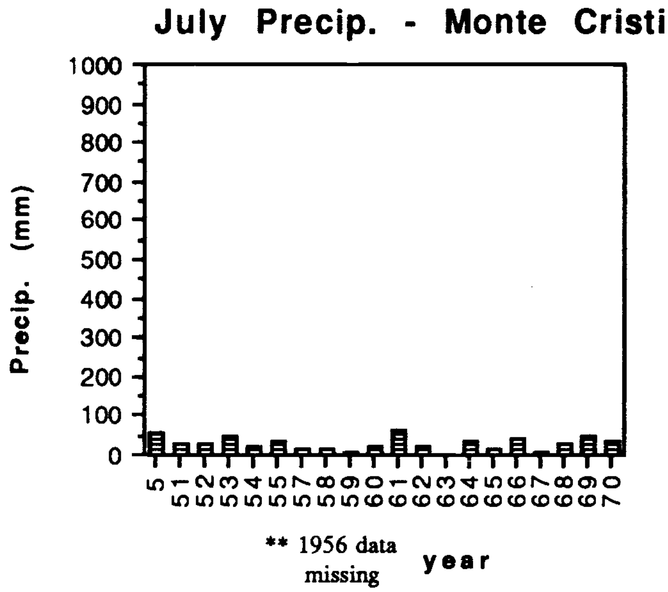
** 1954 data missing

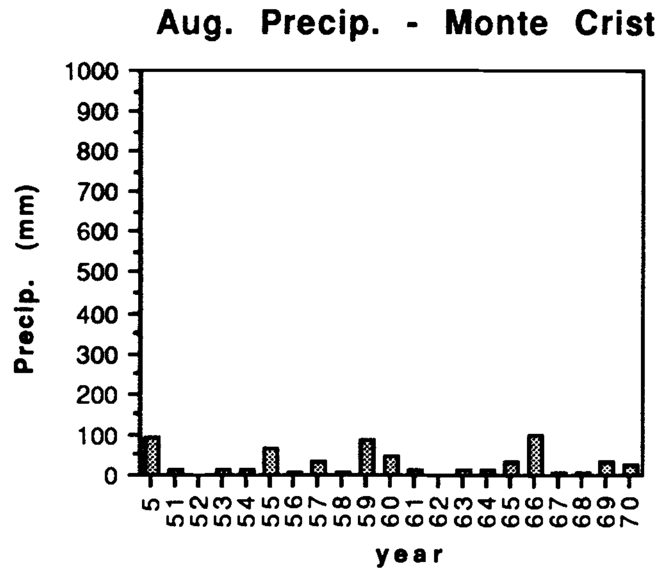
May Precip. - Monte Cristi

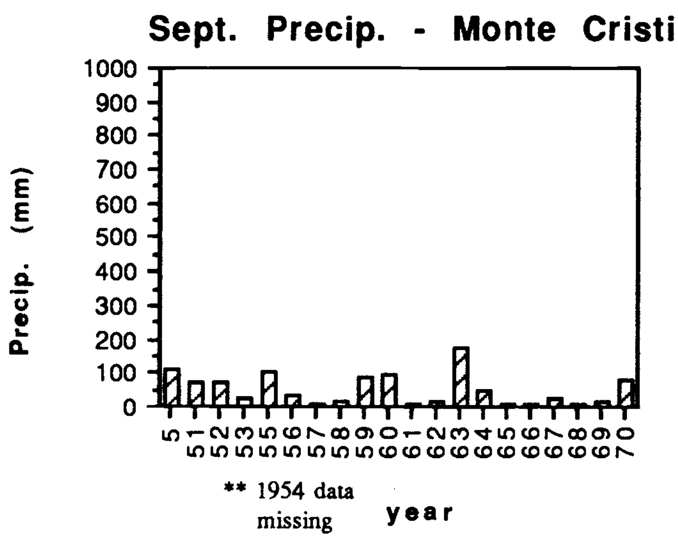


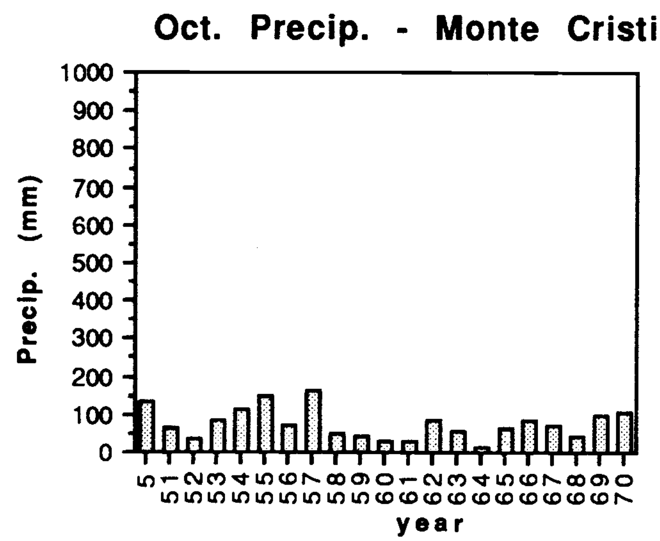
June Precip. - Monte Cristi

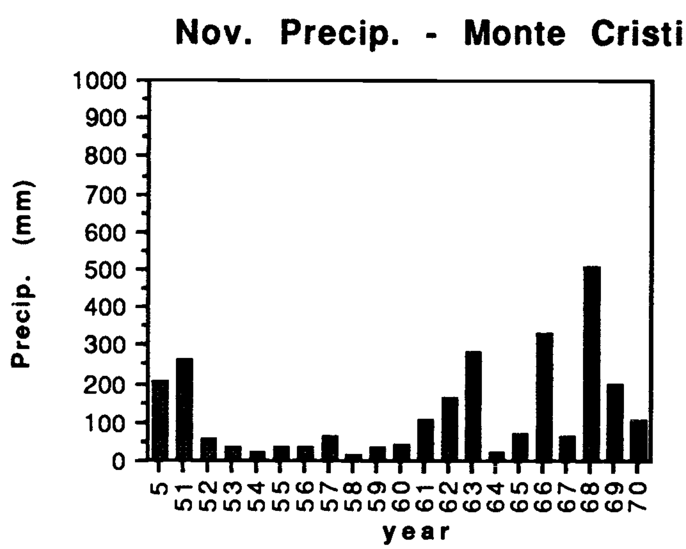


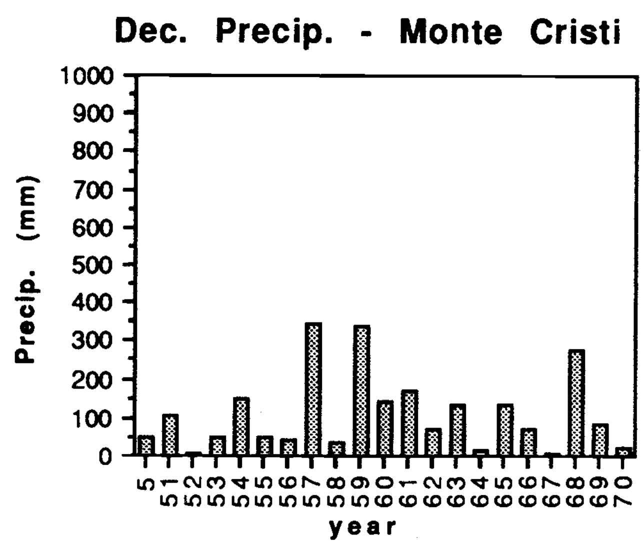

July Precip. - Monte Cristi
Precip. (mm)
year
** 1956 data missing


Aug. Precip. - Monte Cristi
Precip. (mm)
year

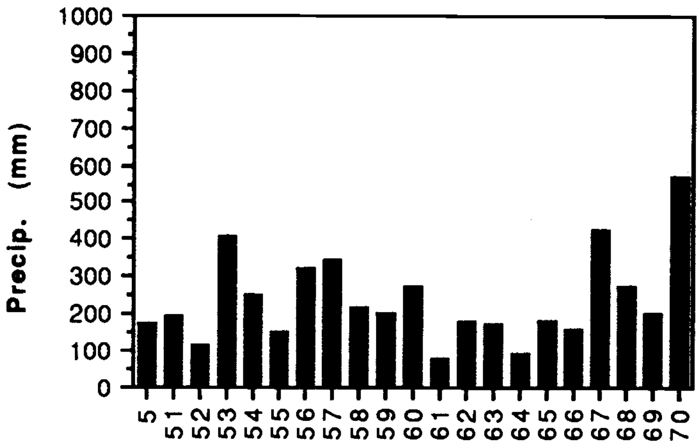

Sept. Precip. - Monte Cristi
Precip. (mm)
year
** 1954 data missing


Oct. Precip. - Monte Cristi
Precip. (mm)
year


Nov. Precip. - Monte Cristi
Precip. (mm)
year

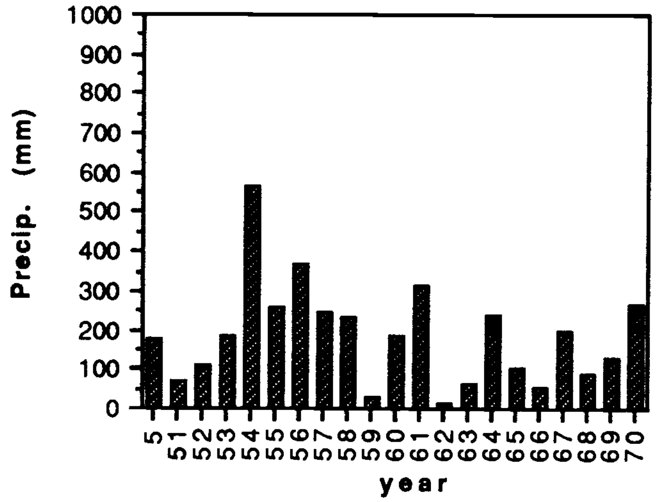

Dec. Precip. - Monte Cristi
Precip. (mm)
year

Jan. Precip. - Puerto Plata

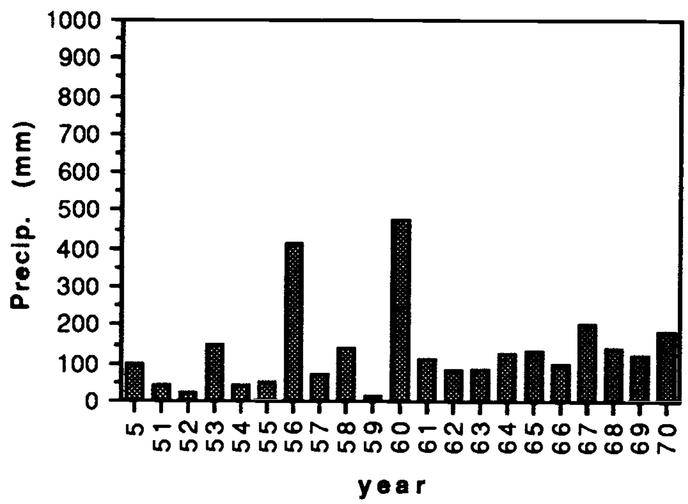


** 5 represents the 1905-26 average in Mather, ed. (1961)

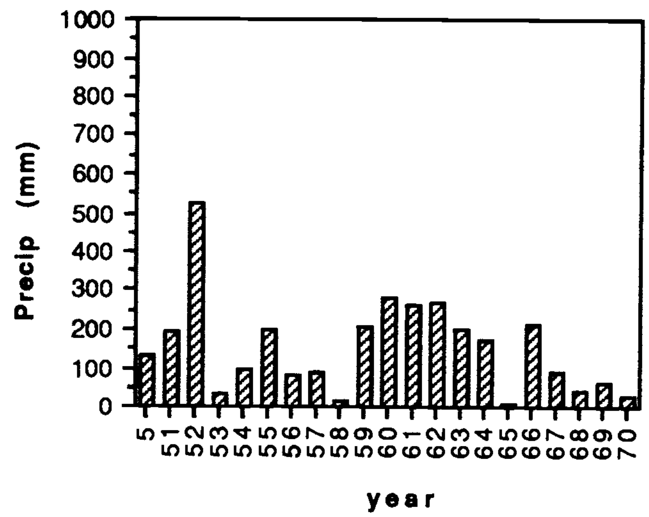
Feb. Precip. - Puerto Plata



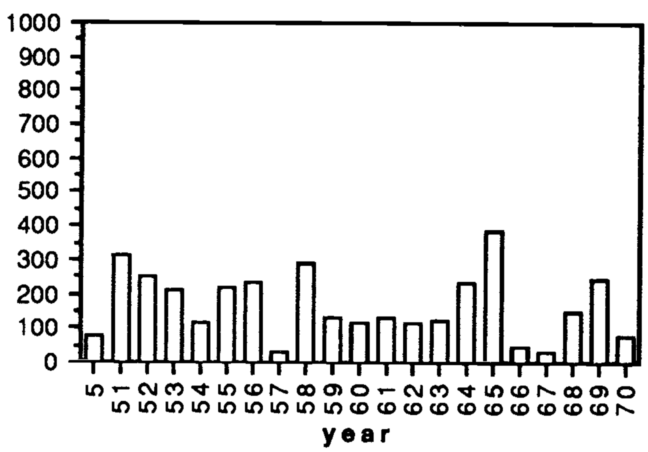
Mar. Precip. - Puerto Plata



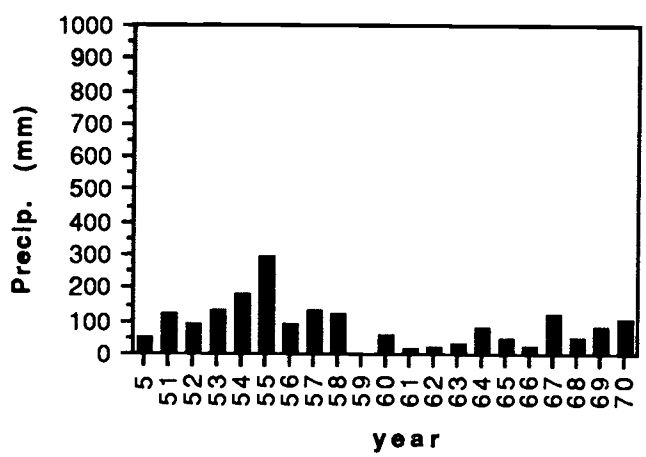
Apr. Precip. - Puerto Plata



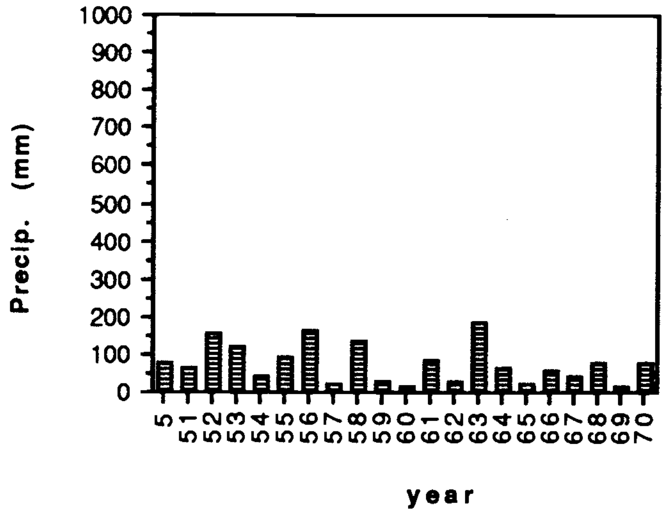
May Precip. - Puerto Plata



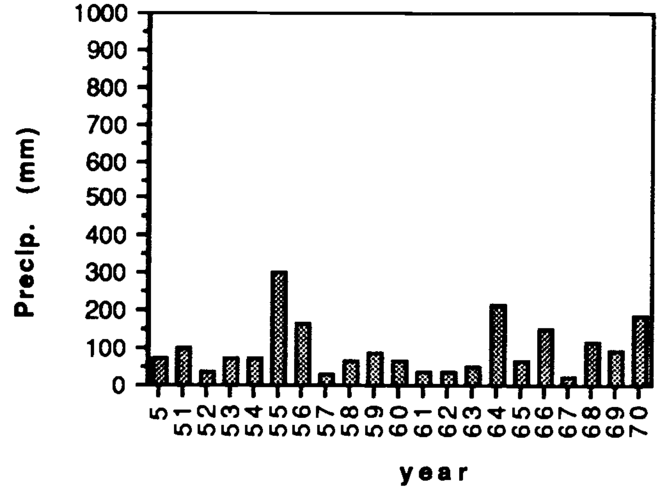
June Precip. - Puerto Plata



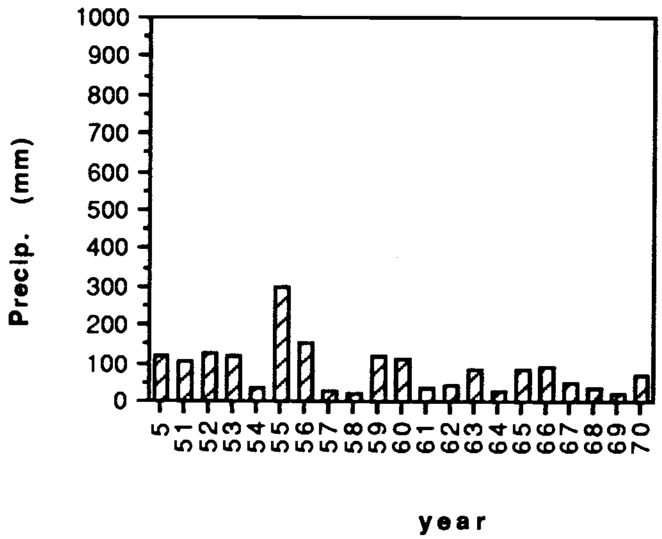
July Precip. - Puerto Plata



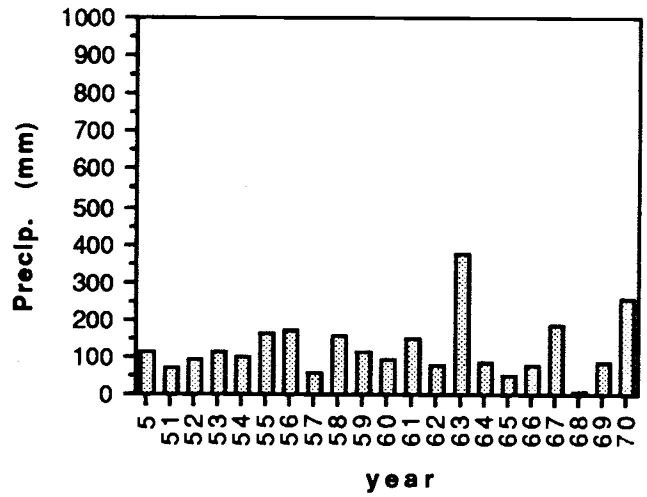
Aug. Precip. - Puerto Plata



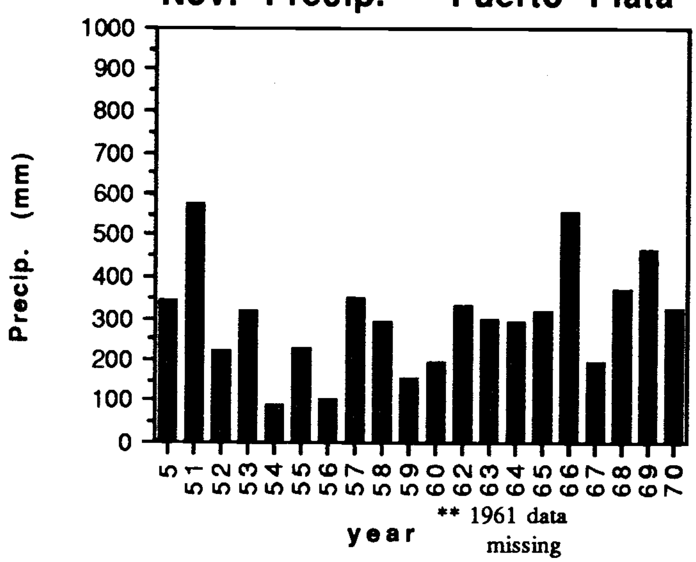
Sept. Precip. - Puerto Plata



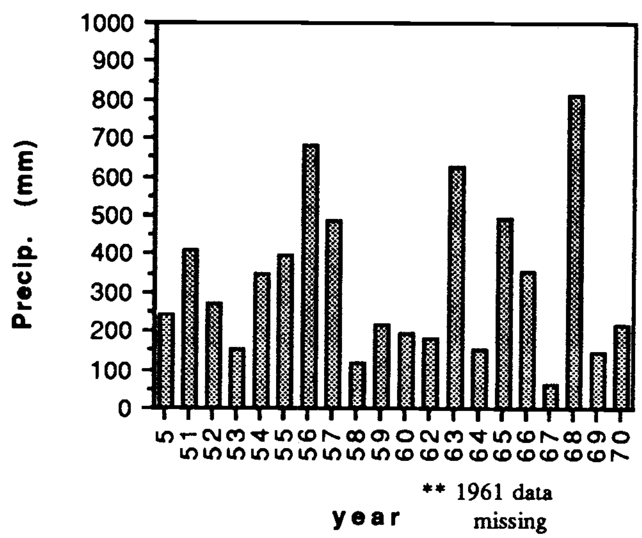
Oct. Precip. - Puerto Plata



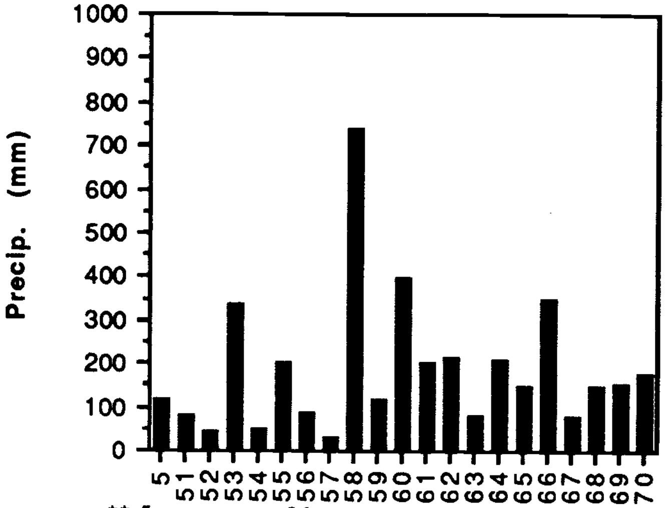
Nov. Precip. - Puerto Plata



Dec. Precip. - Puerto Plata

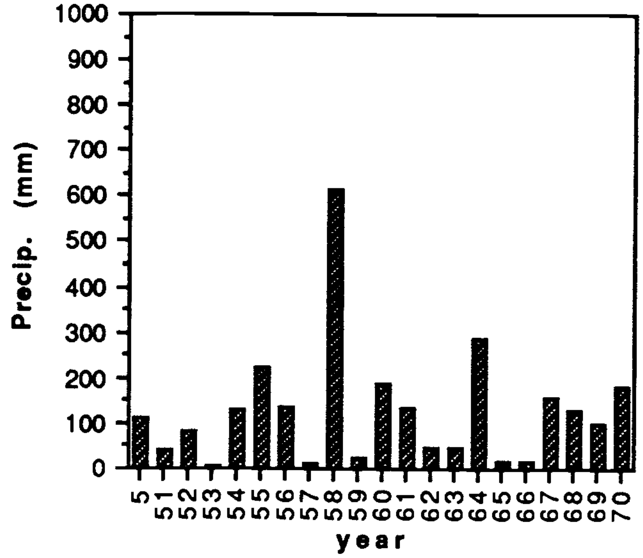


Jan. Precip. - Cap Haitien

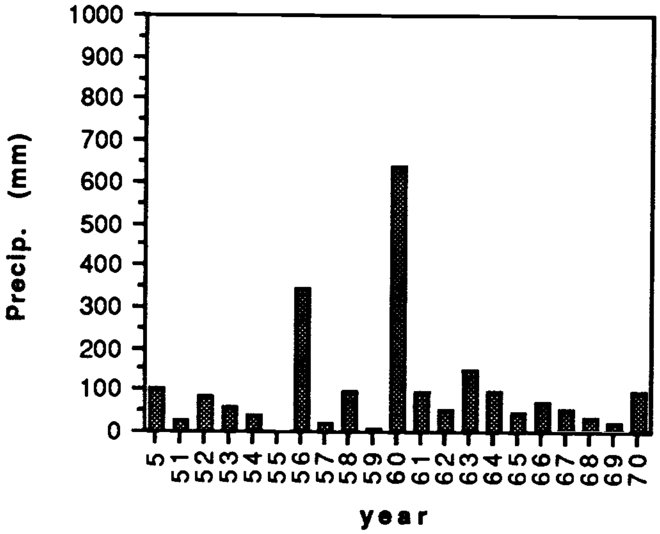


** 5 represents a 26 year average
from Mather, ed. (1961)

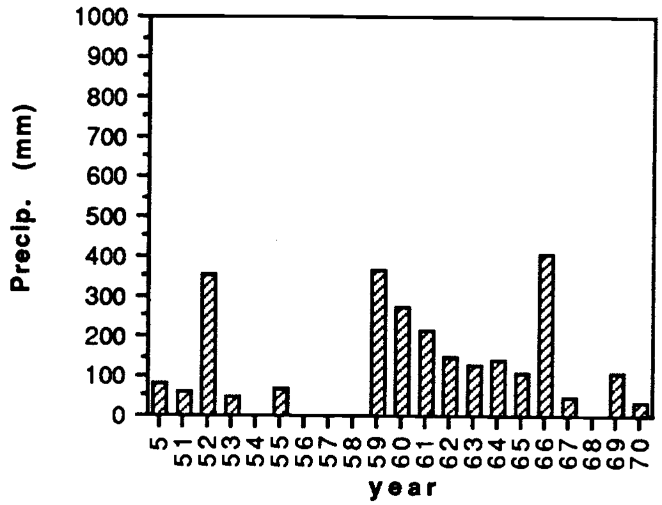
Feb. Precip. - Cap Haitien



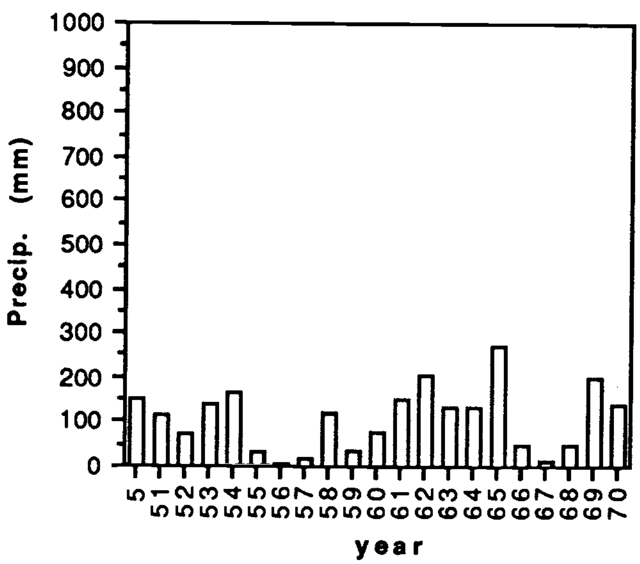
Mar. Precip. - Cap Haitien



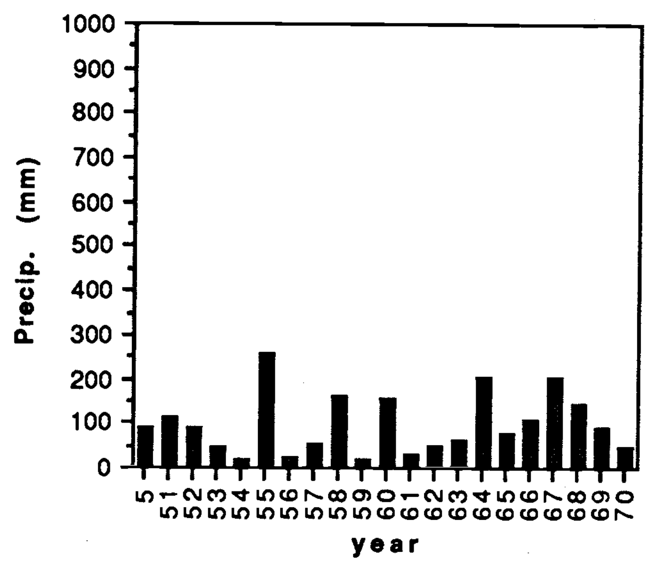
Apr. Precip. - Cap Haitien

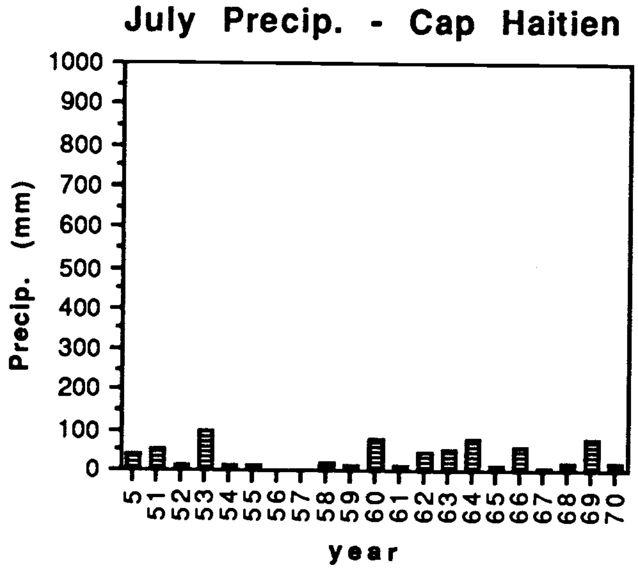


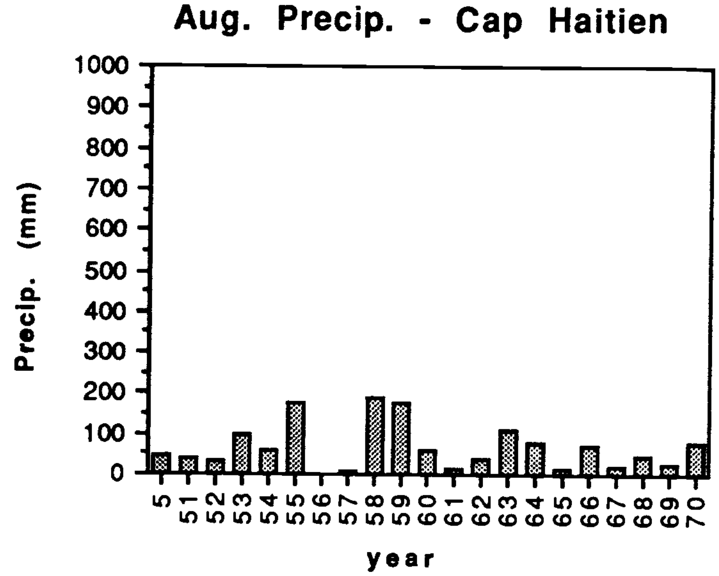
May Precip. - Cap Haitien

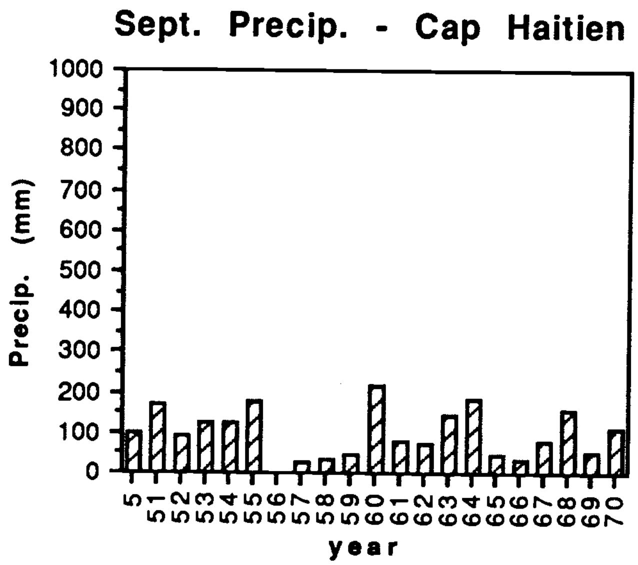


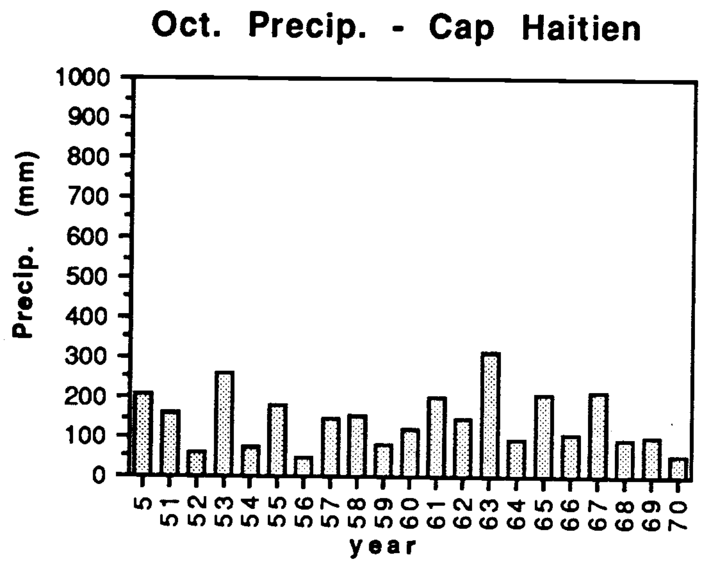
June Precip. - Cap Haitien

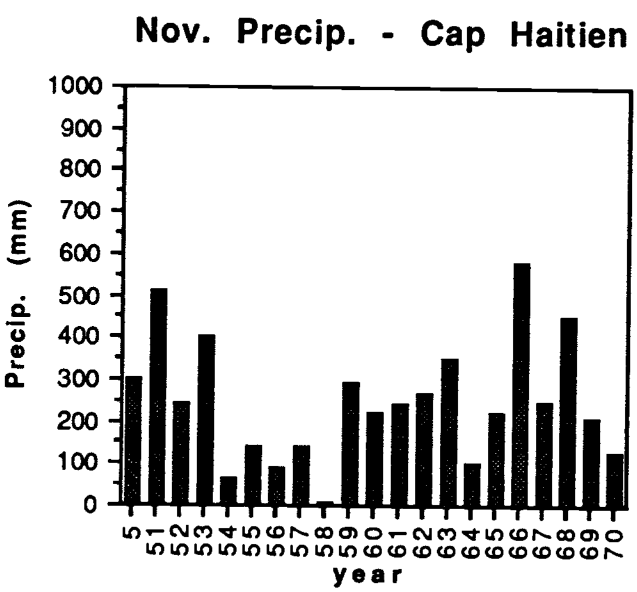


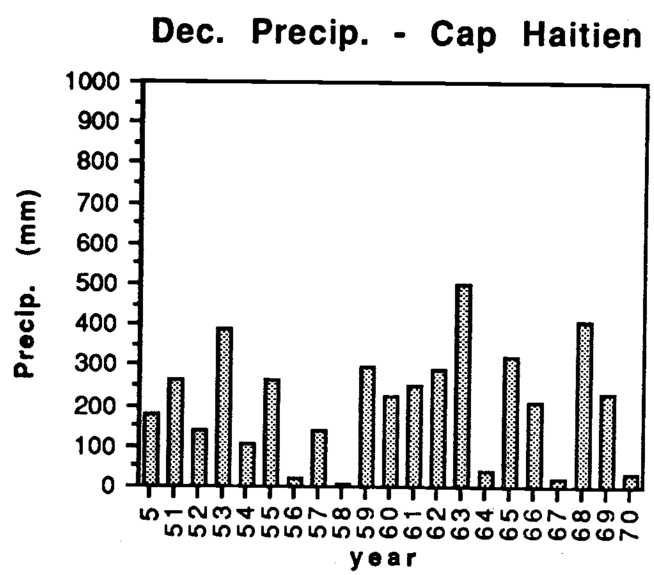

July Precip. - Cap Haitien
Precip. (mm)
0 100 200 300 400 500 600 700 800 900 1000
5 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
year

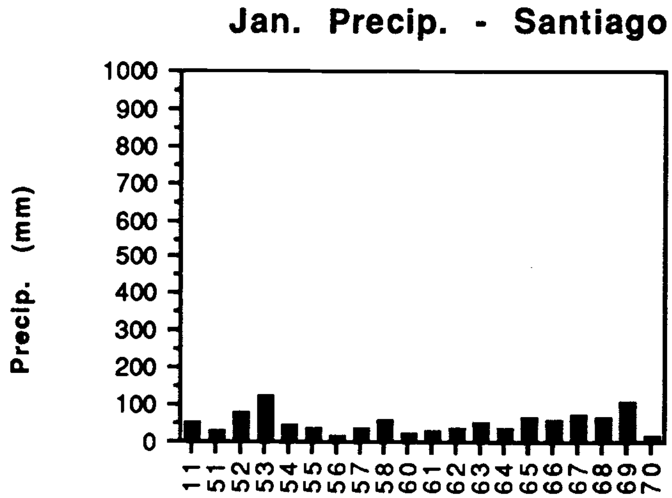

Aug. Precip. - Cap Haitien
Precip. (mm)
0 100 200 300 400 500 600 700 800 900 1000
5 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
year


Sept. Precip. - Cap Haitien
Precip. (mm)
0 100 200 300 400 500 600 700 800 900 1000
5 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
year


Oct. Precip. - Cap Haitien
Precip. (mm)
0 100 200 300 400 500 600 700 800 900 1000
5 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
year

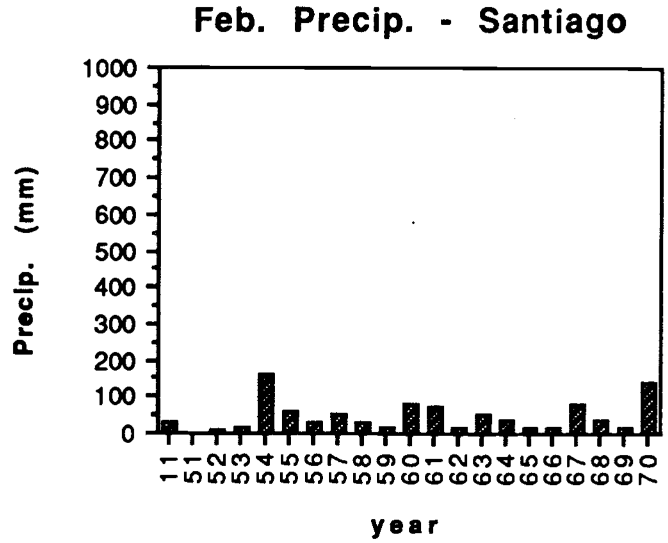

Nov. Precip. - Cap Haitien
Precip. (mm)
0 100 200 300 400 500 600 700 800 900 1000
5 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
year

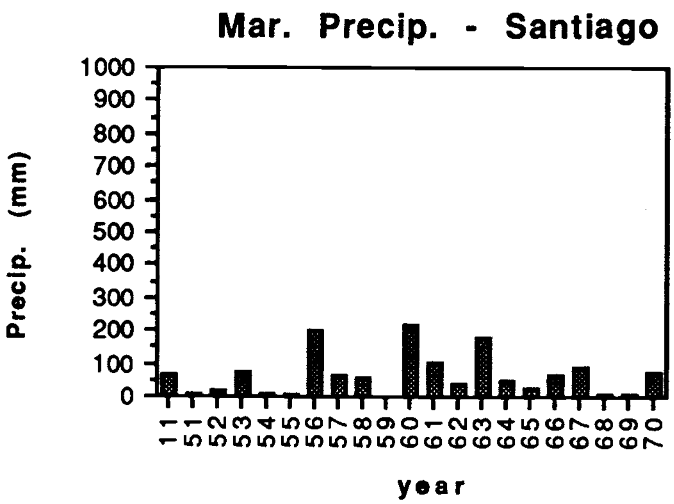

Dec. Precip. - Cap Haitien
Precip. (mm)
0 100 200 300 400 500 600 700 800 900 1000
5 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70
year

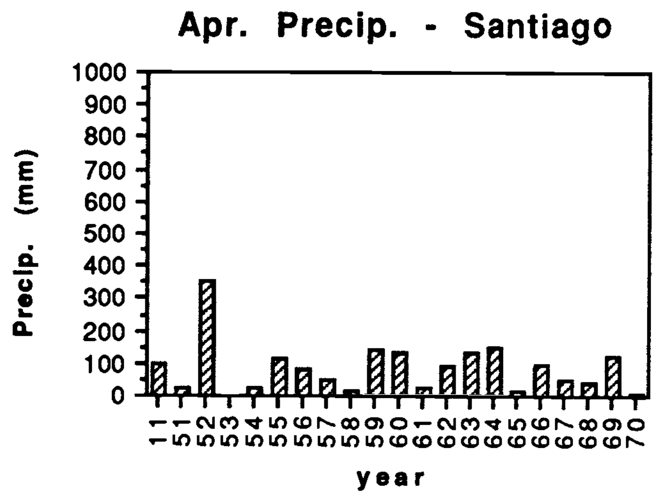


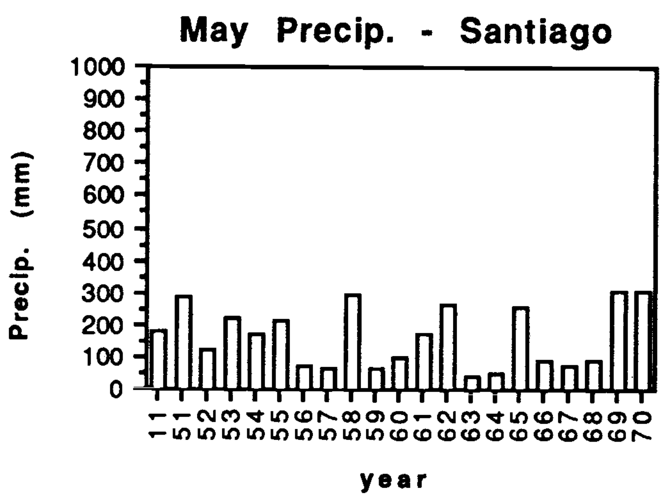
** 11 represents an 11 year average from Mather, ed. (1961) ** 1959 data missing

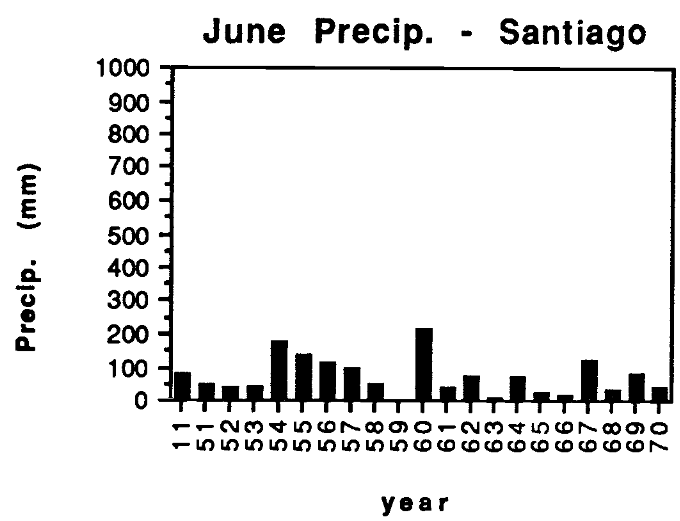
year

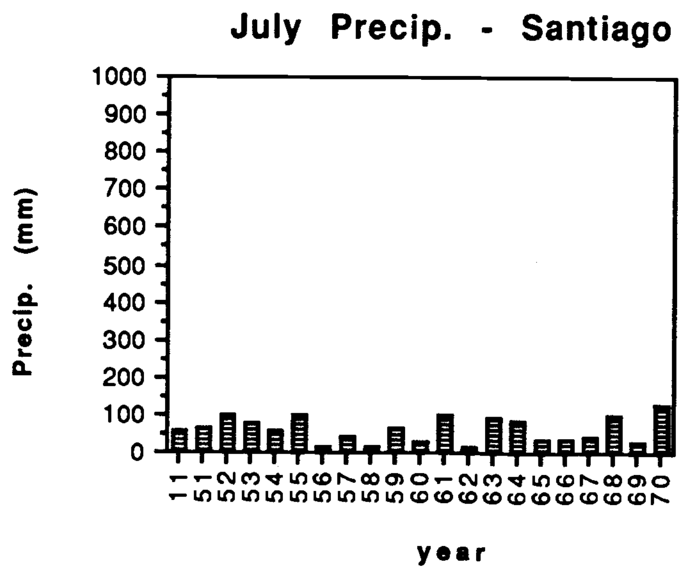


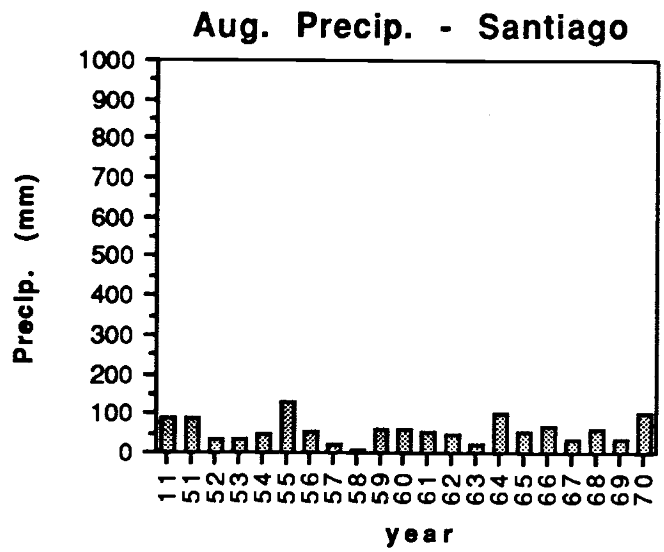


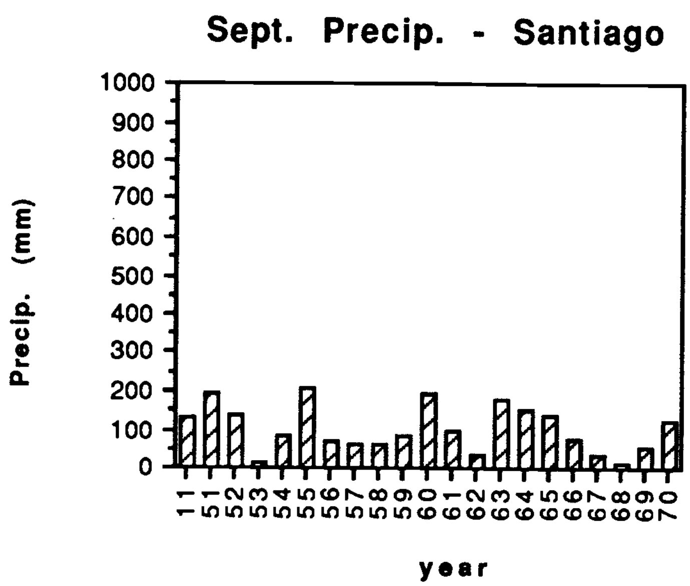


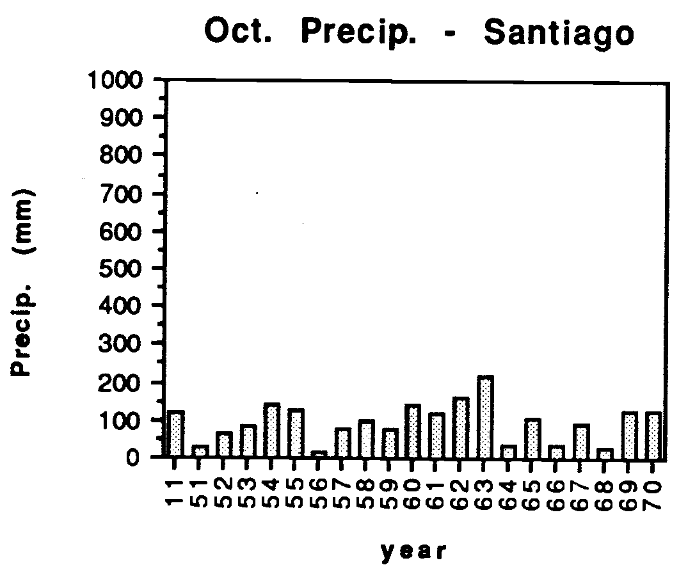


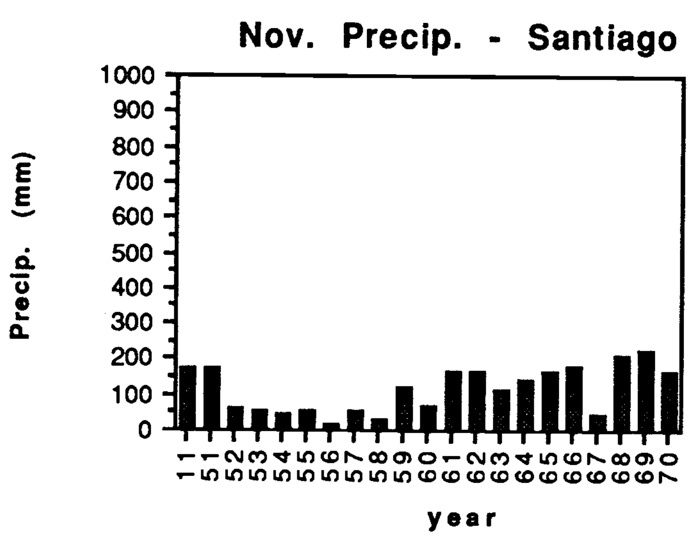


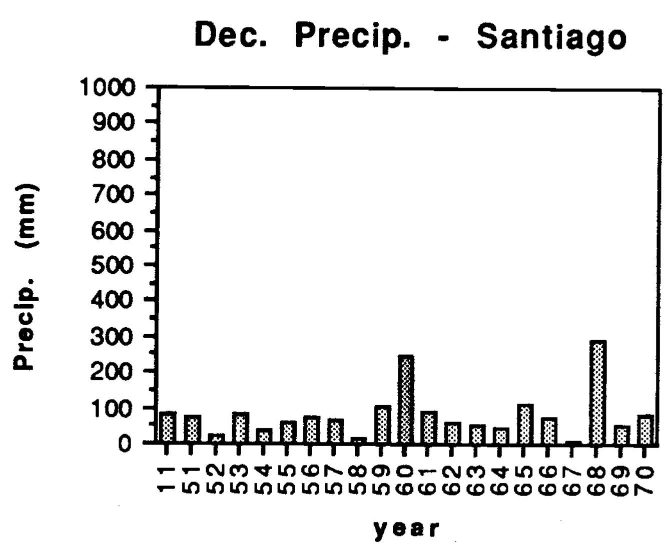

July Precip. - Santiago
Precip. (mm)
0
100
200
300
400
500
600
700
800
900
1000
11
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
year


Aug. Precip. - Santiago
Precip. (mm)
0
100
200
300
400
500
600
700
800
900
1000
11
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
year

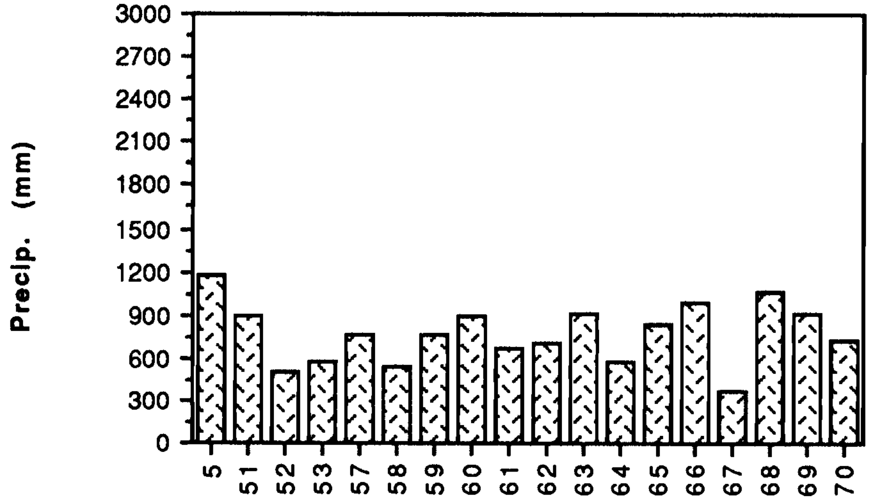

Sept. Precip. - Santiago
Precip. (mm)
0
100
200
300
400
500
600
700
800
900
1000
11
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
year


Oct. Precip. - Santiago
Precip. (mm)
0
100
200
300
400
500
600
700
800
900
1000
11
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
year


Nov. Precip. - Santiago
Precip. (mm)
0
100
200
300
400
500
600
700
800
900
1000
11
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
year


Dec. Precip. - Santiago
Precip. (mm)
0
100
200
300
400
500
600
700
800
900
1000
11
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
year

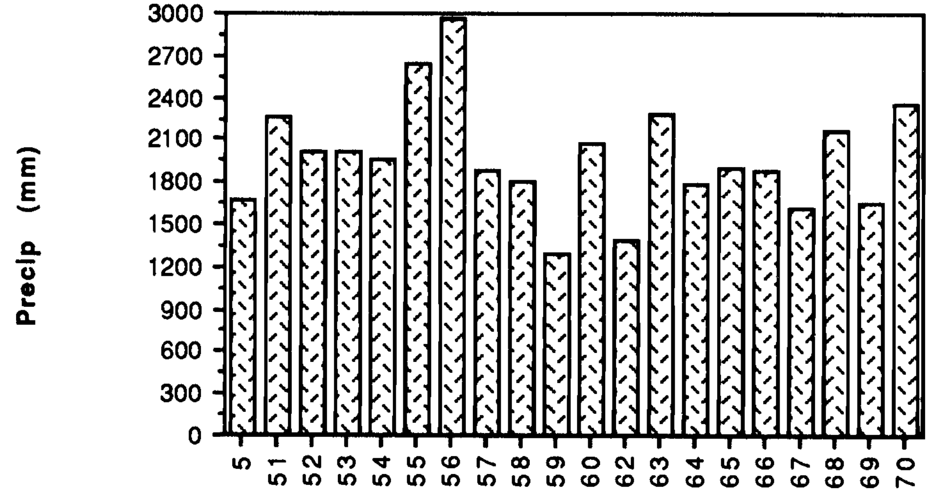
Annual Precip. - Monte Cristi



** 5 represents a 7 year average from Mather, ed. (1961)

** 1954-56 data missing

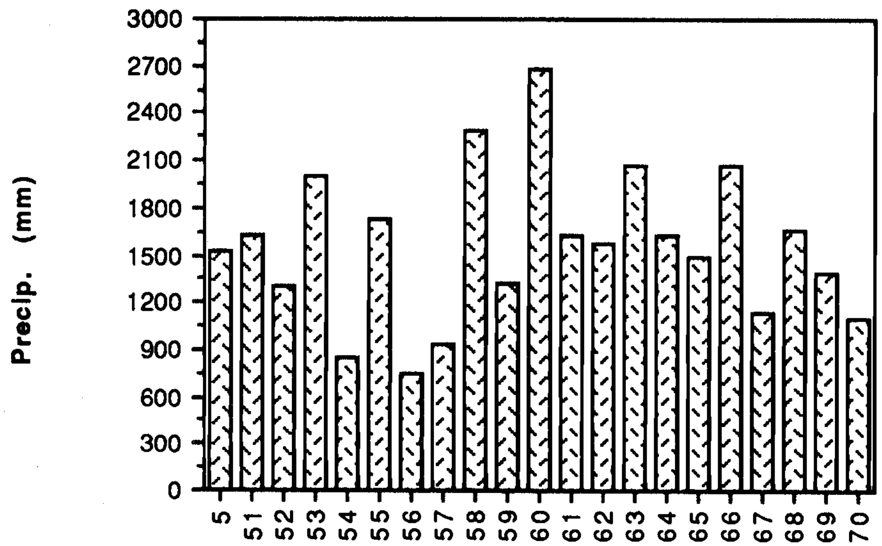
Annual Precip. - Puerto Plata



** 5 represents the 1905-26 average from Mather, ed. (1961)

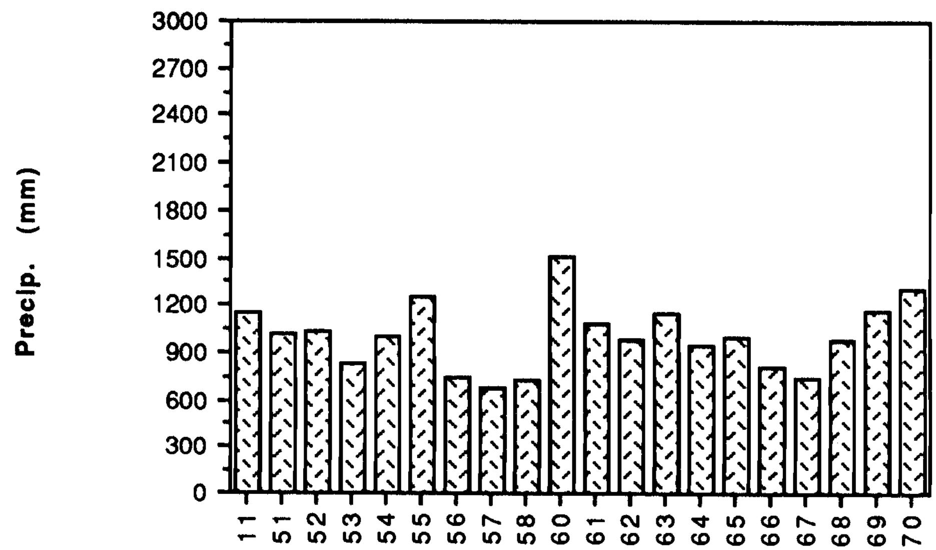
** 1961 data missing

Annual Precip. - Cap Haitien

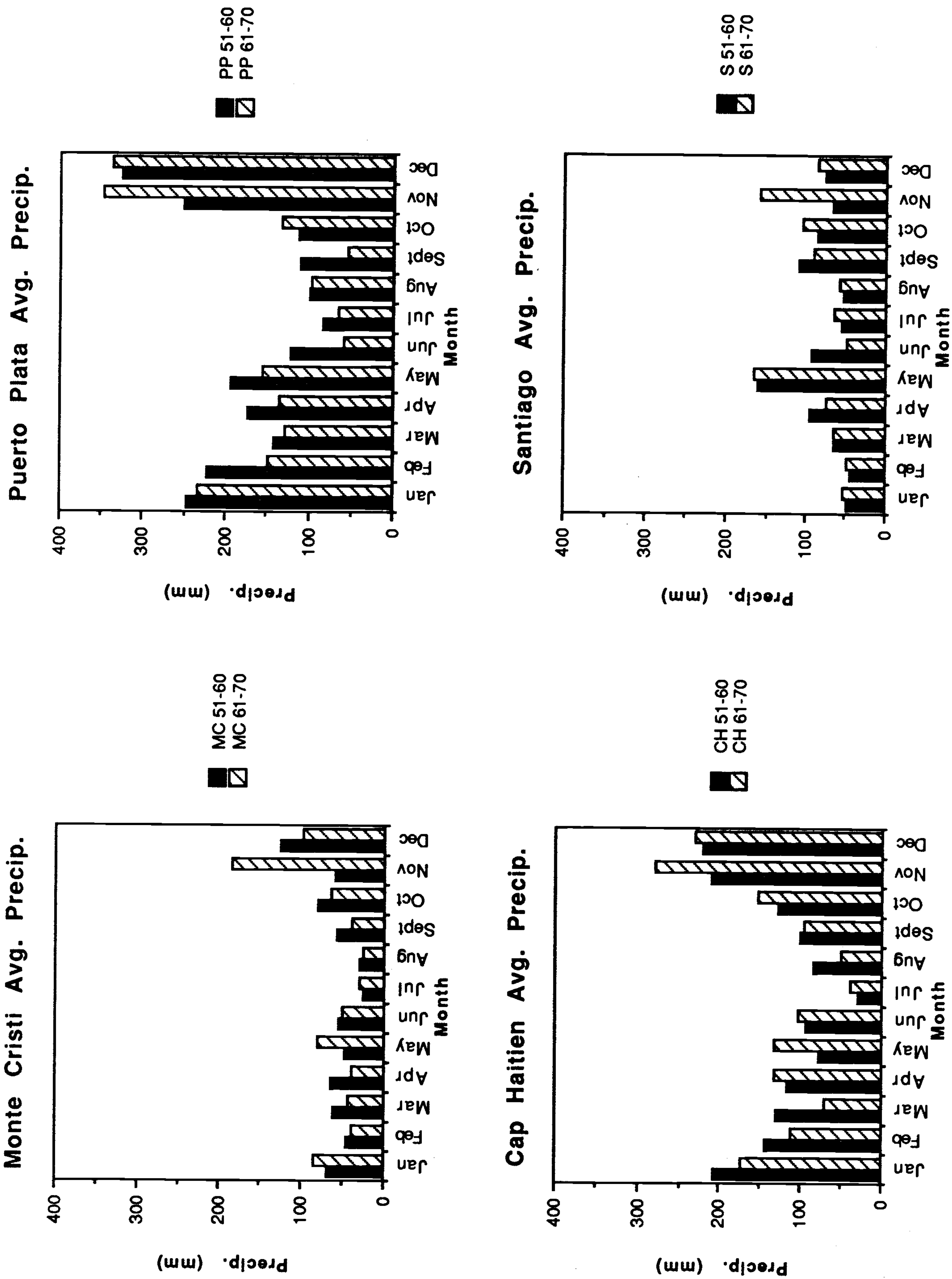


** 5 represents a 26 year average from Mather, ed. (1961)

Annual Precip. - Santiago

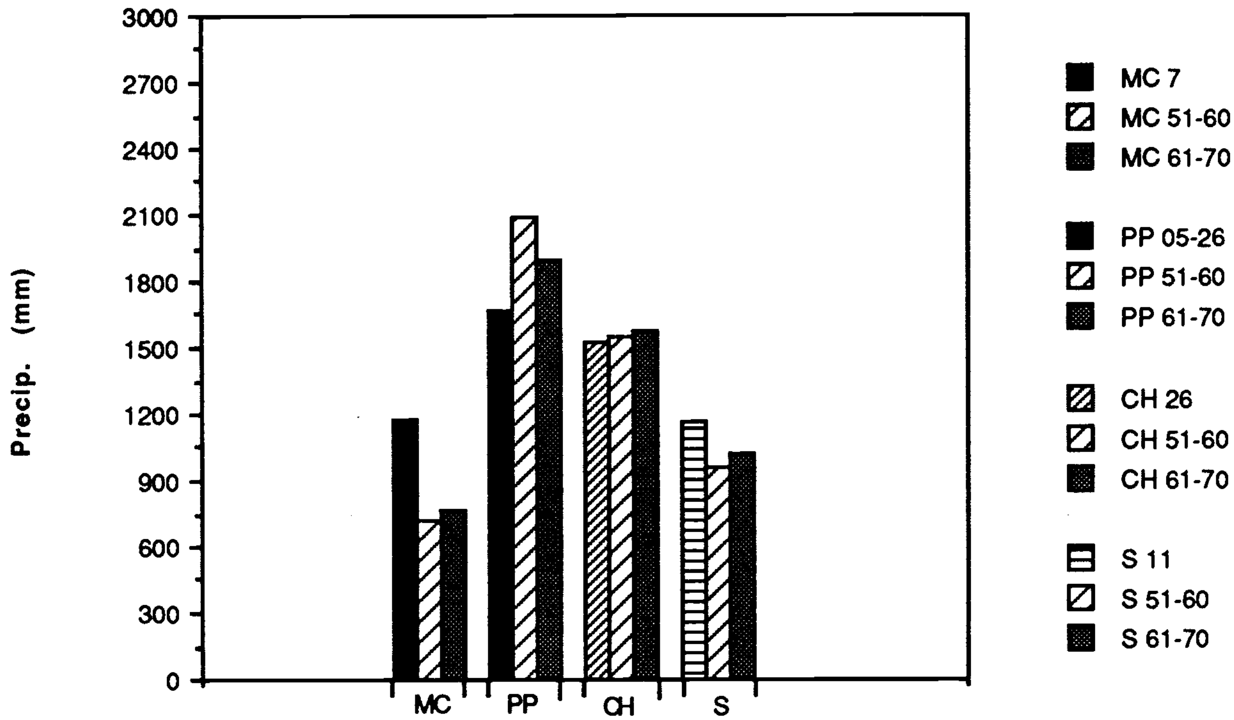


** 11 represents an 11 year average from Mather, ed. (1961)

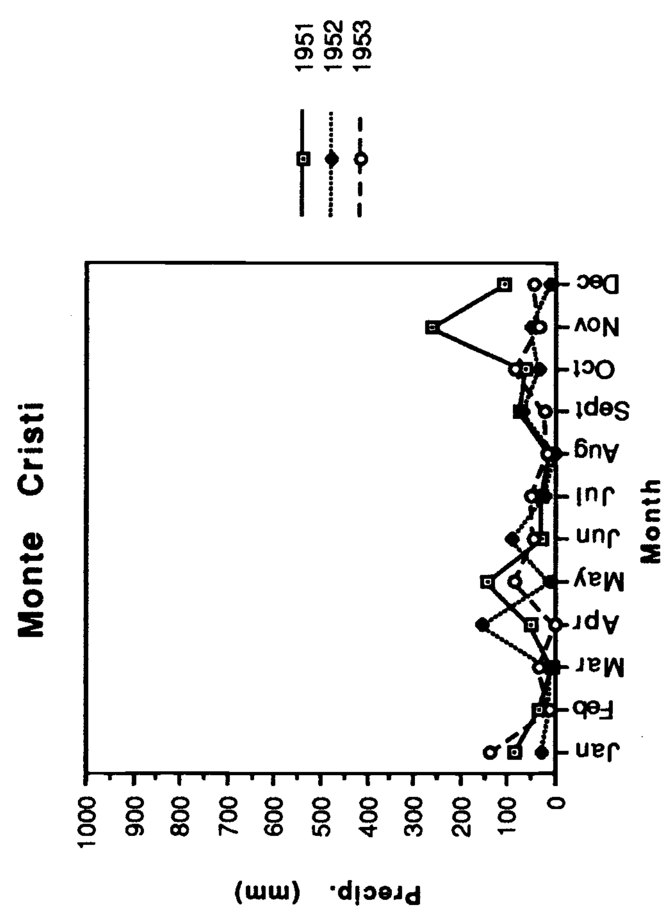


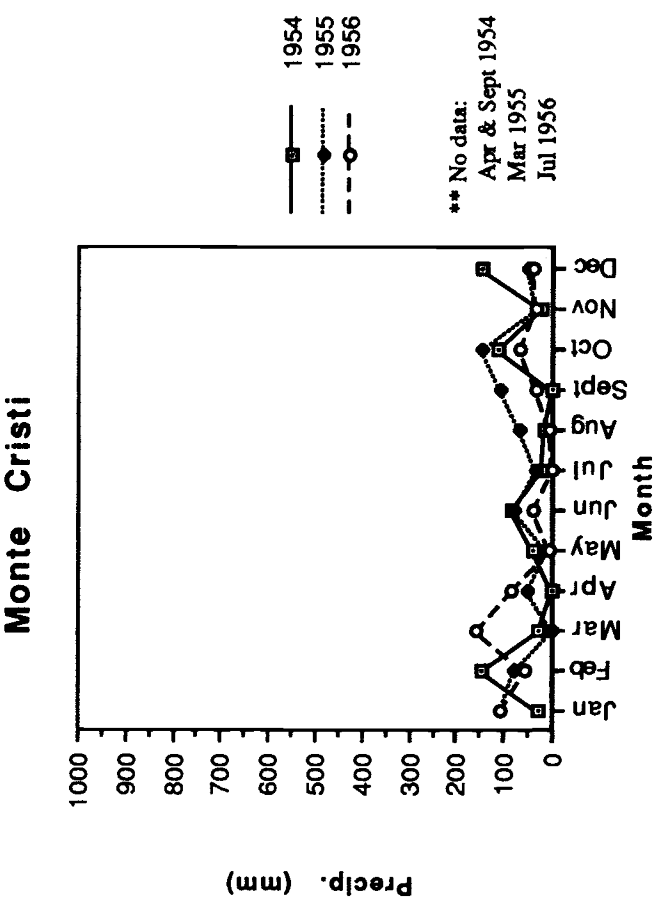
Puerto Plata Avg. Precip.
PP 51-60
PP 61-70
Santiago Avg. Precip.
S 51-60
S 61-70
Monte Cristi Avg. Precip.
MC 51-60
MC 61-70
Cap Haitien Avg. Precip.
CH 51-60
CH 61-70
Precip. (mm)
0
100
200
300
400
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Month

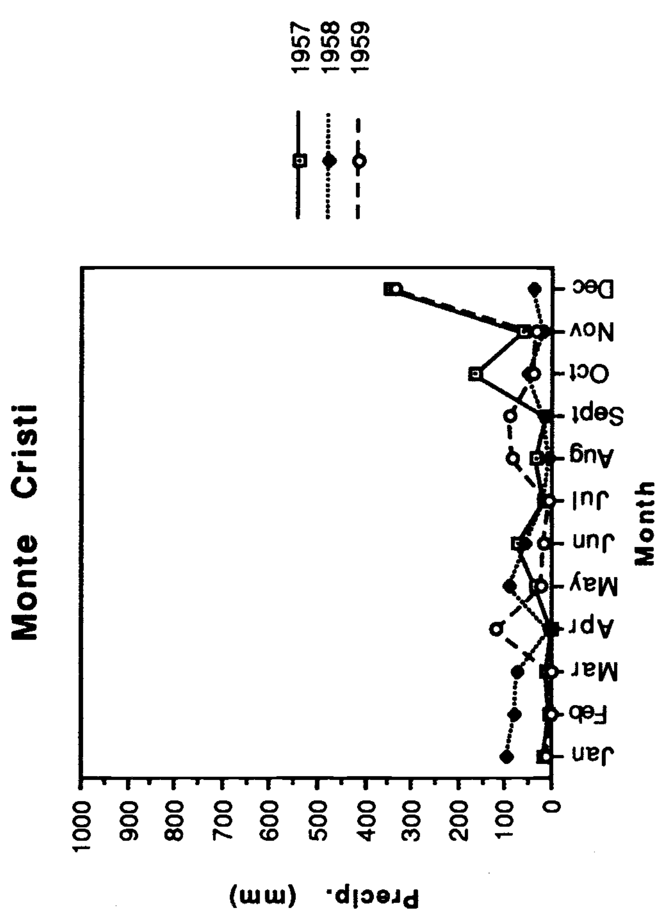
Annual Avg. Precip.

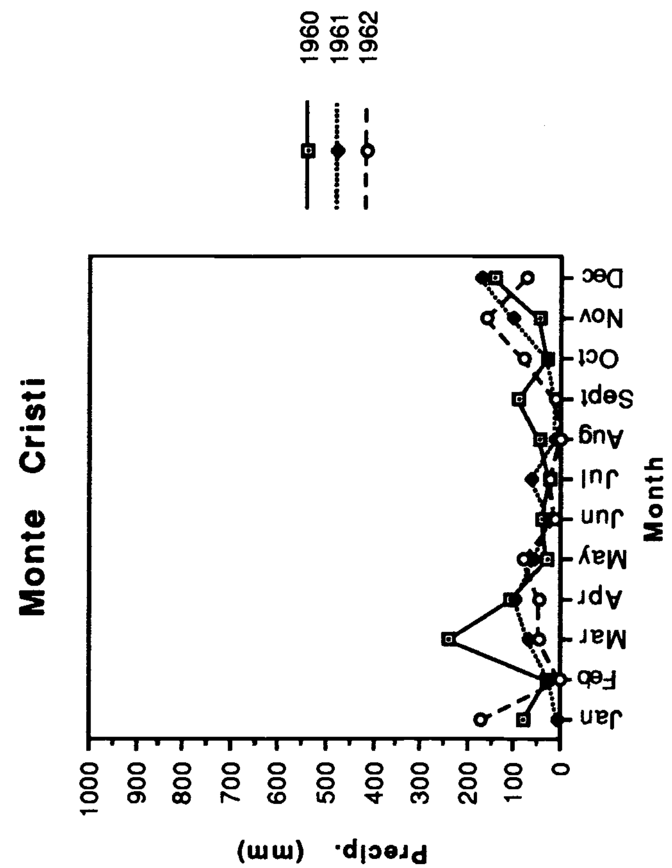


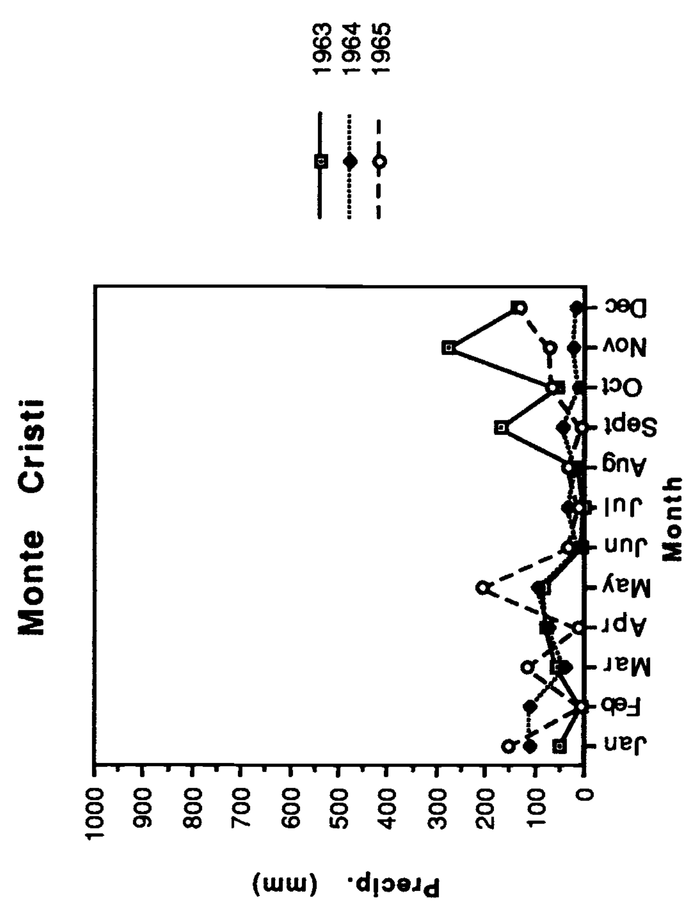
Annual Avg. Precip.


Monte Cristi
Precip. (mm)
1000
900
800
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Month
1951
1952
1953

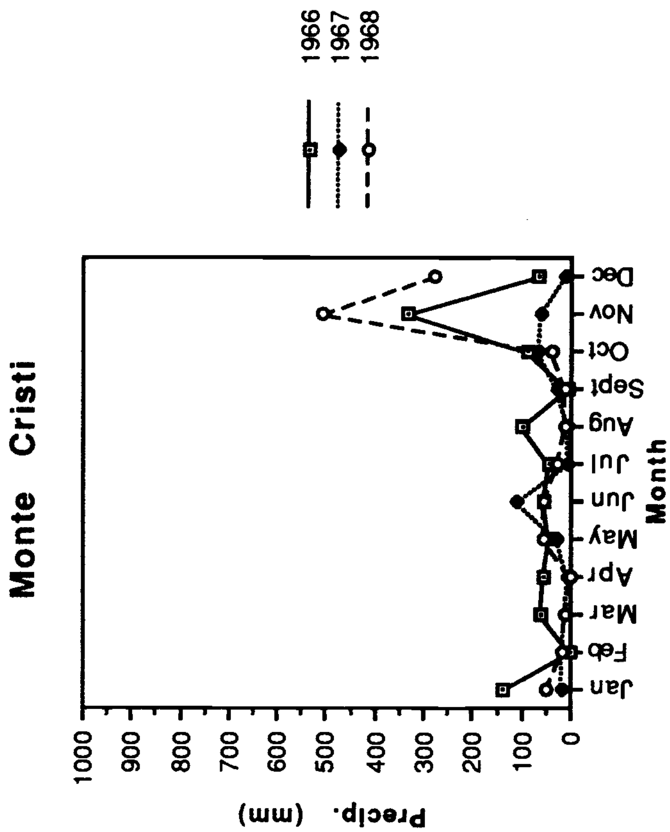

Monte Cristi
Precip. (mm)
1000
900
800
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Month
1954
1955
1956
** No data:
Apr & Sept 1954
Mar 1955
Jul 1956


Monte Cristi
Precip. (mm)
1000
900
800
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Month
1957
1958
1959

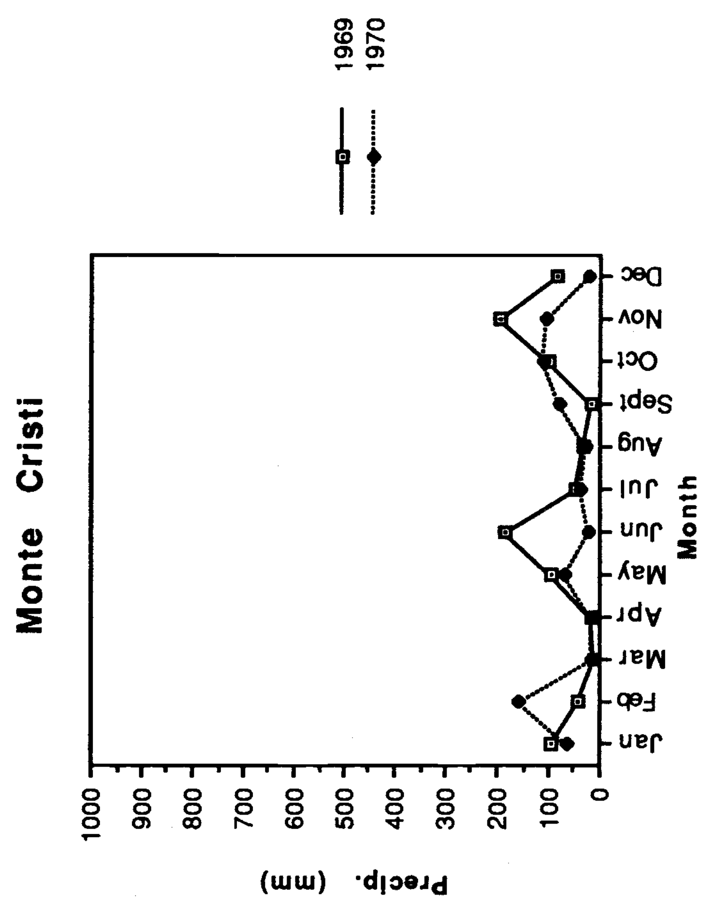

Monte Cristi
Precip. (mm)
1000
900
800
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Month
1960
1961
1962



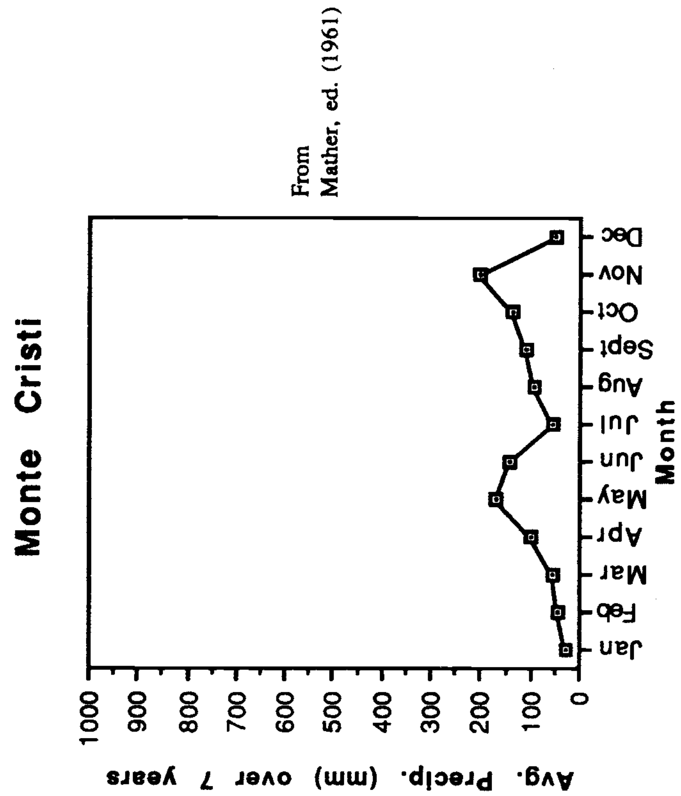
Monte Cristi
1963
1964
1965
Precip. (mm)
1000 900 800 700 600 500 400 300 200 100 0
Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Month



Monte Cristi
1966
1967
1968
Precip. (mm)
1000 900 800 700 600 500 400 300 200 100 0
Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Month

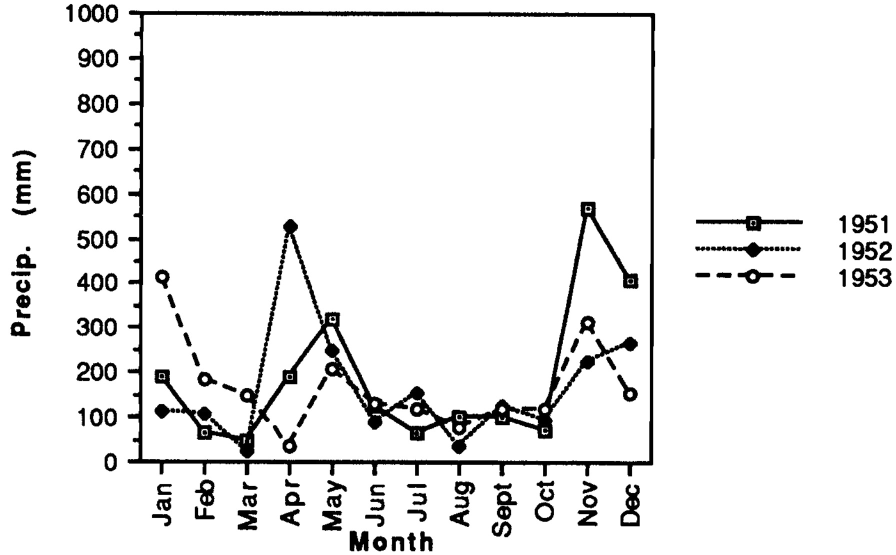


Monte Cristi
1969
1970
Precip. (mm)
1000 900 800 700 600 500 400 300 200 100 0
Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Month

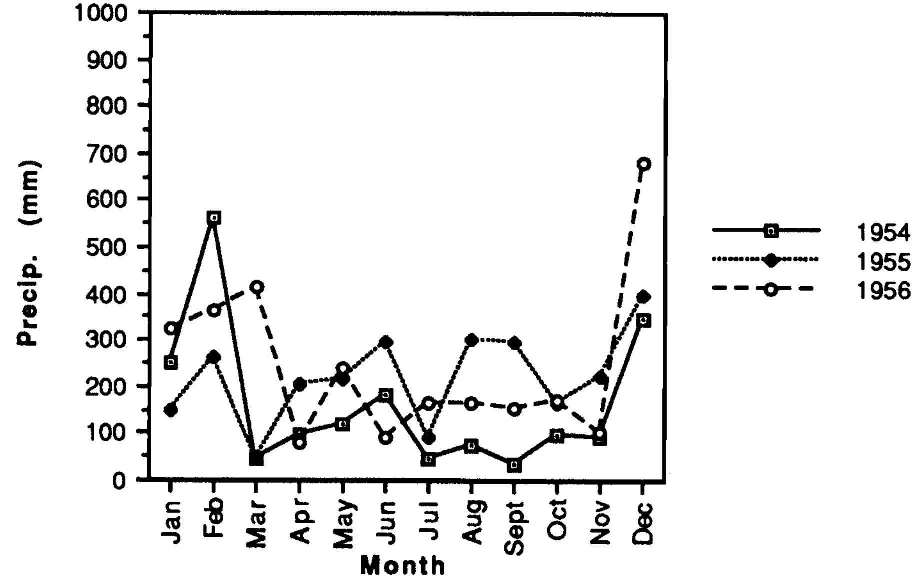


Monte Cristi
From
Mather, ed. (1961)
Avg. Precip. (mm) over 7 years
1000 900 800 700 600 500 400 300 200 100 0
Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Month

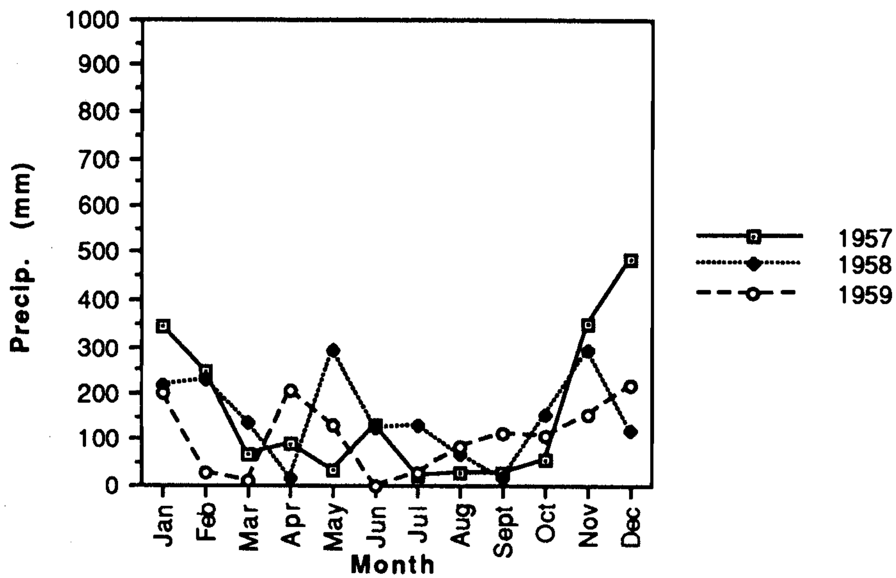
Puerto Plata



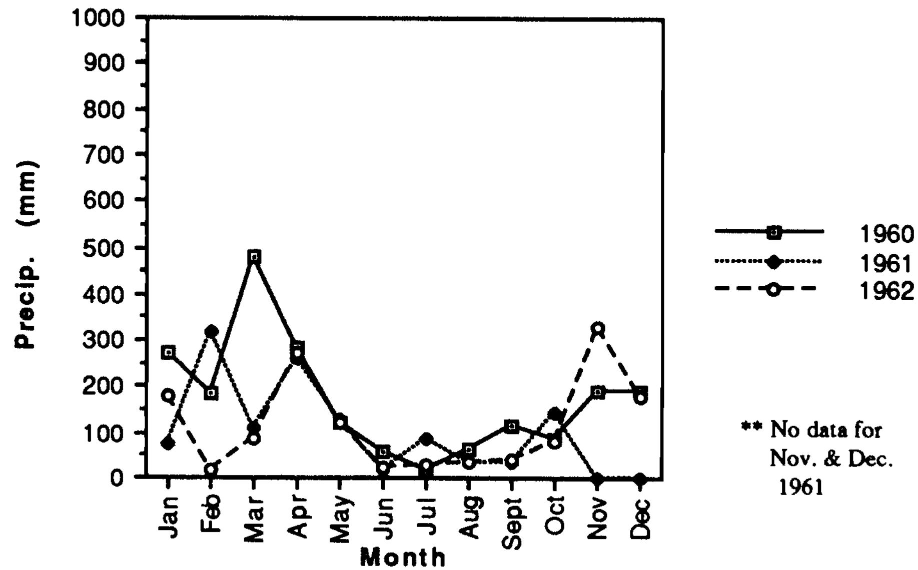
Puerto Plata

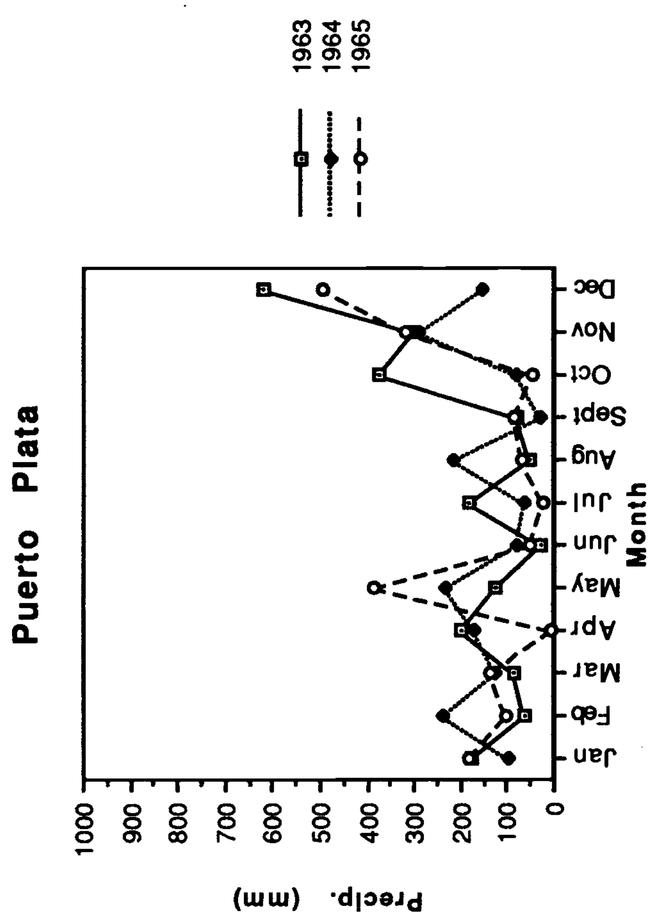


Puerto Plata

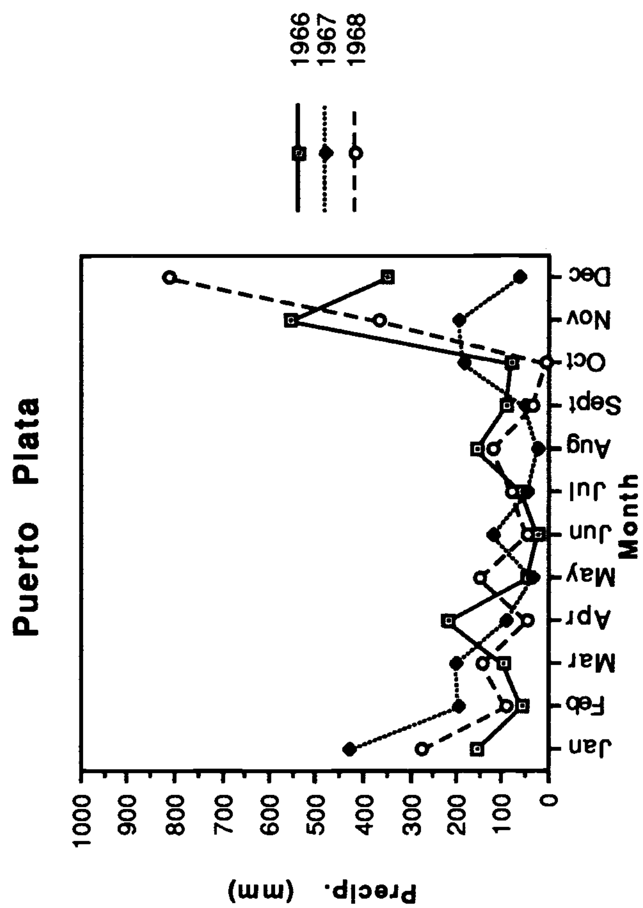


Puerto Plata

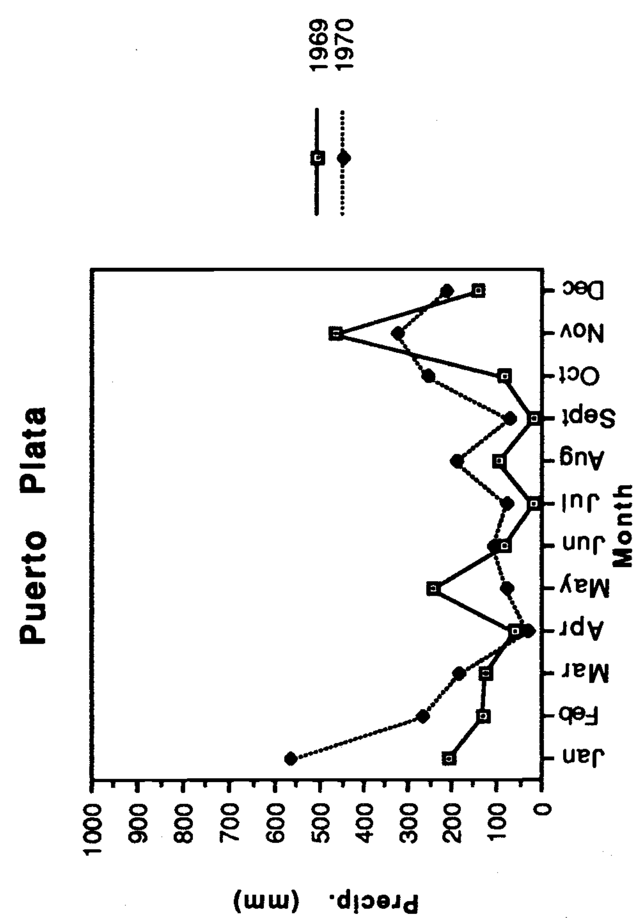




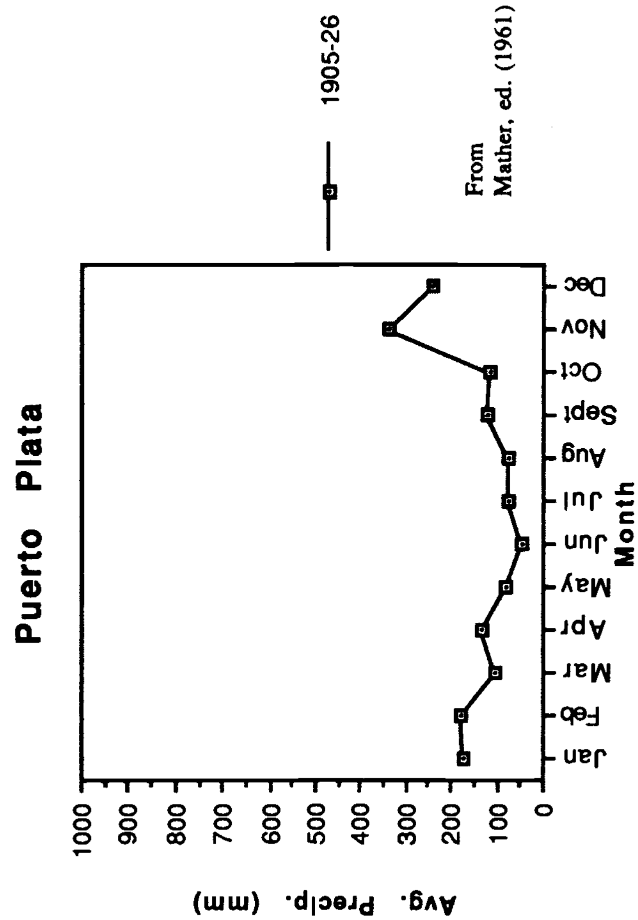
Puerto Plata
1963
1964
1965
Precip. (mm)
1000
900
800
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Month



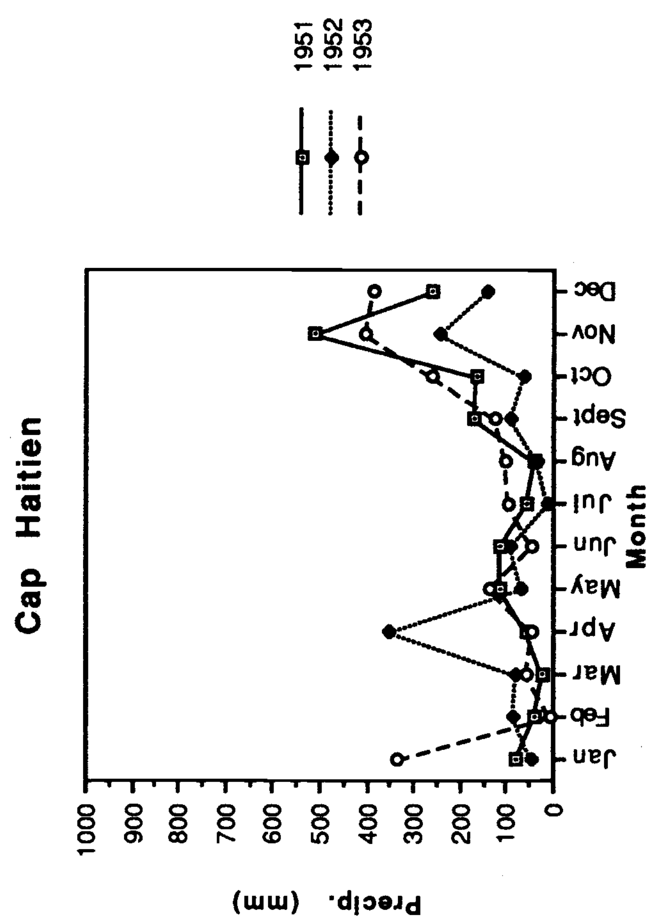
Puerto Plata
1966
1967
1968
Precip. (mm)
1000
900
800
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Month

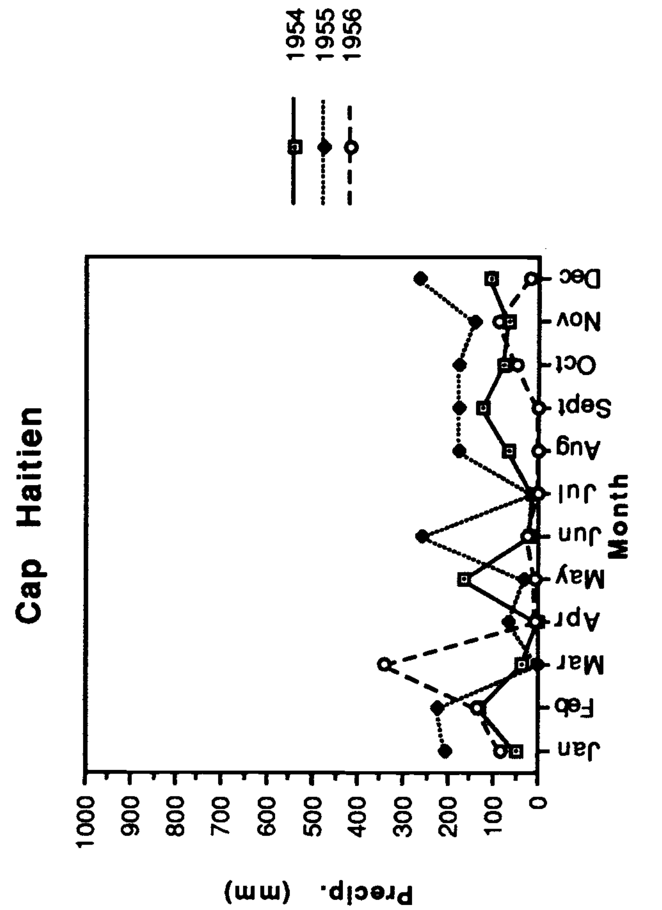


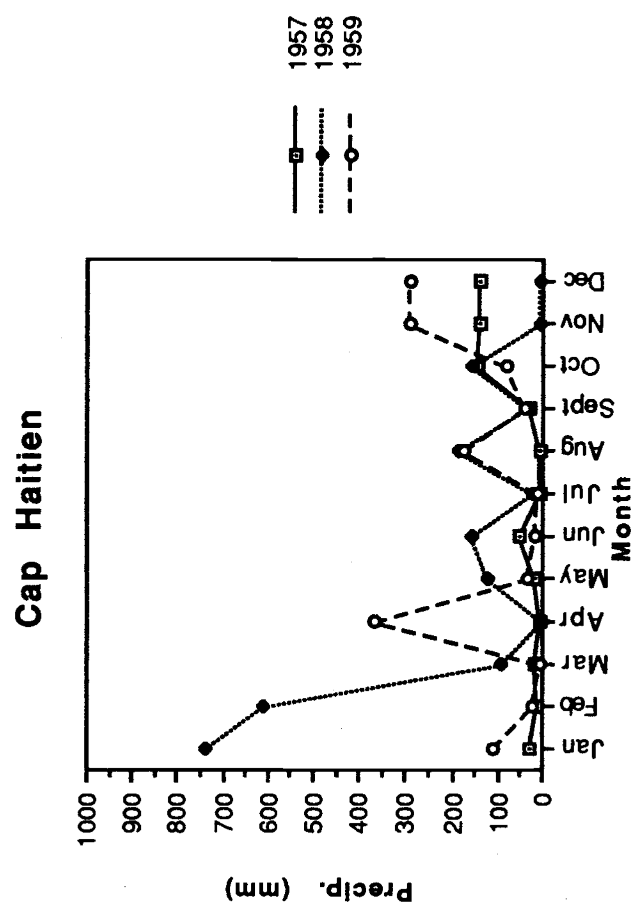
Puerto Plata
1969
1970
Precip. (mm)
1000
900
800
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Month

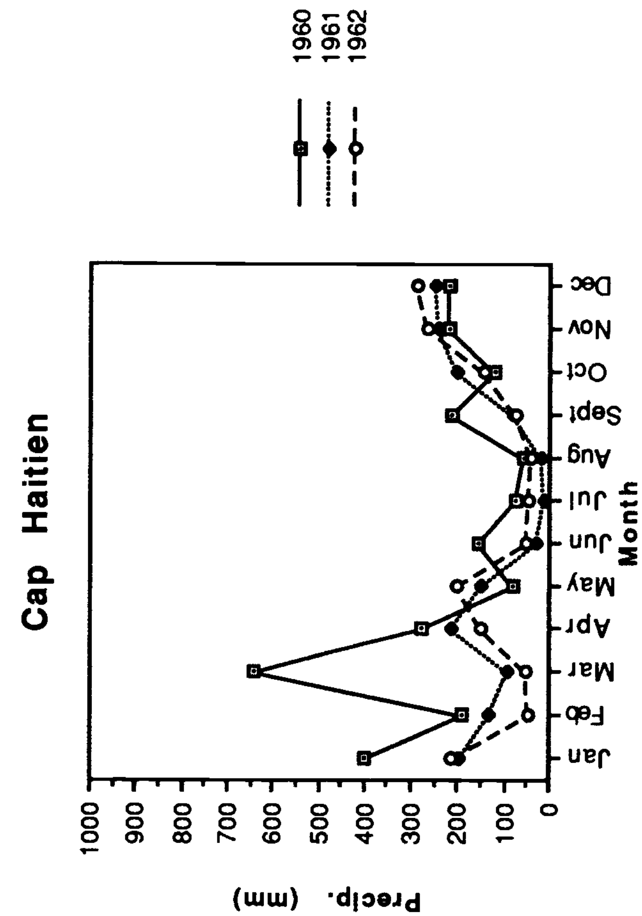


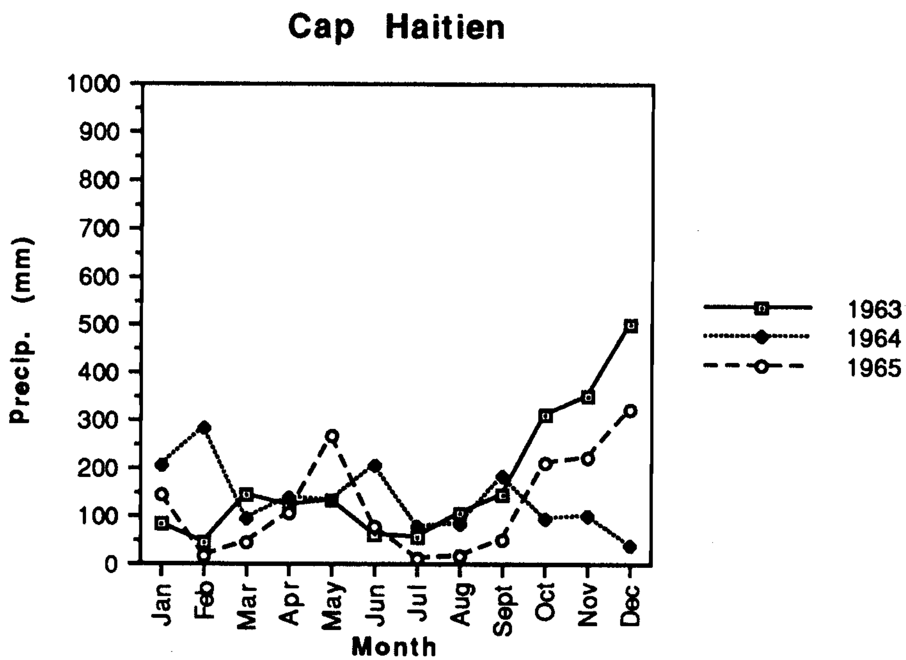
Puerto Plata
1905-26
From
Mather, ed. (1961)
Avg. Precip. (mm)
1000
900
800
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Month

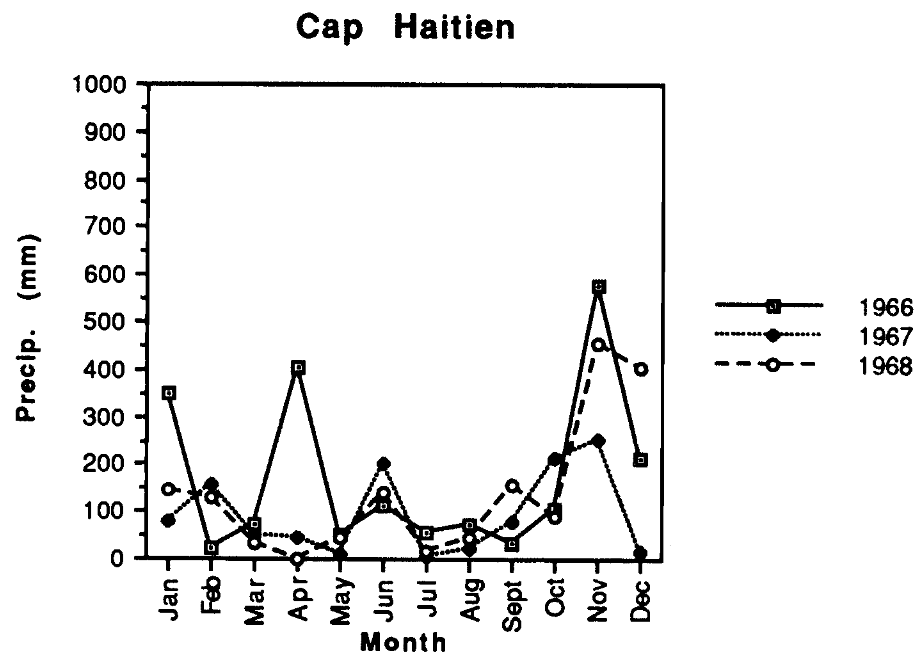

Cap Haitien
Precip. (mm)
1000 900 800 700 600 500 400 300 200 100 0
Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Month
1951
1952
1953

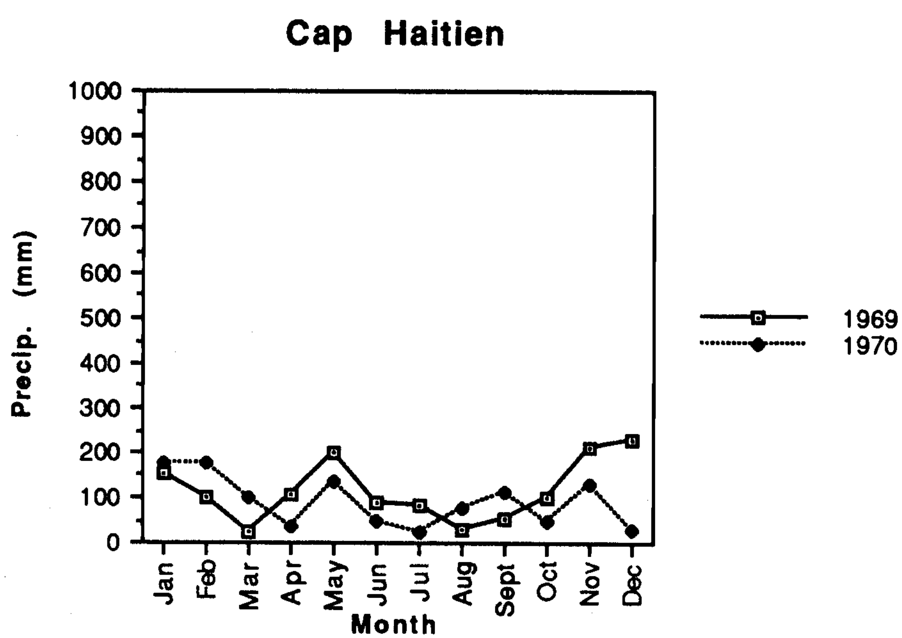

Cap Haitien
Precip. (mm)
1000 900 800 700 600 500 400 300 200 100 0
Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Month
1954
1955
1956

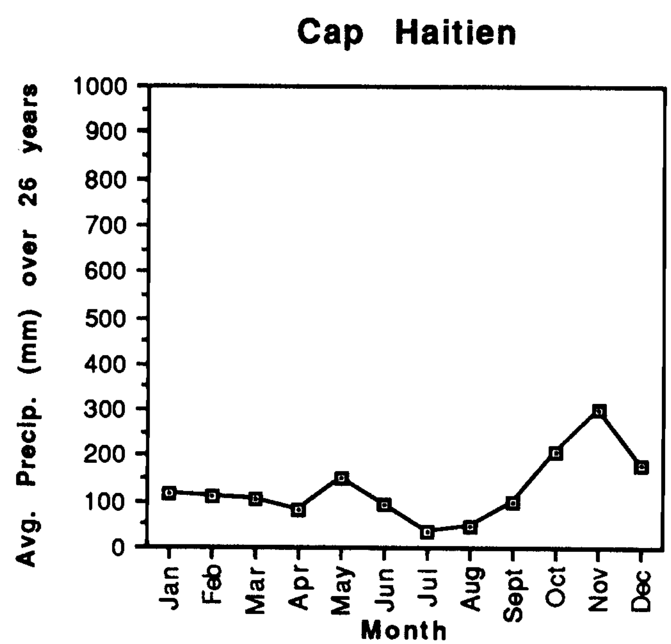

Cap Haitien
Precip. (mm)
1000 900 800 700 600 500 400 300 200 100 0
Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Month
1957
1958
1959


Cap Haitien
Precip. (mm)
1000 900 800 700 600 500 400 300 200 100 0
Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Month
1960
1961
1962

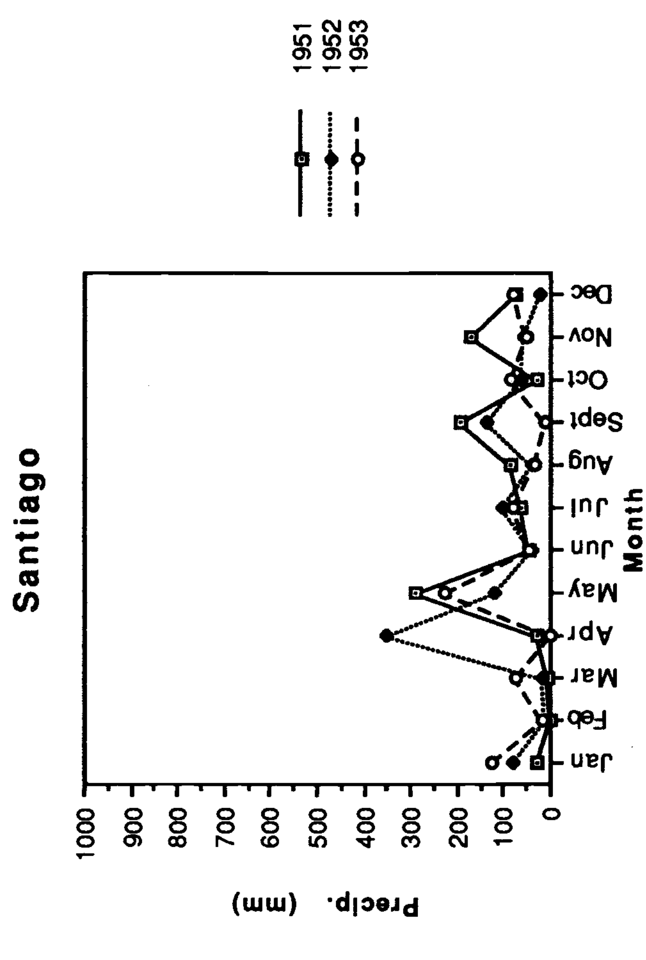


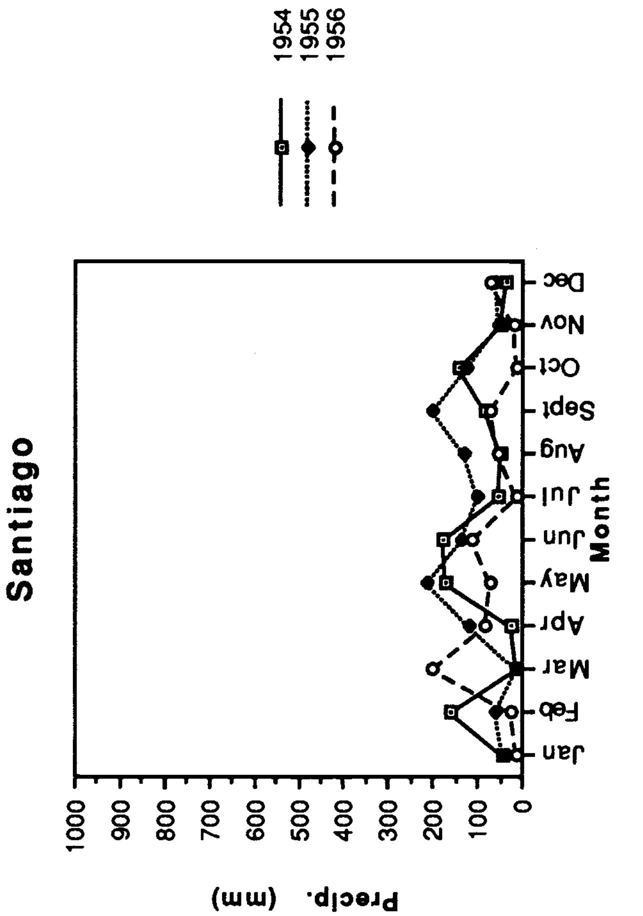


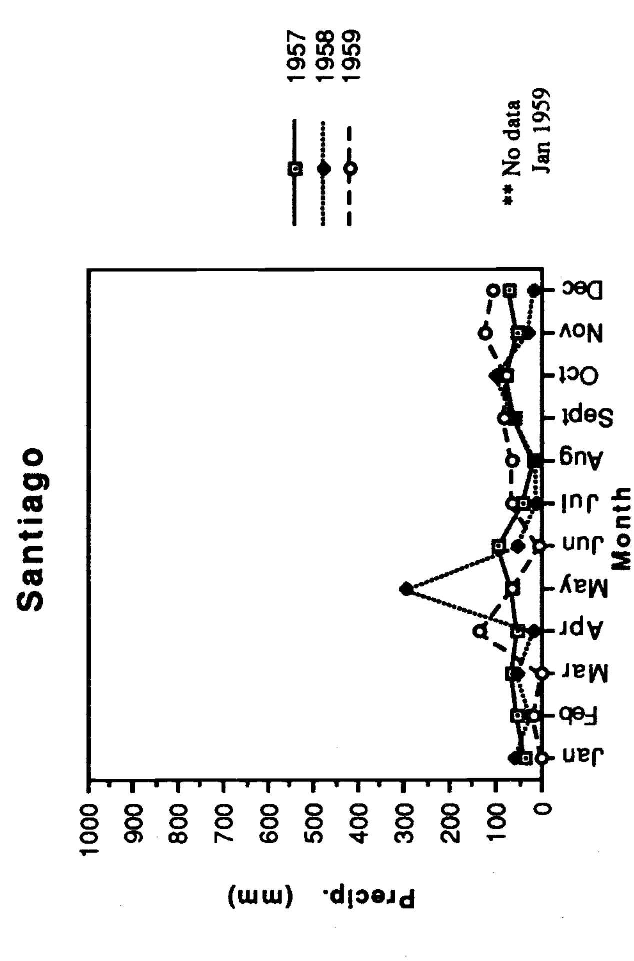


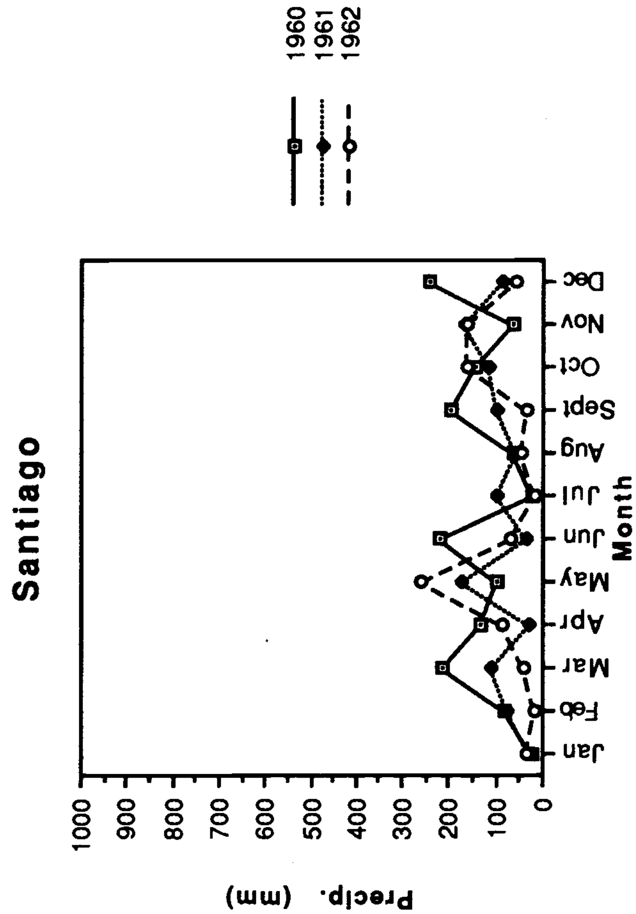


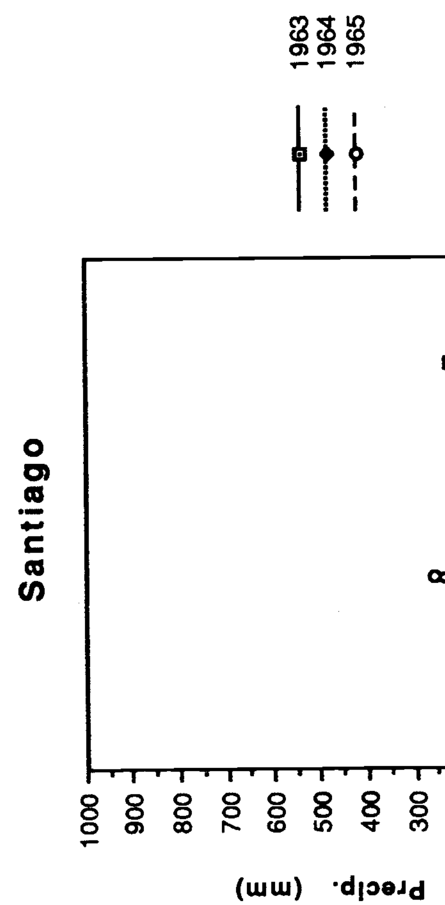
From
Mather, ed. (1961)

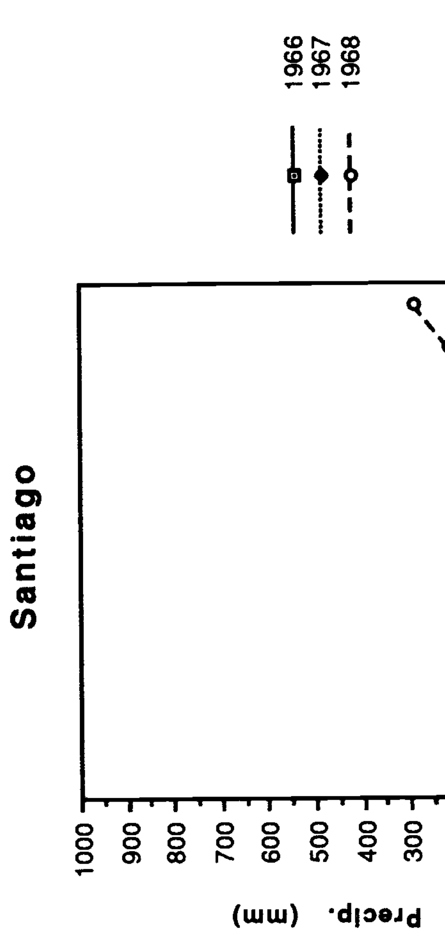

Santiago
Precip. (mm)
0
100
200
300
400
500
600
700
800
900
1000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Month
1951
1952
1953

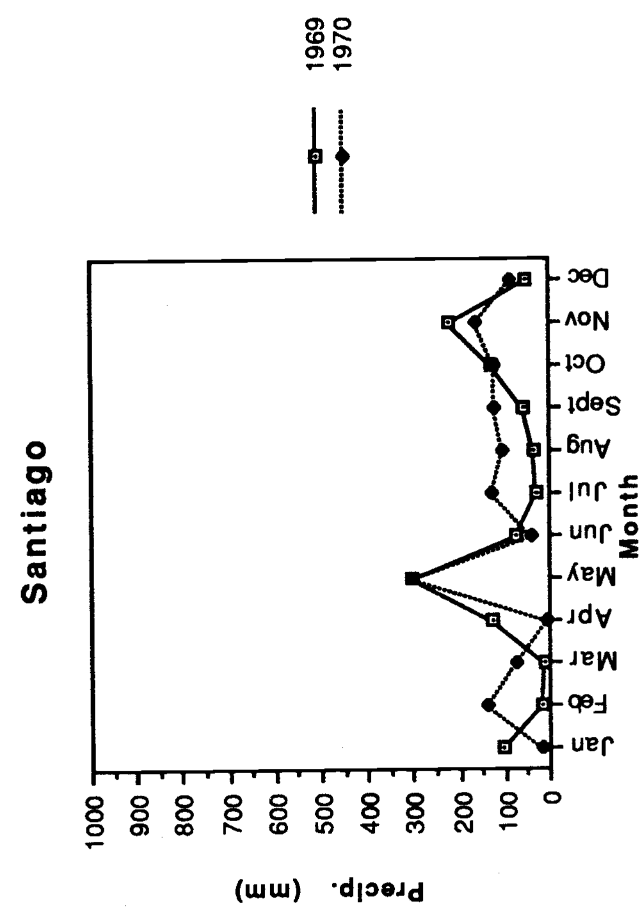

Santiago
Precip. (mm)
0
100
200
300
400
500
600
700
800
900
1000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Month
1954
1955
1956

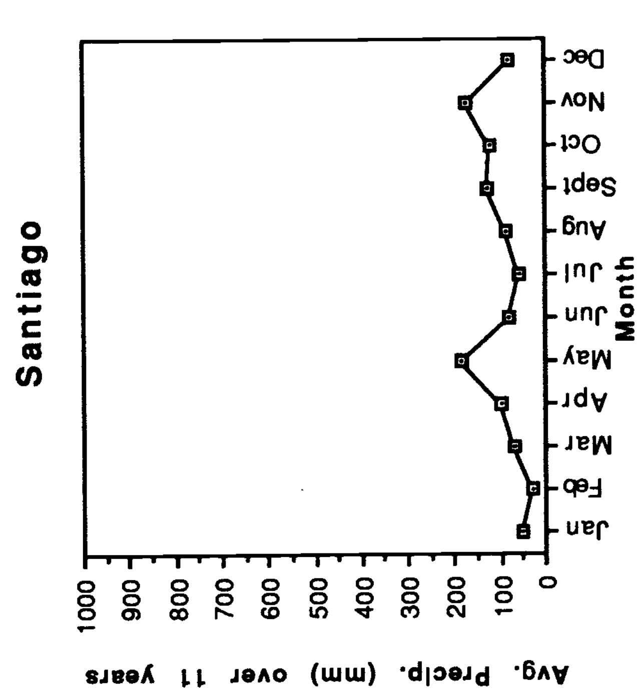

Santiago
Precip. (mm)
0
100
200
300
400
500
600
700
800
900
1000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Month
1957
1958
1959
** No data
Jan 1959


Santiago
Precip. (mm)
0
100
200
300
400
500
600
700
800
900
1000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Month
1960
1961
1962









From
Mather, ed. (1961)

CIESIN

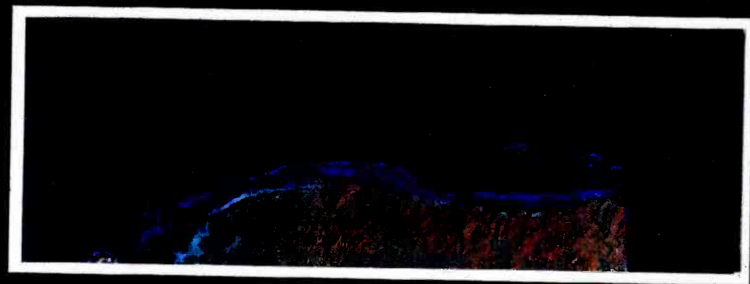
La Costa de Buen Hombre
Republica Dominicana

ERIM

The University of Arizona

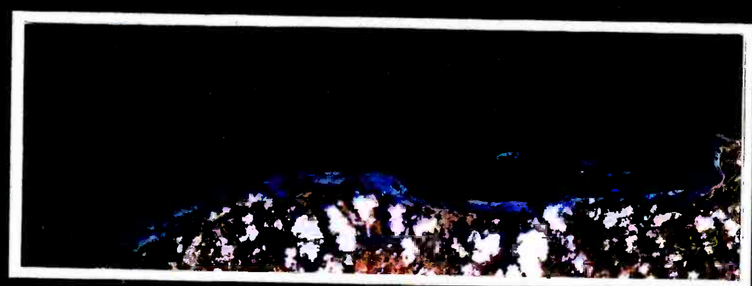
91-23277.9

Landsat Data



MSS False-Color Infrared Composite Path/Row: 9/46 06 February 1975

TM Natural-Color Composite Path/Row: 8/46 02 February 1985



TM Natural-Color Composite Path/Row: 8/46 04 January 1989

0 5 10 15 km

Scale

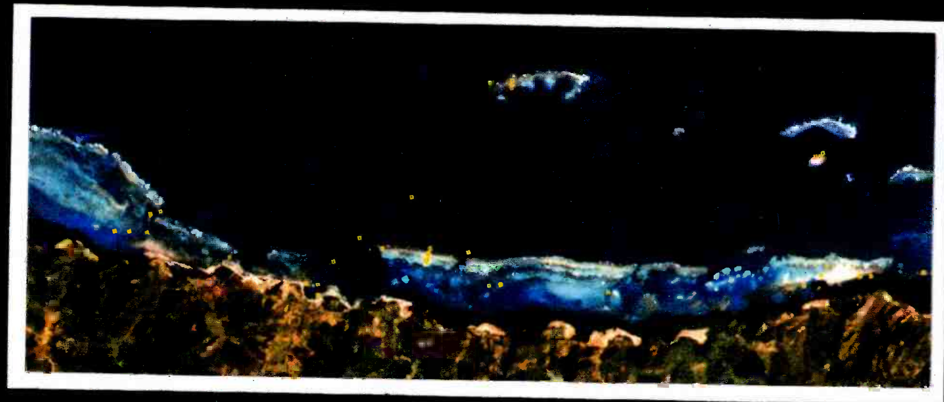
CIESIN

La Costa de Buen Hombre
Republica Dominicana

ERIM

The University of Arizona

91-23277.10



Sample of Marine Survey Sites Visited During Field Data Collection Trip

0 1 2 3 4 5 km

Scale

"Sea Truth" Data Collection

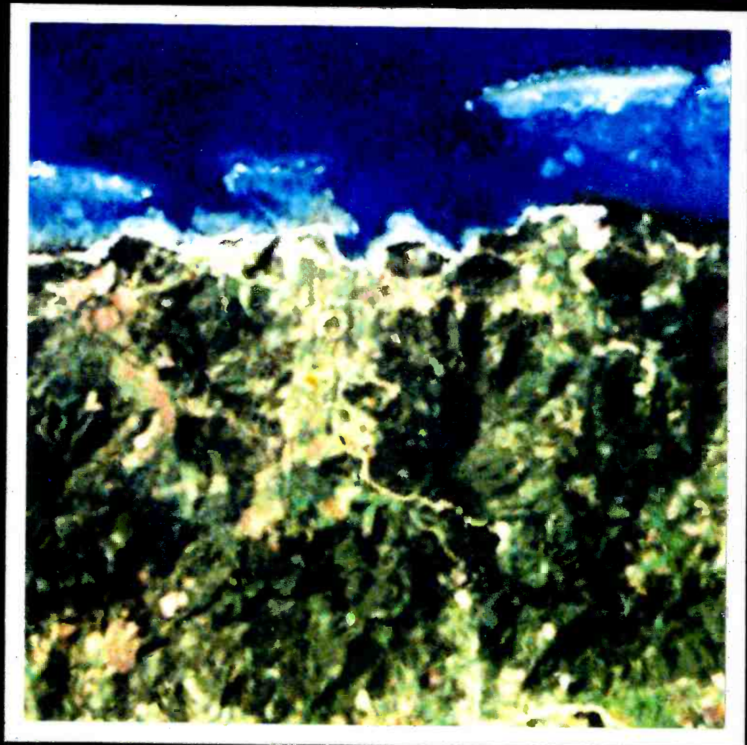
La Costa de Buen Hombre
Republica Dominicana

CIESIN

ERIM

The University of ARIZONA

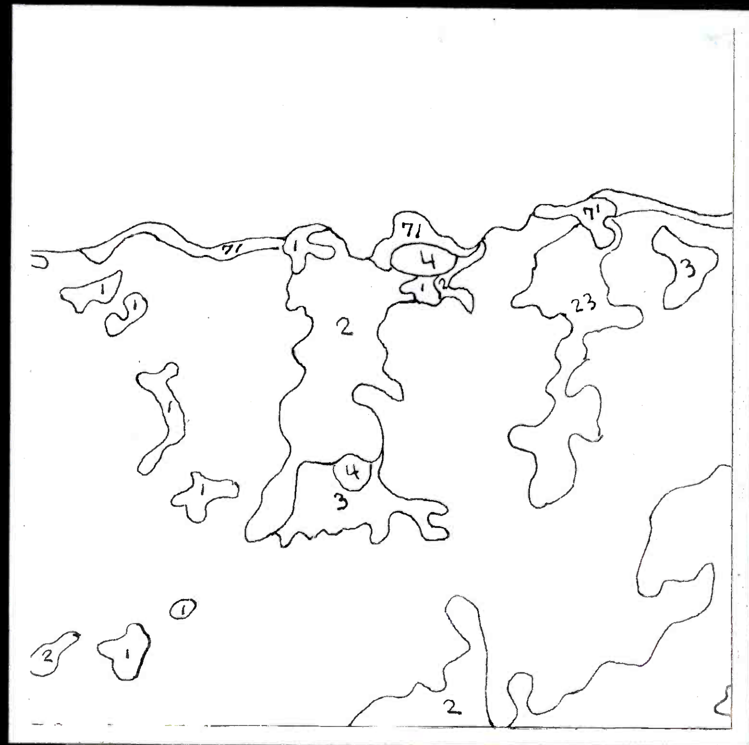
91-23277 6



1985 TM Natural-Color Composite

0 .5 1.0 1.5 km

Scale



Portion of Land Use/Land Cover Map Prepared Through Visual Interpretation of the TM Image

1. Bare Soils
2. Agriculture
3. Range/Savannah
4. Forest

61. Mangrove (Permanently Submerged)
62. Mangrove (Intermittently Submerged)
71. Beach Sand
72. Badlands

C. Clouds

CS. Cloud Shadows

CIESIN

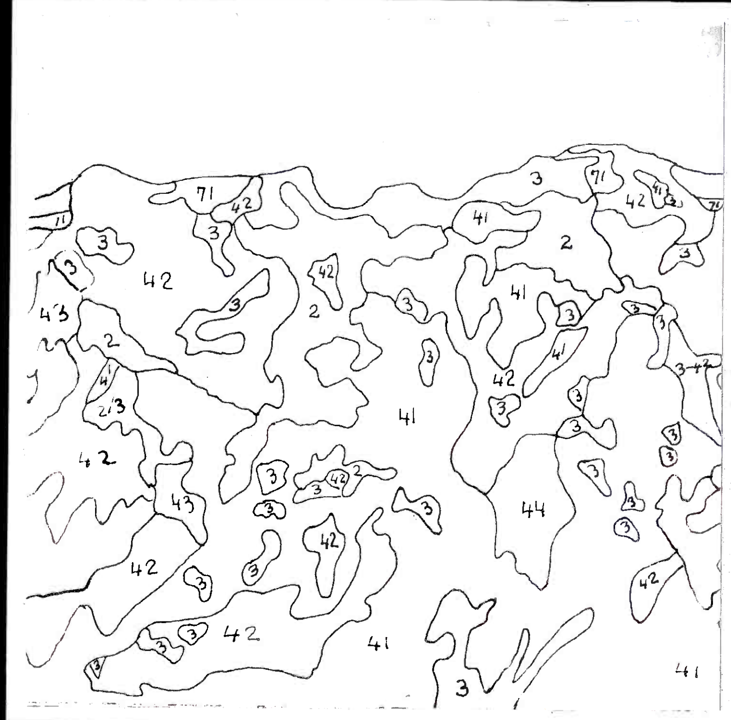
La Costa de Buen Hombre
Republica Dominicana

ERIM

The University of ARIZONA

91-23277.5

1983 Panchromatic Aerial Photo



Portion of Land Use/Land Cover Map Prepared Through Visual Interpretation of the Aerial Photo

0 .5 1.0 1.5 km
Scale

2. Agriculture
3. Range/Savannah
41. Relatively Dense Forest
42. Light Forest
43. Cactus
44. Degraded Forest
45. Drier Forests (Western Study Area)
6. Mangrove
71. Beach Sand
72. Badlands/Steep and Severely Eroded

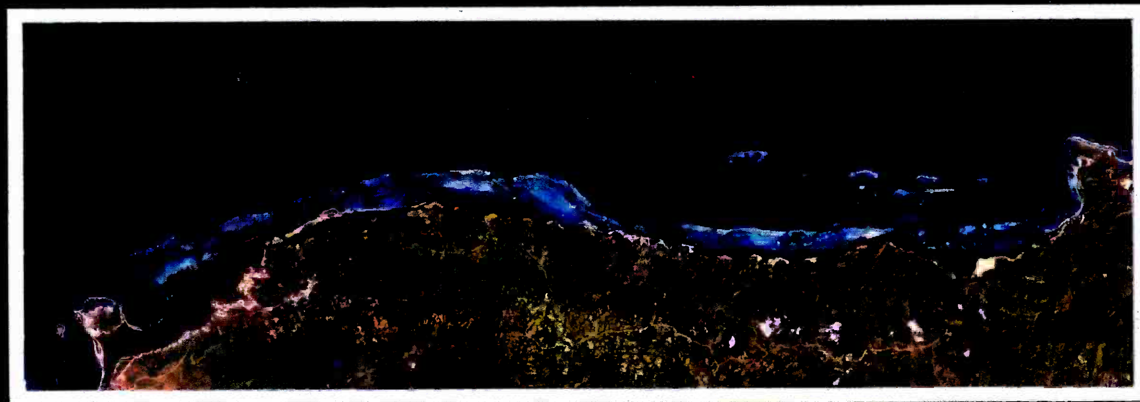
CIESIN

La Costa de Buen Hombre
Republica Dominicana

ERIM

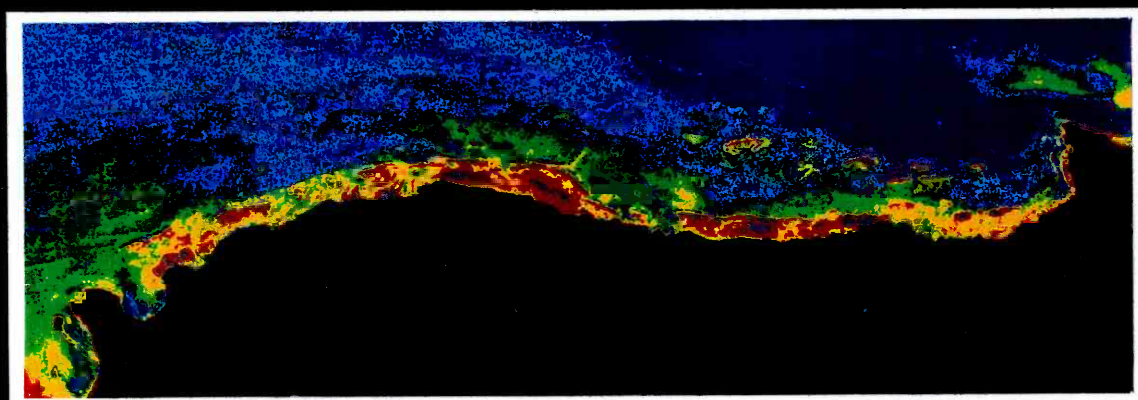
The University of Arizona

91-23277.8



1985 TM Natural-Color Composite Image of the Buen Hombre Coastal Region

Black: Land
Gray: 1-5 ft
Red: 6-10
Yellow: 11-151
Light Green: 6-20
Dark Green: 21-25
Cyan: 26-45
Dark Blue: > 45



TM Color-Coded Bathymetric Image

0 5 10 km
Scale

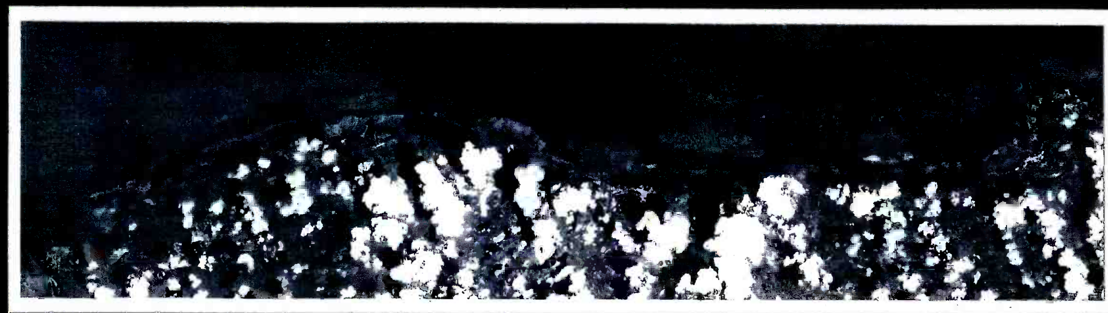
CIESIN

La Costa de Buen Hombre
Republica Dominicana

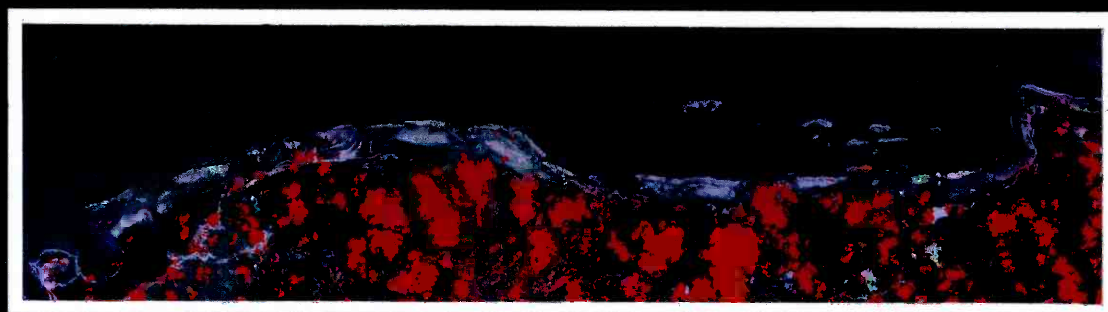
ERIM

The University of ARIZONA

91-23277.7



TM Ratio Change Image
(TM Band 1 04 January 1989/TM Band 1 02 February 1985)



TM Vector Threshold Change Image Created From Bands 1, 2, and 3
(Date 1: 02 February 1985 Date 2: 04 January 1989)

0 5 10 km

Scale

CIESIN

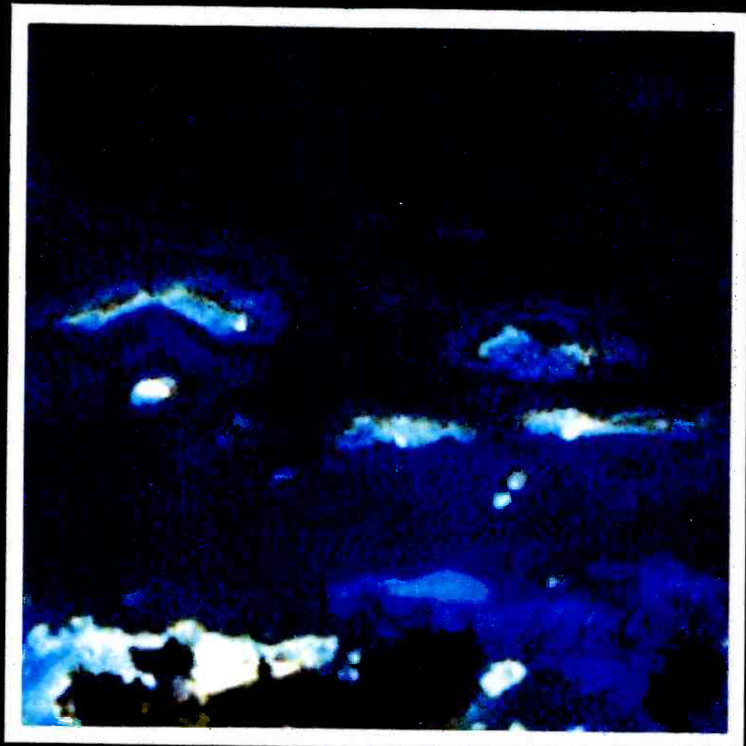
ERIM

The University of ARIZONA

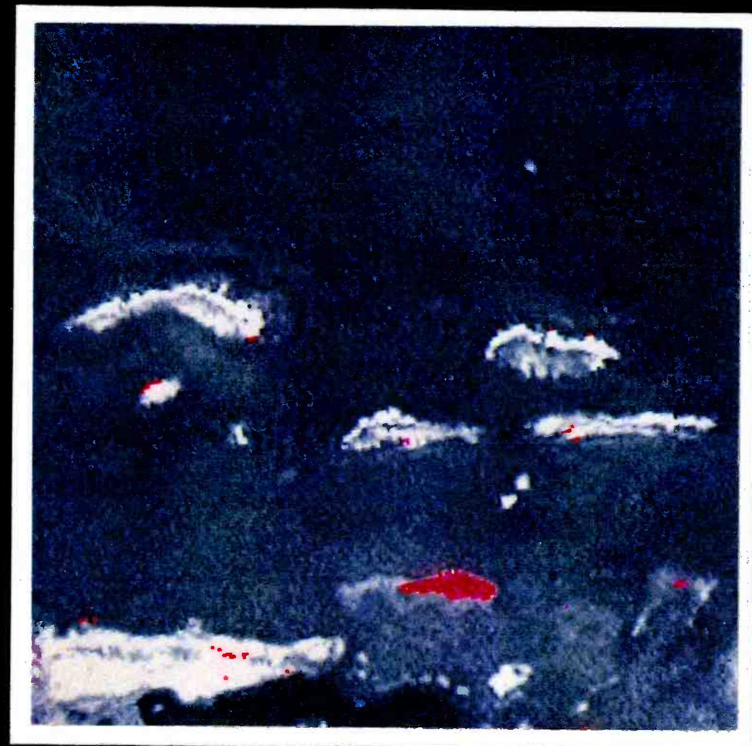
91-23277.3

La Costa de Buen Hombre
Republica Dominicana

Sand Key and Nearby Reefs



1989 TM Natural-Color Composite



TM Vector Threshold Change Image (1985–1989)

0 .5 1.0 1.5 km

Scale

CIESIN

La Costa de Buen Hombre
Republica Dominicana

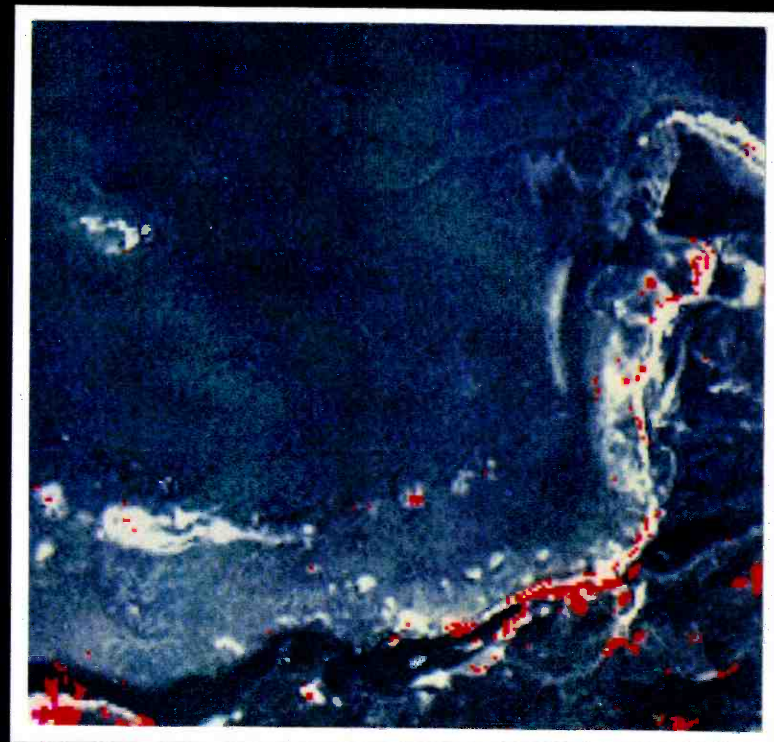
ERIM

THE UNIVERSITY OF ARIZONA

91-23277.2

Coastal Area Near Punta Rucia

TM Ratio Change Image (TM 1 1989/TM 1 1985)



TM Vector Threshold Change Image (1985–1989)

0 .5 1.0 1.5 km

Scale